Occurrence of substances of concern in Baltic Sea Region buildings, construction materials and sites

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Table of Content

Abstract

This study aimed to enhance the understanding of hazardous substances in urban environments and identify their sources, focusing on the potential contribution of building materials to both outdoor and indoor contamination. We conducted targeted pollutant screening across five matrices—construction materials, stormwater, indoor dust and air, and residential wastewater—in five cities in the Baltic Sea Region: Tallinn, Helsinki, Turku, Västerås, and Stockholm. Although not all matrices were screened in every location, key findings emerged:

- Indoor dust samples contained significant amounts of organic pollutants, such as plasticizers, PFAS, and chlorinated paraffins, with some pollutants comprising up to 0.1% by weight.
- Stormwater acts as a conduit for pollutants between the built and natural environments, with samples containing a range of contaminants, including biocides, organophosphate esters, metals, and PFAS. Variations in contamination levels were observed across different cities and building types.
- The study also confirmed the occurrence of biocides, such as diuron, propiconazole, and mecoprop, in stormwater from areas with new wooden claddings, underscoring the environmental impact of building materials.
- PFAS were detected across various matrices, showing significant concentration variations among cities.
- Widespread contamination by TCPP in stormwater runoff, wastewater, and indoor dust was also found.
- Additionally, the study noted the replacement of older contaminants with emerging substances of concern in building materials, stressing the importance of continued research to understand their impacts.

The sampling and analysis results of this project are indicative in nature due to the limited number of samples analysed in each category. These results reveal areas and matrices where more data is needed. They should not be used for risk assessment but can serve as a basis and contribute to future investigations. Rather, they should be seen as indications for where more data is needed to understand the long-term effects and to be able to develop strategies to reduce pollutant levels and health risks from exposure to these contaminants.

Popular Summary

The present report summarises the results obtained from the substance screening conducted in the NonHazCity 3 project. The aim of these screening activities was to document the presence of hazardous substances and their sources within the NonHazCity 3 partner municipalities. This study aimed to identify where hazardous substances are found in urban areas, and their origins. We explored whether building materials contribute to contamination in outdoor and indoor urban environments. Pollutant screening was conducted in construction materials, stormwater, indoor dust and air, and residential wastewater. The screening took place in five cities/regions in the Baltic Sea Region: Tallinn (EE), Helsinki and Turku region (FI), Västerås, and Stockholm (SE).

The investigation focused on the following substance groups commonly present in building materials:
Phthalates: Used to make plastics more flexible, found in products like PVC flooring, cables, roofing membranes and plastic films on metal roofs. These chemicals can be released into the environment and disrupt hormones of living organisms.
Per- and Polyfluoroalkyl Substances (PFAS): Used in a multitude of applications for their resistance to heat, water, and oil. Extremely persistent in the environment and pose significant long-term health risks.
Bisphenols: Used in making plastics and other products. Bisphenol A (BPA) and its substitutes (like BPF and BPS) are endocrine disruptors affecting hormone functions.
Organophosphate Esters (OPEs): Used as flame retardants and plasticizers. Linked to adverse health effects, leach from products and by that significantly impact indoor air quality.
Brominated Flame Retardants (BFRs): Used to reduce flammability in materials like electronics and textiles. Many persist in the environment and can cause neurological and hormonal issues.
Biocides: Used as an in-can preservative, to prevent mold and fungal growth on wood and façade coatings. Pose environment and health risks and contribute to biocide resistance.
Chlorinated Paraffins (CPs): Used as flame retardants and plasticizers. Persist in the environment, bioaccumulate, and may be carcinogenic.
Volatile Organic Compounds (VOCs): Found in paints, solvents, and adhesives, they can cause health issues ranging from irritation to liver and kidney damage.
Metals: Lead, cadmium, mercury, zinc, and copper can cause toxic effects on human health and/or the environment even in trace amounts. These metals are commonly found in construction materials.

Key findings from this study are following
Indoor dust: Dust is a carrier of many chemicals present in the indoor environment and thus reflects what is mobilized from materials. Despite reductions of some pollutants over time, because they have been regulated (restricted and/or subjected to authorization), dust still contains significant pollutants, including plasticizers, PFAS, bisphenols, chlorinated paraffins,

and organophosphate esters. Higher concentrations of hazardous substances were found in houses with PVC flooring and treated surfaces.
Stormwater: Contains various pollutants, including biocides, flame retardants, and metals. Areas with new wooden buildings exhibited higher levels of biocides, that may adversely impact the aquatic environment.
PFAS: Detected across various matrices, including stormwater, wastewater, indoor dust, and construction materials. There are many uses that can release PFAS, but finding the exact sources in the built environment is difficult.
Plasticizers: Found at higher levels in rooms with PVC flooring, indicating that the type of flooring significantly affects chemical levels in dust.
Construction materials are clearly a source of harmful chemicals indoors and in the environment.

Achieving a non-toxic environment within the EU requires stricter regulations, better material choices, improved monitoring systems, and the promotion of safer alternatives.

This investigation has led to a few recommendations for legislators, public authorities and constructors presented below:

Recommendations for regulators

- Implement stricter regulations for hazardous substances in construction material
- Encourage and promote the development and use of safer alternatives

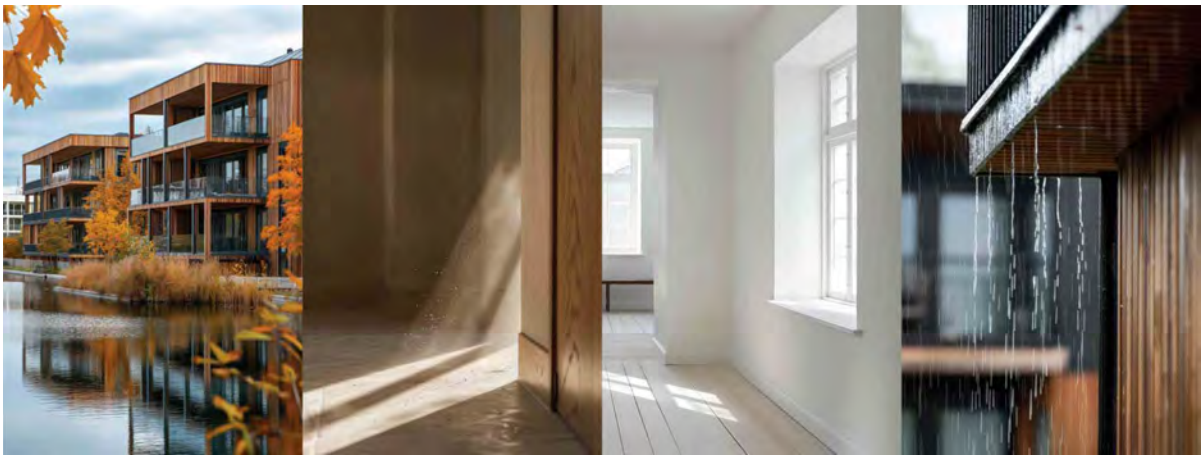
Recommendations for public authorities

- Focus on compliance for regulation in place
- Improve monitoring systems to detect new harmful substances in materials
- Raise awareness about the risks of hazardous substances in construction materials among actors in the construction industry and the public
- Encourage and promote the development and use of safer alternatives
- Improve waste management to ensure recycled construction materials are free from hazardous substances
- Hazardous substance prevention in municipalities: cooperate with city/ district development departments to prevent HS use in construction through procurement

Recommendations for constructors

- Avoid materials treated with harmful chemicals
- Require suppliers to declare all content of substance of concern
- Require suppliers to evaluate possible alternatives and substitute the most harmful chemicals whenever possible
- Improve monitoring programmes and systems to detect new substances in materials
- Encourage and promote the development and use of safer alternatives
- Improve waste management to ensure recycled construction materials are free from hazardous substances

Collaboration between cities and countries is essential to share information and best practices. Joint initiatives should be supported to tackle pollution from construction materials and improve environmental and public health. By following these recommendations, the Baltic Sea Region's environment can be protected, and cities can become safer.



Abbreviations

Definitions of all abbreviations that are used or mentioned in the report, for example different chemical substances.

BBzP: Butyl benzyl phthalate

BFR: Brominated flame retardants

BIT: 1,2-benzisothiazol-3(2H)-one

BPA Bisphenol A

BPF Bisphenol F

BPS Bisphenol S

BPR: Biocidal product regulation

CP: Chlorinated paraffins

CSO: Combined sewer overflows

DCOIT: 4,5-dichloro-2-n-octyl-4-isothiazolin-3-one

DEHA: Di(2-ethylhexyl) adipate

DEHP: diethylhexyl phthalate

DEHT: Di(2-ethylhexyl) terephthalate

DiBP: diisobutyl phthalate

DIDP: Diisodecyl phthalate

DINCH: 1,2-Cyclohexane dicarboxylic acid diisononyl ester

DINP: Diisononyl phthalate

DMP: dimethyl phthalate

DnBP: Di-n-butyl phthalate

ED: Endocrine disruptor

EHDPP: 2-Ethylhexyl diphenyl phosphate

F-gases: Fluorinated gases

FTS: Fluorotelomer sulfonate

HBCDD: Hexabromocyclododecane

IPBC: Iodopropynyl butylcarbamate

LOD: Limit of detection

LOQ: Limit of quantification

MCCP: Medium Chain Chlorinated Paraffin

MIT: 2-methyl-4-isothiazolin-3-one

MW: Molecular weight

ND: Not detected

OIT: Octhilinone

OPE: Organophosphate ester

PBT: Persistent, bioaccumulative, and toxic

PFAS: per- and polyfluoroalkyl substances

PFBS: perfluorobutanesulfonic acid

PFBA: perfluorobutanoic acid

PFCA: perfluorocarboxylic acid

PFHpA: perfluoroheptanoic acid

PFHxS: perfluorohexanesulfonic acid

PFHxA: perfluorohexanoic acid

PFNA: perfluorononanoic acid

PFOS: perfluorooctanesulfonic acid

PFOA: perfluorooctanoic acid

PFPeA: perfluoropentanoic acid

PFSA: perfluorosulfonic acid

PMT: Persistent, mobile and toxic

PNEC: Predicted no effect concentration

POPs: Persistent Organic Pollutants

PUR: Polyurethane

PVC: Polyvinyl chloride

SCCP: Short Chain Chlorinated Paraffin

TBBPA: Tetrabromobisphenol-A

TBEP: Tris (2-butoxyethyl) phosphate

TBP: Tri-n-butyl phosphate

TCEP: Tris(2-chloroethyl) phosphate

TCIP: Tris(2-chlorisopropyl)phosphate

TCPP: tris(2-chloro-1-methylethyl) phosphate

TDCPP: Tris(1,3-dichloro- 2-propyl) phosphate

TEP: Triethylphosphate

TEHP: Tris (2-ethylhexyl)-phosphate

TMCP: Tris-m-kresylphosphate

TMPP Trimethylolpropane phosphate

TNBP: Tri-n-butyl phosphate

TP: Transformation product

VOC: Volatile Organic Compounds

VPvB: Very persistent and very bioaccumulative

WWTP: Wastewater treatment plant

Introduction

The NonHazCity 3 Building Material Catalogue for tox free construction (NHC3, 2023), as well as the scientifically based consumer web application CheckED (www.nhc.check-ed.eu) already show that construction materials are significant sources of indoor and environmental exposure to hazardous chemicals. While a non-toxic environment is a prominent objective within the EU, the necessary data and tools to achieve this goal are not yet fully established. Given the ecological sensitivity of the Baltic Sea Region, however, understanding the presence and sources of hazardous substances is crucial. This requires both a thorough literature review and empirical data collection.

Therefore, in this NonHazCity 3 project, 6 of the project partners and one AO have gotten together to screen certain substances in construction materials and contact media (water, dust, air). Municipalities, universities and NGOs from 5 cities formed a screening group, cooperating on substance screening and compiling results.

The analytical screening investigations are summarised in this report and aim to enhance our understanding of the relationship between construction material composition and the occurrence of hazardous substances in indoor dust, urban stormwater, and urban wastewater in the Baltic Sea Region. The investigation focused on a selection of relevant substance groups present in construction materials, chosen for their specific functions. All substance groups are further described in chapter “Source mapping”, where the literature is systematically reviewed. The basic information about the different chemical groups below, uses and effects, are found on ECHA website. Further references are found at the end of the report.

Phthalates and alternatives (plasticizers) are a group of chemicals used to increase the flexibility of plastics in a variety of consumer products, including flooring, cables, and wall coverings. Their ability to leach into the environment and affect human health makes them a substance of concern. Phthalates are documented to be widespread in indoor environments. Several substances within the group are toxic for reproduction and have endocrine-disrupting effects.

Per- and Polyfluoroalkyl Substances (PFAS) are used in a multitude of applications for their resistance to heat, water, and oil. The persistency and ubiquity of PFAS in the environment, as well as their ability to remain in water and soil for extended periods unaltered, raises significant concerns about their long-term environmental impact.

Bisphenols is a group of chemicals used mainly during synthesis and as functional additives in the compositions of various plastics and chemical products. Bisphenol A (BPA) is the most well-known bisphenol mainly used for polycarbonate plastic and epoxy resin production. Other notable compounds are bisphenol F, S, AF, which are frequently used to replace BPA. BPA is a proven endocrine disruptor (ED). BPAF, BPB, BPF, and BPS have been shown to exhibit estrogenic and/or anti-androgenic activities similar to or even greater than that of BPA.

Organophosphate esters (OPEs) are primarily used as flame retardants and plasticizers in various consumer products, including construction materials. These substances are linked to adverse health effects, especially in enclosed environments. The OPE TCEP is on the candidate list due to its SVHC properties and is replaced by other OPEs, for example TCPP and TDCP.

Brominated Flame Retardants (BFRs) are a group of chemicals commonly used to reduce the flammability of materials such as electronics, textiles, construction materials and furniture. Their environmental concern stems from their persistence and bioaccumulation, potentially leading to

neurological and endocrine disruption. In the environment higher brominated compounds can degrade due to sunlight producing lower brominated compounds explaining the prevalence of lower brominated congeners in the environment.

Diuron, triazines, and isothiazolinones (biocides in/on wood and facade coatings). Biocides are substances used in chemical products / construction materials to prevent biological growth such as moulds and fungi. While effective, they can pose risks to the environment and to human health by causing allergies and contribute to biocide resistance in microbial populations.

Chlorinated Paraffins (CPs) are complex mixtures used as flame retardants and plasticizers in a wide range of industrial applications, including the construction sector. They are categorized by their carbon chain length and degree of chlorination. Concerns include their persistence, bioaccumulation, and potential carcinogenic effects. These substances can leach out during the lifecycle of the construction materials, contributing to environmental contamination.

Volatile Organic Compounds (VOCs) are a large group of chemicals that easily evaporate at room temperature. Common sources in construction include paints, solvents, and adhesives. Health effects can range from eye, nose, and throat irritation to more serious effects like liver and kidney damage.

Metals, such as lead, cadmium, and mercury, may cause toxic effects, even when present in trace amounts. Also, essential metals such as zinc or copper are toxic in high concentrations. Common health effects of metals are for example damage to lungs, liver, kidneys and other internal organs, carcinogenicity, reproductive problems, damage to fish gills and acute toxicity. Main concerns related to heavy metals in construction and building materials are related to leaching to the environment and toxicity to especially aquatic biota. Cadmium is restricted, but there are risks for a scattered distribution and leakage since the compounds can occur in existing buildings. In addition, cadmium is always present in varying concentrations in zinc, which means that wherever zinc is emitted, cadmium is emitted with it. The metals copper and zinc are common in construction material, functioning as cover sheets for roof and facades, but are also added for biocidal reasons, as their respective cations have such properties.

In the following sections, we present:

i) An overview of the sources, pathways, and potential effects of the substance groups listed above (source mapping).

ii) A summary of methods and matrices analysed by the 6 project partners.

iii) The most significant findings from the analytical screening investigations conducted in five cities/regions around the Baltic Sea.

The five underlying screening reports from our project partners, containing more detailed and localised data, are included in the Annex to this report.

Turku: Stormwater (Appendix 1)

Helsinki: Stormwater and construction material (from a construction site) (Appendix 2)

Tallinn: Construction material (from a hardware store) (Appendix 3)

Västerås: Stormwater, preschool air and dust, construction material (floor material from preschools) (Appendix 4)

Stockholm: Preschool dust (Appendix 5A), stormwater (Appendix 5B), wastewater (Appendix 5C), construction material (paint for outdoor use and roof material from a hardware store (Appendix 5D), sheet material from a construction site (Appendix 5E), and floor material from schools and preschools (Appendix 5F)

Source mapping

Substance Flow Analysis (SFA) quantifies the stocks and flows of chemicals within a defined system, such as a geographic region or technical system, over a specified period, usually a year. SFA includes inflows (e.g., imports and production), flows within the system (processing and end-use), emissions to the environment, and outflows to external recipients (e.g., exports or landfills). Sometimes, SFA also considers the environmental distribution of substances.

In this project, the SFA was limited to mapping products and materials from which hazardous substances (HS) are released and identifying their primary distribution pathways into targeted matrices during the screening exercise. A literature search for each substance group helped determine the relevant matrices for analysis, with key sources listed in the tables below. For a proper SFA these findings would be followed by a quantification of stocks and emissions from each material or product type.

Substances can emit to both indoor and outdoor environments through various pathways. This project selected several substances from different groups to be analysed in multiple matrices, aiming to illustrate the primary distribution pathways within the indoor and outdoor environment targeted in the NonHazCity 3 project. For VOCs, the problems related to emissions from construction products are mainly seen in the indoor environment. Figure 1 depicts these pathways, including exposure routes for humans.

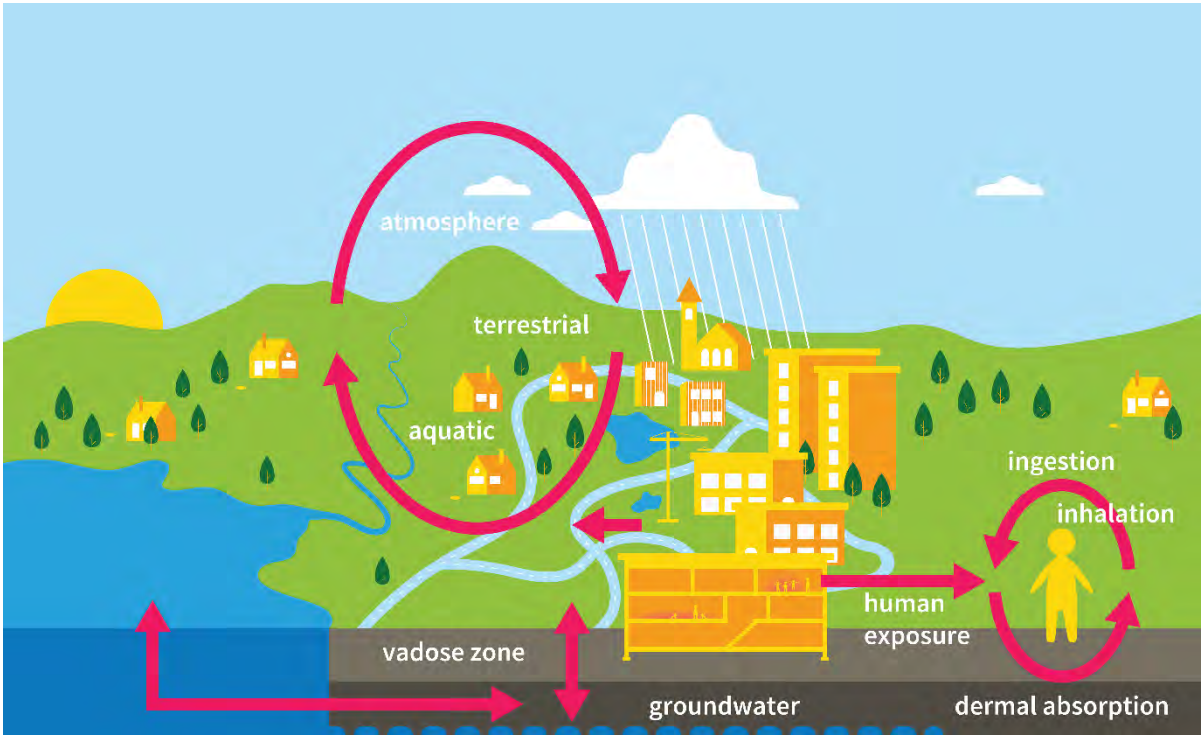


Figure 1. An illustration showing the pathways and fate of pollutants, both in the environment and regarding human exposure.

This chapter provides information about selected sampled substance groups, identifies construction products that may contain these substances, and outlines their pathways to indoor and outdoor environments.

General pathways from construction products in indoor environments include emissions to indoor air and dust, with dust potentially incinerated with waste or emitted into wastewater. From wastewater, substances can reach surface water and sludge; if sludge is used on farmland, it can contaminate groundwater. Storm water and outdoor air contamination can lead to surface water and sediment pollution. Human exposure can occur via indoor and outdoor air, dust, and, in some cases, drinking water. Substances primarily reach the environment through stormwater and wastewater. See Figure 2 below.

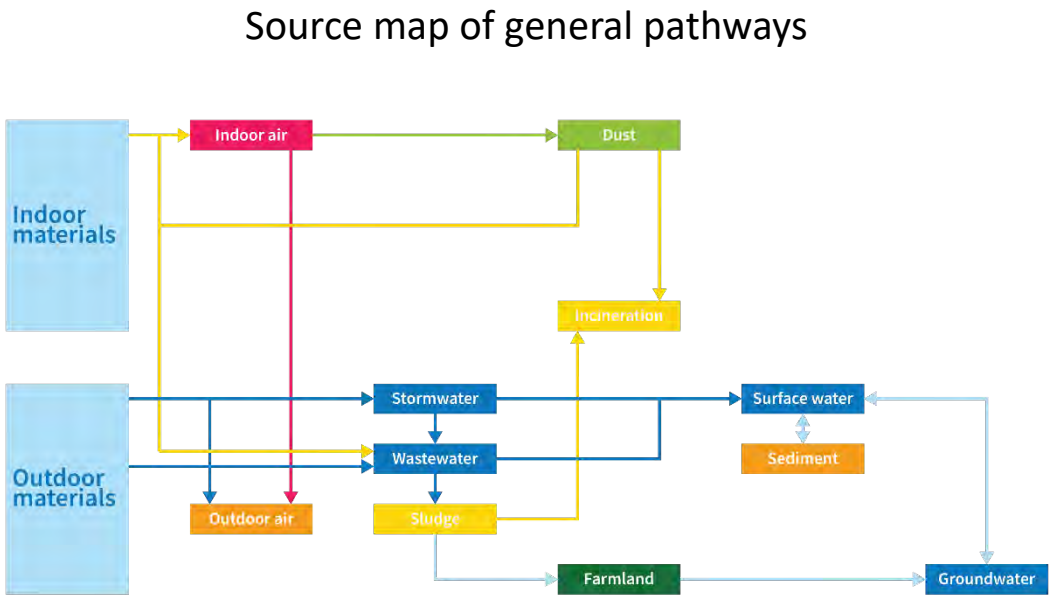


Figure 2. The general pathways for substances to emit to the indoor and outdoor environment.

The chapters below describe the substance groups in terms of use, effects, exposure, and legislation. Each chapter includes a literature study showing where substances can be found in different matrices, with relevant studies or reports listed in a table. Source maps were created based on this information and previous research and findings in the NonHazCity 3 Catalogue report. After the source map with pathways in each chapter there is a short summary of the results from this investigation. To read more about the results, see the result chapter.

Recycling materials poses challenges; it is difficult to reuse or recycle products containing hazardous substances, and the content of old products can be hard to determine.

Phthalates

Use

Phthalates are a group of chemicals based on the same chemical structure and properties, produced in large volumes. Most phthalates are added to plastic to improve its softness, flexibility, and resilience. Phthalates are primarily used to plasticize PVC, with the phthalate content reaching up to 50%. PVC is considered a low-maintenance material with good characteristics, but it often contains hazardous additives such as phthalates. Since phthalates do not bond to the materials they are added to, they migrate from the material to water and dust, causing adverse health effects to both

humans and the environment. Even though there are phthalate-free plasticizers available today, phthalates are still used in many products. Phthalates are found in cosmetics, personal care and household products, food packaging, toys, electronics, construction materials, and medical devices.

Within this NonHazCity 3 project, the focus is on building and construction materials. Products that may contain phthalates include flooring materials, roofing materials, water pipes, facade panels, cables, carpets, window frames, gutters, coatings, sealants, and many others.

Adverse effects

Phthalates can cause adverse health effects upon exposure; several substances within the group are toxic for reproduction and endocrine-disrupting according to chemical legislation (CLP, 2024). The chemical structure of the group is similar to the female sex hormone oestrogen, which can, among other things, affect male reproductive development and decrease sperm count and quality (Swedish Chemicals Agency, 2015).

Legislation

Many phthalates have harmonised classifications in the EU legislation CLP, and about 20 substances are on the candidate list, meaning they are Substances of Very High Concern according to the EU chemical legislation REACH. Several phthalates are also included in REACH Annex XVII as substances with restricted use in toys and childcare articles.

For a long time, diethylhexyl phthalate (DEHP) was the most produced phthalate, but it is now restricted. It has been partly replaced by diisononyl phthalate (DINP) and diisodecyl phthalate (DIDP), which are commonly used today.

Exposure

As stated in the Catalogue, humans are exposed to phthalates through the skin when they touch products containing phthalates. Another pathway is through dust when phthalates adsorb to dust particles, which can be inhaled. Phthalates can also leach into stormwater in the outdoor environment from surface layers on buildings. They can also emit into the air and then be deposited into stormwater.

Phthalates have also been detected in wastewater. Table X shows examples of studies where phthalates have been detected in different matrices. According to the monitoring of DEHP in wastewater sludge in Stockholm, the occurrence of DEHP in wastewater sludge has greatly decreased from 2002 to 2022 (Stockholm city, 2024).

Source mapping and measured occurrence

In scientific papers, phthalates have been found mainly in the indoor environment, in dust and air. However, they have also been found in stormwater and wastewater sludge. Several examples of papers showing these findings are listed in Table 1.

Correlations have been found between the amount of phthalates in materials and the concentrations found in dust and indoor air, according to a Swedish report measuring the substances in materials and in dust/air in three preschools in Sweden (Langer et al. 2020). A clear correlation was found when comparing phthalate concentrations in materials and dust in preschools before and after renovating the surface layers. The same correlation was found regarding phthalates in materials and indoor air in these preschools. The results show that when the concentrations of phthalates heavily decrease in materials (flooring, etc.), they also decrease in dust and air.

Table 1. Examples of studies that have detected phthalates in storm water, indoor air, dust, wastewater and wastewater sludge.

Matrix	Substances analysed	Reference	Comment	Country
Dust in preschools	DEHP, BBzP, DnBP, DiBP, DEP, DMP, DiNP, DPHP and DiDP	Larsson et al. 2017	Highest levels: DEHP and DiNP	Sweden
Dust in preschools	DEHP, DiBP, DnBP, DiNP, DiDP	Langer et al. 2021	Highest levels: DiNP	Sweden
Dust in preschools	DMP, DEP, DNBP, DIBP, BBzP, DEHP, DPP, DiNP, DiDP	Christia et al. 2019	Highest levels: DiNP, DHPP	Sweden
Dust in preschools	DiBP, DnBP, BBzP, DEHP, DMP, DEP, DiNP, DiDP, DPHP	Langer et al. 2020	Highest levels: DiNP, DEHP and DiDP	Sweden
Dust in offices	DMP, DEP, DNBP, DIBP, BBzP, DEHP, DPP, DiNP, DiDP	Christia et al. 2019	Highest levels: DiNP, DEHP	Sweden, Netherlands
Dust in homes	DMP, DEP, DNBP, DIBP, BBzP, DEHP, DPP, DiNP, DiDP	Christia et al. 2019	Highest levels: DiNP, DEHP	Netherlands, Ireland, Belgian
Indoor air in preschools	DEHP, DiBP, DnBP, DiNP, DiDP	Langer et al. 2021	Highest levels: DiBP and DnBP	Sweden
Indoor air in preschools	DiBP, DnBP, BBzP, DEHP, DMP, DEP, DiNP, DiDP, DPHP	Langer et al. 2020	Highest levels: DiBP, DnBP, DEHP	Sweden
Indoor air in homes	DMP, DEP, DiBP, DnBP	Sakhi et al. 2019	Highest levels: DEP and DiBP	Norway
Storm water	DEHP, DiNP, DiDP	Müller et al. 2019	Highest levels: DINP	Sweden
Storm water	DEHP, DiNP, DiDP	Müller et al. 2022	Highest levels: DINP	Sweden
Storm water	DEHP	Nickel et al. 2021		Germany
Wastewater sludge	DEHP	Stockholm City Environmental barometer	DEHP levels have decreased from ~90 to ~ 15 µg/g from 2005 to 2022.	Sweden

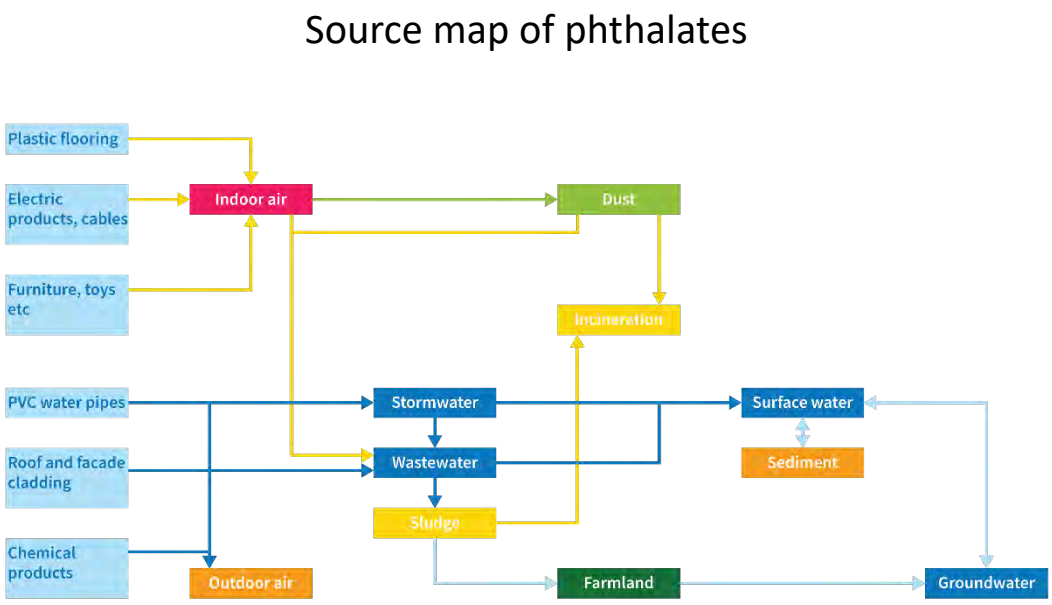


Figure 3. A Source map showing the sources of phthalates in construction products and the pathways into different reservoirs in the indoor and outdoor environment.

Figure 3 illustrates how a source map can illustrate the spread of phthalates from construction products to the environment. The grey boxes show common sources of phthalates in construction products in Europe. The substances are found mainly in dust and air in the indoor environment and in stormwater in the outdoor environment. Typically, dust is vacuumed or cleaned and ends up in wastewater or is incinerated. From the wastewater, phthalates can end up in surface water or sludge, and in some countries, the sludge is spread on farmland. Phthalates in groundwater can end up in surface water and from surface water phthalates can end up in e.g. the sediment.

Results from the sampling

In short, phthalates have been sound in the sampling in this investigation both in dust, stormwater and in material samples.

Phthalate (and alternative plasticizer) analysis was conducted on preschool dust samples collected in Stockholm and Västerås, with a total of 26 samples. A broad range and distribution of plasticizers were observed. Typically, Stockholm recorded the highest concentrations of DINP (1035 µg/g) and DINCH (1034 µg/g), whereas Västerås had the highest concentrations of DEHT (1015 µg/g). A few preschools exhibited high levels of DEHP, in Stockholm 282 µg/g and in Västerås 784 µg/g.

Phthalate analysis was conducted on stormwater samples collected from Stockholm, Västerås, Turku, and Helsinki. The highest concentration was observed in Helsinki (DINP 1.7 µg/L), while the lowest concentration was noted in Stockholm, where no phthalates were quantified.

Construction materials were collected in four cities: Stockholm, Västerås, Tallinn, and Helsinki. PVC contained various plasticizers (13-20% DINP, DINCH, DEHT, DIDP).

PFAS

Use

Per- and polyfluoroalkyl substances (PFAS) are polymeric and non-polymeric chemicals comprising more than 10,000 individual compounds. The group can be categorised into the following sub-groups:

- "Classic" PFAS and their precursors (like PFOA and PFOS)
- Fluoropolymers: polymers made of fluorinated monomers (plastics)
- F-gases: fluorinated gases that have a high global warming potential

PFAS have several useful properties, making them widely used for various industrial and engineering applications or the manufacture of consumer goods. PFAS are resistant to heat, radiation, and weathering; they are chemically inert and repel stains. Due to these properties, they are commonly used for surface treatments, industrial processes, and numerous other applications.
In construction materials, PFAS are used in textiles including carpets and upholstery, wood boards, OSB and chipboards, insulation materials, electronic equipment, floorings such as resilient linoleum and laminated plastic floor coverings, plastic piping, mounting foams, indoor and outdoor paints, plaster, coatings, sealants, and architectural foils.

Adverse effects

Due to the very strong carbon-fluorine bond, PFAS are extremely resistant to degradation, earning them the moniker "forever chemicals". Many PFAS are also mobile in the environment and can be found in surface and groundwater, soil, sediment, and biota. Some PFAS are bioaccumulative, meaning that the concentration of PFAS increases in organisms over time, contaminating food chains. Known adverse effects of PFAS include endocrine disruption, reproductive toxicity, carcinogenicity, liver toxicity, and immunosuppression. The toxicological profiles of many PFAS have not been studied, but many are suspected to have similar adverse effects to those that have been studied.

Legislation

Currently, PFOS, PFOA, PFHxS, and their salts and related compounds are globally regulated under the Stockholm Convention on Persistent Organic Pollutants. Long-chain PFCAs (carbon chain length 9 to 21) have been proposed for addition to the Convention for global elimination. In the EU, PFCAs (C9-14), their salts, and precursors are restricted. Additionally, several PFAS, such as PFBS, PFHxS, and PFHpA, are on the REACH Candidate List of Substances of Very High Concern. A proposal for a group-based ban on PFAS, including fluoropolymers, is currently being processed in the EU.

Exposure

The main exposure route of PFAS for humans is through food and drinking water, where PFAS end up via industrial and domestic wastewater, stormwater run-off, atmospheric deposition, and direct emissions (e.g., from aqueous film-forming foams (AFFFs) used in firefighting). Exposure can also occur through inhalation of dust or volatile PFAS in the air or absorption through the skin.

Source mapping and measured occurrence

PFAS are used in a variety of outdoor and indoor building materials. From indoor materials, PFAS can be released into dust or indoor air (volatile compounds). Outdoors, PFAS can enter soils or surface and groundwater through runoff or be released directly into the air. In addition to

construction materials, PFAS are used in a variety of other consumer products and industrial processes, where they can be released into the environment.

Table 2. A selection of studies that have detected PFAS in indoor air, dust, storm water, wastewater and biota.

Matrix	Substances analysed	Reference	Comment	Country
Dust in homes	PFSAs, PFCAs, PFPAs, PAPs, FOSAs, FOSEs, FTOHs, PFOSAs	Poothong et al, 2020. de la Torre et al. 2019	Highest exposure to and prevalence of perfluoro carboxylic acids	Norway, Belgium, Italy, Spain
Indoor air in homes	Precursors of PFAAs	Poothong et al, 2020	Highest exposure to precursors of PFOA and PFOS through air	Norway
Dust in preschools	PFSAs, PFCAS, PAPs, FOSAs	Giovanoulis et al. 2019	Highest concentrations of diPAPs	Sweden
Stormwater	PFSAs, PFCAs	Vahtera et al. 2022. Nickel et al. 2021		Finland, Germany
Wastewater sludge	Ultrashort PFAS, PFCAs, FTSAs, FTCAs, PAPs, PFSAs, FOSAs, PFPAs, PFPiAs, EOF	Fredriksson et al. 2022, Kärrman et al. 2019	Predomination of precursor and intermediate PFAS, temporal decline in C8 PFAS	Sweden, Faroe islands, Norway, Denmark, Finland
Wastewater effluent	Ultrashort PFAS, PFPiAs, PFPAs, PFSA and PFCA precursors, PFCAs, PFSAs, EOF	Kärrman et al. 2019, Nickel et al. 2021	PFCAs, PFSAs and ultrashort PFAS dominating	Greenland, Iceland, Faroe islands, Norway, Denmark, Sweden, Finland, Germany
Surface water	Ultrashort PFAS, PFPiAs, PFPAs, PFSA and PFCA precursors, PFCAs, PFSAs, EOF	Kärrman et al. 2019	Highest concentrations for PFCAs and PFSAs over other groups of PFAS	Greenland, Island, Faroe islands, Norway, Denmark, Sweden, Finland
Soil	PFCAs, PFSAs, FTSA, FOSA, FOSAA, diPAPs, doSAmPAP, FOSEs, TOP assay	Reinikainen et al. 2024, Wellmitz et al. 2023, Sörengård et al. 2022		Sweden, Germany, Finland
Bird eggs	Ultrashort PFAS, PFPiAs, PFPAs, PFSA and PFCA precursors, PFCAs, PFSAs, EOF	Kärrman et al. 2019	Highest concentrations for PFCAs and PFSAs over other groups of PFAS	Greenland, Iceland, Faroe Islands, Sweden
Marine mammals	Ultrashort PFAS, PFPiAs, PFPAs, PFSA and PFCA precursors, PFCAs, PFSAs, EOF	Kärrman et al. 2019	Highest concentrations for PFCAs and PFSAs over other groups of PFAS	Greenland, Faroe islands, Denmark
Terrestrial mammals	Ultrashort PFAS, PFPiAs, PFPAs, PFSA and PFCA precursors, PFCAs, PFSAs, EOF	Kärrman et al. 2019	Highest concentrations for PFCAs and PFSAs over other groups of PFAS	Greenland, Iceland, Sweden, Finland
Fish	Ultrashort PFAS, PFPiAs, PFPAs, PFSA and PFCA precursors, PFCAs, PFSAs, EOF	Kärrman et al. 2019	Highest concentrations for PFCAs and PFSAs over other groups of PFAS	Greenland, Denmark, Norway, Sweden, Iceland, Faroe islands, Norway, Denmark, Sweden, Finland

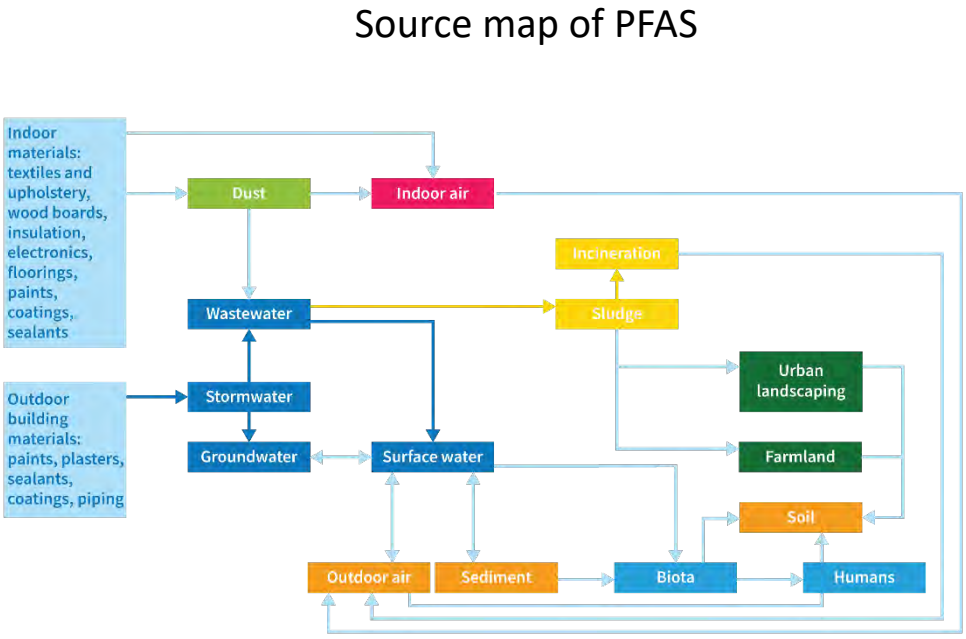


Figure 4. A Source map showing the sources of PFAS in construction products and the pathways into different reservoirs in the indoor and outdoor environment.

Figure 4 illustrates how a source map can depict the spread of PFAS from construction products. The grey boxes show some common sources of these substances in construction products in Europe. PFAS are found in various matrices such as indoor dust, indoor air, surface water, wastewater, sediment, and biota.

Results from the sampling

In short, PFAS were analysed and found in several matrices in this investigation. In stormwater, PFAS samples were taken in Stockholm, Västerås, Helsinki, and Turku. The highest concentrations were found in Stockholm, except for one spot in Helsinki. In Västerås, the concentrations were low.

Only Stockholm took samples in wastewater, and 11 PFAS substances were analysed. They were found to be prevalent within a concentration range from LOQ to 30 ng/L.

PFAS in dust was analysed in preschools in Stockholm and Västerås, with 26 samples taken. A broad range and distribution of PFAS substances were observed.

Bisphenols

Use

Bisphenols are a group of high-production volume chemicals used for a wide range of applications, mainly during synthesis and as functional additives in various plastics and chemical products. Bisphenol A is the most well-known chemical from this class. Its major uses are the production of polycarbonate plastic and epoxy resins (more than 95% of all Bisphenol A). Other notable compounds include Bisphenol F, S, AF, and TBBPA.

Recently, BPA has been regulated, leading to alternatives such as BPS, BPF, BPAF, and TBBPA being among the main substitutes, although their endocrine-disruptive potential is suspected to be of comparable magnitude.

In the construction sector, sources of bisphenols include polycarbonate plastic materials such as polycarbonate roofing sheets (porch/veranda, conservatory, greenhouse glazing), epoxy resins (composite floor coatings, fluid-applied flooring, metal coatings, other composites, reinforced concrete, high-performance coatings), PVC plastic (and its products, such as PVC floorings, roofing membranes, wall cladding, piping, etc., (Lamprea et al., 2018), layers in plastic products, sealing membranes, electric and electronic equipment, recycled plastic, and other plastic products.

Adverse effects

As described in the Catalogue (NHC3, 2023), BPA is a proven endocrine disruptor (ED). It is toxic to reproduction and causes negative developmental and neurological effects in humans. BPA is also toxic to aquatic life. BPA readily degrades in the environment but, since it is used and emitted in such high amounts, it occurs in many environmental matrices. Health concerns for many bisphenols are similar. Many BPA analogues exhibit endocrine-disrupting effects, cytotoxicity, genotoxicity, reproductive toxicity, dioxin-like effects, and neurotoxicity in laboratory studies. In the environment, bisphenols have adverse ED and PBT/vPvB properties. BPAF, BPB, BPF, and BPS have been shown to exhibit estrogenic and/or anti-androgenic activities similar to or even greater than that of BPA (Chen et al., 2016).

Legislation

In 2021, ECHA assessed 148 bisphenols and bisphenol derivatives as a group of chemical compounds. It was found that 34 bisphenols may need to be restricted under the EU's chemicals legislation, REACH, as they may interfere with hormonal systems and affect reproduction. Presently, BPA use restrictions are limited to thermal paper, drinking bottles for children, and food contact materials.

As of 2024, several bisphenols are included in the list of Substances of Very High Concern, including: BPA (CAS no.: 80-05-7); BPS (CAS no.: 80-09-1); BFB (CAS no.: 77-40-7); TBBPA (CAS no.: 79-94-7).

Exposure

Although dietary intake is considered the main exposure route for BPA, it can also be absorbed through the skin due to contact with polycarbonate products or via inhalation of BPA with air and dust in the indoor environment. BPA has a tendency to bind to dust/particulate matter and has been detected in the indoor environment (Hahladakis et al., 2022). The quality of indoor air is a concern due to BPA's association with dust particles. Ingestion and inhalation of dust are important exposure routes, especially for young children and toddlers. Occupational exposures to BPA via inhalation pose a great risk. Workers in BPA handling factories can be considered the highest risk group compared to the general population (Vasiljevic et al., 2021).

Other bisphenols such as TBBPA, BPF, and BPS occur widely in household dust at notable concentrations, suggesting significant exposure to these chemicals. BPAF, BPAP, BPP, and other bisphenols are also detected but at much lower concentrations (Wang et al., 2015).

BPF and BPS have a potency similar to BPA for estrogenic, anti-estrogenic, androgenic, and anti-androgenic activities (Rochester et al., 2015).

Source mapping and measured occurrence

BPA is the most investigated bisphenol as it is the most widely used and widespread. Thus, regarding the fluxes and reservoirs of bisphenols, scientific literature mostly reports on BPA.

Scientific studies report that bisphenols (BPA, BPF, BPAF, BPS, TBBPA, and others) are present in household dust due to emissions from various plastic household items, electric and electronic equipment, and construction materials. Regarding building exteriors, BPA has been reported to leach from construction materials by rain, contributing to environmental contamination. It is found in influent wastewater and also in treated wastewater. It is also detected in sewage sludge, to which it has an affinity. Household waste is a potential source of bisphenols. They may be released from waste sorting/treatment operations, as well as through weathering and the breakdown of waste and litter. In fact, plastic littering is a significant source of bisphenol occurrence in the marine environment.

Studies report that BPA can be released into the atmosphere via fugitive environmental emissions into air and water from landfills and waste treatment plants, as well as uncontrolled burning of household waste (including building waste). Landfilling is the greatest source of BPA into groundwater through landfill leachates. Although BPA has a short half-life in air, it has an affinity for particulate matter/dust. Thus, atmospheric transport of dust is a viable mechanism for the long-range transport of BPA, as it is detected in remote locations.

Table 3. Examples of studies that have detected bisphenols in construction materials, indoor air, dust, surface water, sediment, sewage sludge, and other matrices.

Matrix	Substances analysed	Reference	Comment	Country
Construction materials, stormwater.	BPA	Lamprea, K., et al., 2018.	Found in PVC materials, elastomeric membranes, high performance coatings, polycarbonate materials. Leaching tests with water.	France
Plastic waste emissions into air, dust, groundwater, marine, surface water.	BPA	Hahladakis et al. 2022.	Review study. Plastic waste management – an important pathway of BPA into air and groundwater (from waste management sites, landfills).	Quatar
Indoor air and dust, outdoor air and dust	BPA, BPS, BPZ, BPAF, BPAP, BPP, TBBPA	Vasiljevic et al. 2021.	Review study on bisphenol properties sources and levels in indoor and outdoor air.	Canada
Household dust	BPF, BPA, BPB, BPS, BPZ, BPAP, BPAF, BPP, TBBPA.	Wang et al. 2015.	Measure of different bisphenols in household dust in 12 countries.	US
Landfill leachates	BPA	Urase et al. 2003	BPA detected in landfill leachates.	Japan

Air (aerosols)		Fu et al. 2010.	Bisphenol A in the atmosphere	Japan
Indoor dust, surface water, sediment	BPA, BPS	Qiu et al. 2019	Review study on BPA and BPS occurrence in various matrices, including environmental matrices.	China
Wastewater, sewage sludge	BPA	Mohapatra et al. 2011.	Investigation of occurrence of BPA in influent, effluent wastewater and sludge.	Canada
Surface water, Sediment	BPA	Staples et al. 2018	Long term BPA analysis in surface water and sediment.	Europe, North America.

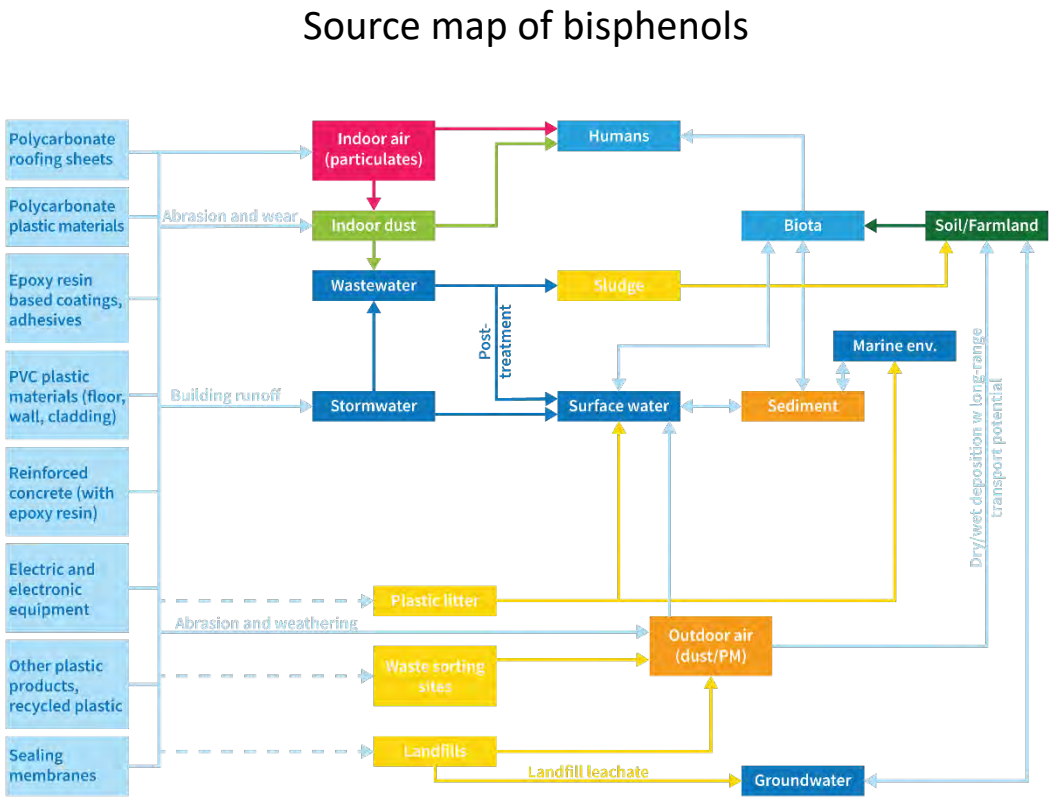


Figure 5. A Source map showing the sources of bisphenols in construction products and the pathways into different reservoirs in the indoor and outdoor environment.

Figure 5 shows how a source map can illustrate the spread of bisphenols from construction products. The grey boxes show common sources of these substances in construction products in Europe. Bisphenols are found in various matrices such as indoor dust, indoor air, surface water, and sediment.

Results from the sampling

In short, bisphenol analysis was mainly conducted in dust in this investigation. A total of 26 samples were taken from preschool dust in Stockholm and Västerås. All samples showed the prevalence of bisphenols, with the highest concentrations of BPA in Stockholm and TBBPA in Västerås.

Organophosphate esters (OPEs)

Use

Organophosphate esters (OPEs) possess flame retardant properties and are used as substitutes for restricted brominated flame retardants. They are added to various materials, including construction materials, to reduce flammability. These substances can also be used as plasticizers. They do not form a chemical bond with the products they are added to, which means they can spread into the environment. As written in the Catalogue (NHC3, 2023), OPEs are used in construction products, e.g., as flame retardants in PVC plastics, polyurethane (PUR) materials, foams and sprays, furniture, textiles, and electronic equipment. OPEs can also be used as plasticizers in floor polishes, coatings, thermoplastics, and epoxy resins.

Adverse effects

The most discussed OPEs are the chlorinated ones. They have been associated with adverse effects such as neurotoxicity, developmental toxicity, damage to reproductive function, endocrine disruption, carcinogenicity, as well as bioaccumulation and persistence in the environment.

Presence and exposure

These compounds are pollutants commonly detected in a variety of environmental matrices, including the atmosphere, surface water, indoor air, dust, sediments, and soil. Humans are exposed to OPEs through routes such as skin contact, ingestion, and inhalation. Three chlorinated OPEs - TCEP, TCIPP, and TDCIPP - are restricted for use in children's toys in the European Union.

Source mapping and measured occurrence

In scientific papers, OPEs are mainly found in dust and indoor air. Several examples of papers showing these findings are listed in Table 4. Correlations were found between the amount of OPEs in materials and the concentrations found in dust and air, according to a Swedish report measuring the substances in materials and dust in three preschools in Sweden (Langer et al., 2020). This was particularly evident when analysing OPEs in materials and dust/indoor air in a preschool before and after renovating the surface layers. The results show that the concentration of OPEs drastically decreased both in materials (flooring, etc.) and in dust/air.

Correlations were also found between OPEs in other types of materials and indoor air. Levels of some emerging BFRs and OPEs decreased significantly in indoor air and dust in childcare centres when flame-retarded nap mats were replaced with FR-free alternatives (Stubbings et al., 2018). In another study, Liang et al. (2017) investigated detailed migration pathways of OPEs from insulation materials into indoor environments.

Table 4. Examples of studies that have detected OPE in mainly indoor air and dust.

Matrix	Substances analysed	Reference	Comment	Country
Dust in preschools	TCEP, TCPP, TDCPP, TBOEP, TPhP	Langer et al. 2020	Highest levels found of TBOEP, TCEP and TDCPP	Sweden
Dust in preschools	TCEP, TCPP, TDCPP, TBOEP, TPhP	Langer et al. 2021	Highest levels found: TCEP, TDCPP, TBOEP	Sweden
Dust in homes and preschools	TIBP, TNBP, TCEP, TCIPP, TDCIPP, TBOEP, TPHP, EHDPP, TEHP, TMPP	Langer et al. 2016	Highest levels found: TBOEP and TCEP	Denmark
Dust in preschools	TBEP, TCPP, TPhP	Fromme et al. 2014	Highest levels found: TBEP.	Germany
Dust	TBOEP, TCIPP TiBP, TnBP, TEP, TCEP, TDCPP, TCPP and more	Zhou et al. 2017a	Highest levels found: TBOEP and TCIPP	Germany
Indoor air		Langer et al. 2021		
Indoor air in preschools	TBEP, TCPP, TPhP	Fromme et al. 2014	Highest levels found: TBEP.	Germany
Indoor air	TiBP, TnBP, TEP, TCEP, TDCPP, TCPP and more	Zhou et al. 2017a	Highest levels found: TCPP, TiBP, TnBP.	Germany
Indoor air in homes and preschools	TEP, TIBP, TBP, TCEP, TCPP, TBOEP, TPhP, EHDPP	Langer et al. 2020	Highest levels found of TIBP, TCEP and TCPP	Sweden

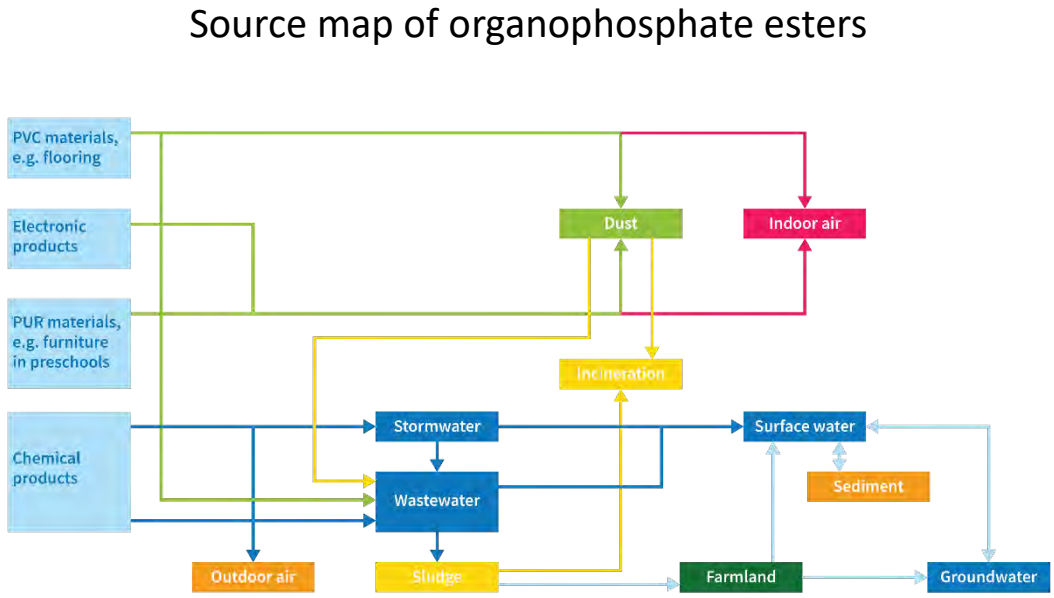


Figure 6. A Source map showing the sources of OPEs (organophosphates) in construction products and the pathways into different reservoirs in the indoor and outdoor environment.

Figure 6 shows how a source map can illustrate the spread of OPEs from construction products. The grey boxes show some common sources of phthalates in construction products in Europe. OPEs are found in dust and indoor air within indoor environments. Typically, dust is vacuumed or cleaned and ends up in wastewater or is incinerated. Liang et al. (2017), in their study published in the Journal of Hazardous Materials, detailed the migration pathways of OPEs from insulation materials into indoor environments such as indoor air.

Results from the sampling

In short, OPE analysis was conducted on stormwater, wastewater and materials in this investigation. Stormwater samples were collected from Stockholm, Västerås, Turku, and Helsinki. TCPP was detected at low concentrations in Stockholm (four locations), Turku (all locations), and Helsinki (one location), but it was not found in Västerås. TCPP is known for its use as a flame retardant in construction products such as foam materials. In BVB, TCPP is found in about 50 products at concentrations of 3-20%, mostly in foam/polyurethane products such as foam plastic insulation, joint foam, and intumescent sealant.

Wastewater sampling was conducted in Stockholm. Among the OPEs detected, TCPP was identified as the most abundant.

Among the construction materials collected in four cities—Stockholm, Västerås, Tallinn, and Helsinki—TCPP was only found in an insulation material collected in Tallinn (3.7% TCPP).

Brominated flame retardants

Use

Brominated flame retardants (BFRs) are a group of halogenated organic chemical compounds used as additives in various consumer and industrial products, including construction materials, to reduce

flammability and retard the spread of fire. This is sometimes necessary to meet national or international fire safety requirements.

Historically, major chemicals in this group have included polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCDD), and tetrabromobisphenol-A (TBBPA). Currently, the most hazardous BFRs have largely been replaced by organophosphate flame retardants (OPFRs), but other non-restricted BFRs remain on the market. BFRs still in use include tetrabromobisphenol-A (TBBPA) and some other novel brominated compounds. Legacy flame retardants are still found in plastic products as they enter the market through the recycling of old plastic products.

BFRs are found in polystyrene (EPS and XPS) insulation (particularly HBCDDs), other insulation materials, mounting and sealing foams, elastomeric foams, polyurethane foams, floor coverings, various plastic products, electronic equipment, furniture, household textiles and upholstery, and materials made from recycled plastic, polycarbonate, and epoxy resins.

Adverse effects
As detailed in the Catalogue (NHC3, 2023), many PBDEs and HBCDDs are persistent, mobile, and toxic chemicals with bioaccumulative properties. Many BFRs currently available on the market are suspected to have carcinogenic, mutagenic, and/or endocrine-disruptive properties.

Legislation

- The use of pentaBDE (EC 251-084-2) and octaBDE (EC 251-087-9) was banned in the EU in 2003, followed by decaBDE (EC 214-604-9).
- In 2010, tetra-, penta-, hexa-, and heptaBDE were banned under the POPs Regulation, with decaBDE added later.
- HBCDD and its major diastereoisomers were included in the REACH Authorisation list in 2011 and also banned under the POPs Regulation.
- Recently, TBBPA (EC 201-236-9) and BTBPE (EC 253-692-3) have been identified as SVHCs due to their carcinogenicity and potential vPvB properties, respectively.
- In 2011, the RoHS Directive introduced restrictions on polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) in electrical and electronic equipment (ECHA, 2023).

However, some novel BFRs are in use today and can be found in indoor environments (Fromme et al., 2014), as well as old BFRs, since they enter the raw material cycle through the recycling of plastic products.

Exposure
Main human exposure routes to BFRs are through dietary intake, while indoor sources of BFRs also contribute to daily exposure through ingestion of dust and inhalation of dust and air (Fromme et al., 2016). BFRs can be released from construction materials through abrasion or volatilisation. Due to their persistence and high volumes used, elevated concentrations are found globally in the environment, despite restrictions on their production and use. PBDEs have the potential for long-range atmospheric transport and have been detected in the Arctic and other remote areas (Möller et al., 2011).

Source mapping and measured occurrence
Scientific studies report that BFRs are present in the indoor environment, found in household dust and air, with construction materials being one of their sources. Main routes of exposure to BFRs

from construction materials are through inhalation and ingestion of dust and indoor air. BFRs are also ubiquitous in the environment and found even in remote areas (e.g., Arctic). Studies reveal that certain measures, such as cleaning patterns and the removal of household items, can significantly affect indoor dust concentrations (Sugeng et al., 2018).

Table 5. Examples of studies that have detected BFRs in construction materials, indoor air, dust, surface water, sediment, and sewage sludge.

Matrix	Substances analysed	Reference	Comment	Country
Household equipment, construction materials.	PBDEs, HBCDDs, novel BFRs (NFRs), such as TBBPA	Vojta et al. 2017	Significant concentration of BFRs found in almost all matrixes analysed. Waste sorting and waste disposal sites are a significant pathway for BFR contamination.	Czech Republic
Freshwater samples, freshwater sediment and freshwater biota.	PBDEs, HBCDDs, novel brominated FRs (NBFRs)	Iqbal et al. 2017	A review study that reviews many previous investigations.	Various (but including Europe)
Atmosphere (air samples), sewage sludge, aquatic and surface sediments, terrestrial and aquatic biota	PBDEs, HBCDDs, novel brominated FRs (NBFRs)	Law et al. 2006	A review study that reviews many previous investigations.	Europe
Indoor dust and indoor air.	PBDEs, bromobenzenes, novel BFRs	Venier et al. 2016	Measurable and even significant concentrations of BFRs are found.	Czech Republic, US, Canada.
Indoor dust and indoor air.	PBDEs, HBCDDs, decabromodiphenyl ethane (DBDPE)	Wemken etal. 2019	Measurable and even significant concentrations of BFRs are found.	Ireland, UK.
Indoor dust and indoor air.	PBDEs, HBCDDs, novel brominated FRs (NBFRs)	Malliari et al. 2017	A review study that reviews many previous investigations.	Worldwide
Air and seawater in the Arctic	PBDEs, NFRs (HBB, DPTE, PBT).	Möller et al. 2011	BFRs detected in air and seawater samples	European Arctic (East Greenland sea)
Sewage sludge	PBDEs, TBBPA	Öberg et al. 2002	Main sources of BFRs in sewage sludge are certain industries.	Sweden

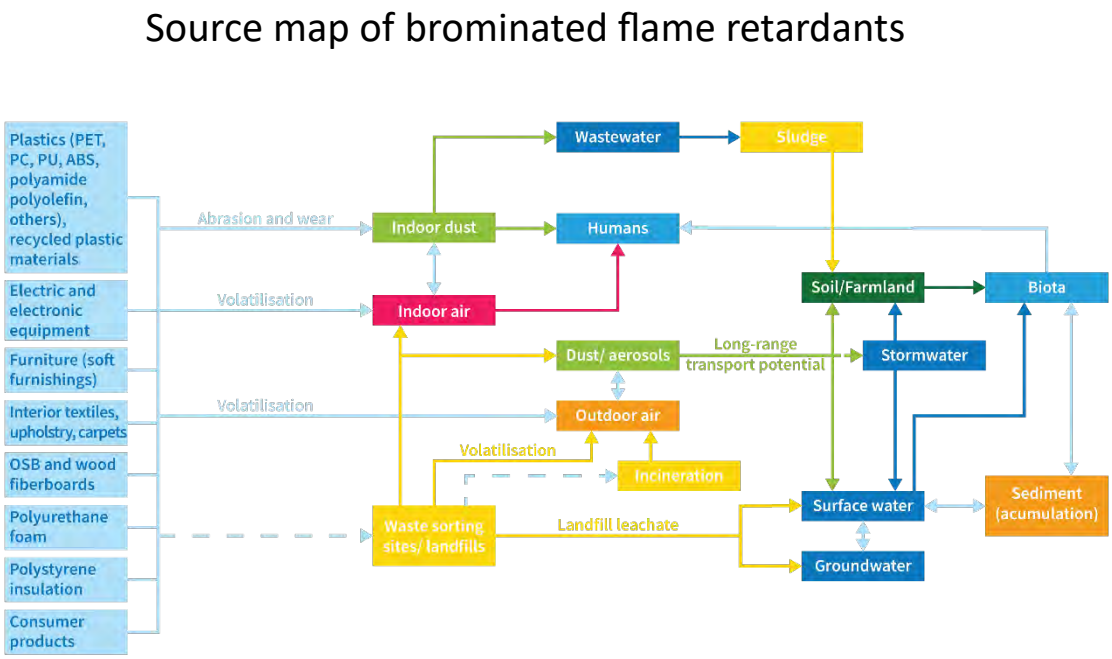


Figure 7. A Source map showing the sources of brominated flame retardants in construction products and the pathways into different reservoirs in the indoor and outdoor environment.

Figure 7 shows how a source map can illustrate the spread of brominated flame retardants from construction products. The grey boxes show common sources of these substances in construction products in Europe. Brominated flame retardants are found in various matrices such as indoor dust, indoor air, and freshwater.

Results from the sampling

In short, brominated flame retardants were found in dust in preschools in Stockholm and Västerås. In Västerås, eight samples were taken and two substances were found in low concentrations. In Stockholm, TBBPA was found in 15 of 19 dust samples, with a mean concentration of 0.19 µg/g.

Biocides

Use

Biocides are widely utilized in the construction industry to enhance the durability and functionality of construction materials. Incorporated into paints, adhesives, wood products, and various coatings, these chemical substances are engineered to prevent the deterioration caused by microorganisms such as fungi, bacteria, and algae. While biocides are essential for preserving material longevity and ensuring structural integrity, their application is not without significant environmental and health considerations.

Biocides used in construction materials are designed to protect these materials from microbial damage, yet their presence in the environment post-application raises significant concerns. This section delves into how these substances enter and impact environmental systems, focusing on the mechanisms of release, types of ecosystems affected, and the broader ecological consequences.

Exposure

In construction, biocides serve multiple critical functions:

- Paints and Coatings: Biocides prevent the growth of mold and mildew on both interior and exterior painted surfaces, maintaining aesthetic qualities and preventing material decay.
- Wood Preservatives: Wood treatments with biocides protect against rot and insect damage, essential for structural components exposed to moisture and susceptible to biological attack.
- Adhesives and Sealants: The inclusion of biocides in these products prevents microbial degradation, which can compromise the binding integrity and effectiveness of these materials over time.

Biocides such as zinc pyrithione, copper-based compounds, and isothiazolinones are among the common types used in these applications due to their broad-spectrum efficacy against a range of microbial threats.

Adverse effects

- The ecological and health impacts of biocides from construction materials can be considerable, affecting various aspects of the environment:
- Aquatic Toxicity: Many biocides are highly toxic to aquatic organisms. Studies have shown that runoff containing biocides like triclosan and copper-based compounds can be particularly harmful to fish, amphibians, and invertebrates, disrupting reproductive systems and affecting biodiversity. For instance, research by Andrews et al. (2022) demonstrated that biocides in runoff could cause sub-lethal effects in fish, such as changes in hormone levels and reproductive behaviours.
- Soil Contamination: Biocides that leach into the soil can alter its chemical composition and microbiota. This can affect soil fertility and the health of plants and animals that depend on soil ecosystems. The accumulation of biocides in soil can also pose risks to human health through direct contact or consumption of contaminated groundwater and crops.
- Air Quality and Human Health: The volatilization of biocides impacts indoor and outdoor air quality, with potential health effects including respiratory problems, skin irritation, and other allergic reactions. Continuous exposure to biocide-contaminated air in enclosed spaces has been linked to increased risks of asthma and other respiratory conditions.

Legislation

The regulation of biocides in the European Union is primarily governed by the Biocidal Products Regulation (BPR), which ensures that biocides are safe for use and do not pose unacceptable risks to the environment. Despite stringent regulations, the persistence of biocides in the environment indicates a need for enhanced enforcement and possibly stricter guidelines on the use and disposal of biocide-containing materials.

The use of biocides in construction materials is subject to rigorous regulation, especially within the European Union, where the Biocidal Products Regulation (BPR, Regulation (EU) No 528/2012) plays a critical role in ensuring their safety and environmental compatibility. However, the ongoing detection of biocides in environmental samples points to areas where regulatory frameworks may need strengthening and where additional mitigation measures could be implemented.

Source mapping and measured occurrence

Despite their benefits, the use of biocides in construction materials raises several environmental and health concerns. Biocides can enter the environment through several primary pathways, each linked to their use in construction:

- Leaching and Runoff**:** During rain events, biocides can leach from exterior construction materials into the surrounding soil and waterways. This runoff can carry significant concentrations of biocides, contributing to non-point source pollution that can disrupt aquatic ecosystems. <>Biocides are often not permanently bound to the materials in which they are used, such as paints and wood treatments. Over time, these substances can leach out due to weathering, rain, or even routine cleaning processes. For example, biocides in exterior paints can wash off building surfaces during rainstorms, entering stormwater systems and eventually aquatic habitats.
- Volatilization**:** Volatile organic compounds (VOCs) in biocides can off-gas into indoor environments, degrading air quality and posing health risks to building occupants. Prolonged exposure to these compounds has been linked to respiratory issues, allergic reactions, and other health problems. <> Some biocides, especially those used in indoor applications like paints and sealants, can volatilize into the air during and after application. This contributes to indoor air pollution and, when ventilated to the outdoors, can become part of the atmospheric contaminant load affecting urban and rural air quality.
- Disposal and Degradation**:** Post-consumer disposal of construction materials treated with biocides can lead to further environmental contamination. As these materials degrade in landfills, biocides can leach into groundwater, posing long-term ecological and human health risks. The end-of-life disposal of construction materials treated with biocides can also be a significant source of environmental contamination. Materials discarded in landfills can degrade, releasing biocides into landfill leachate, which may eventually contaminate groundwater or surface waters.

Some examples of publications showing these findings are shown in Table 6.

Table 6. A selection of studies that have detected Biocides in indoor air, dust, storm water, groundwater etc.

Matrix	Substances analysed	Reference	Country and comment	
Surface water	biocides	Andersson et al. 2019	Chronic effects of biocides on aquatic species and ecosystem function	Europe
Surface water	biocides	Andrews et al. 2022	Impact of biocides from construction runoff on aquatic ecosystems	Europe
Groundwater and soil	biocides	Fisher, & Werschkun 2020	Leaching of biocides from construction materials: Risk to soil and groundwater.	Europe
Surface water	biocides	Harclerode et al. 2021	Impact of biocidal wash-off from buildings on urban water quality.	Europe

Surface water	biocides	Johnson et al. 2021	Acute and chronic toxicity of construction material biocides in aquatic environments.	Europe
Soil	biocides	Lee et al. 2020	Impact of biocides on microbial communities in soil.	Europe
Surface water	biocides	Miller et al. 2021	Environmental impacts of biocide leaching from construction materials.	Europe
Indoor air	biocides	Zhang & Choi 2019	Indoor air quality issues related to the use of biocides in construction materials.	China
Indoor air	biocides	Zhang, & Li 2019	Indoor air quality effects from the volatilization of biocide-containing building materials.	China
surface water	diuron, isoproturon, cybutryne, terbutryn	Durak, et.al. 2021	The current biocide concentration standards in waters were exceeded only in the case of cybutryne samples from the Wisła River, and in the case of the Wisłoka River, they almost exceed the permissible threshold.	Poland
soil, wastewater	Methylisothiazolinone (MIT)	Novak et al. 2020	Methylisothiazolinone (MIT) occurs in soil and sewage samples in Poland.	Poland
soil, stormwater	Methylisothiazolinone (MIT)	Bollmann et al. 2017	Biocides leach from the facade material leading to highly polluted runoff water (up to several mg L–1 biocides) being infiltrated into the soil surrounding houses.	Denmark
surface water	Biocides	Paijens et al. 2021	Annual mass loads discharged in the Seine River were higher for WWTPs than CSOs.	France
surface water	Biocides	Paijens et al. 2020	•Identification of the most used biocides in constructoin materials •Leaching of biocides from construction materials. •Transport of the biocides and occurence in the aquatic environment.	France

facade runoff	diuron and carbendazim	Burkhardt et al. 2011	Concentrations of diuron and carbendazim in runoff were 7 and 0.7 mg/L respectively at the beginning of the experiment, under laboratory conditions. After the equivalent of 6 years of rainfall in the Swiss Plateau, concentrations were up to two orders of magnitude lower with 70 µg/L for diuron and 40 µg/L for carbendazim.	Switzerland
facade runoff	diuron	Burkhardt et al. 2012	Under natural weather conditions, concentrations of diuron in façade runoff were reported between 10 and 25 mg/L in the first months and close to 2 mg/L after 1 year of exposure.	Switzerland
facade runoff	Terbutryn M1 TP of terbutryn and cybutryn. The four main TPs of terbutryn (i.e., terbutryn sulfoxide, 2-hydroxy-terbutryn, desethyl-terbutryn and desethyl-2-hydroxy-terbutryn).	Bollmann et al. 2016, Burkhardt et al. 2012	Terbutryn was detected in a similar amount in and studies, from 1 to 5 mg/L in the first months to less than 1 mg/L after 1-year-exposure. The M1 TP of terbutryn and cybutryn was also detected at up to 12 mg/L. The four main TPs of terbutryn (i.e., terbutryn sulfoxide, 2-hydroxy-terbutryn, desethyl-terbutryn and desethyl-2-hydroxy-terbutryn) in façade runoff at concentrations ranging from 0.05 to 1.5 mg/L.	Denmark, Switzerland
facade runoff	OIT	Bollmann et al. 2017	Concentrations of OIT ranged from less than 20 µg/L to 14 mg/L and six out the seven studied TPs were detected in most of the samples, at up to 8.8 mg/L for N-octyl oxamic acid.	Denmark
Roof runoff	Mecoprop	Burkhardt et al. 2011	In roof runoff, concentrations of mecoprop varied fromfrom 1–10 µg/L and very high concentrations (400 µg/L) were measured after a long dry period in summer.	Switzerland
Roof runoff	Benzalkoniums	Van de Voorde et al. 2012	For benzalkoniums, concentrations in roof runoff (sum of C12 and C14 benzalkoniums) ranged from 5 to 30 mg/L immediately after treatment.	Netherlands

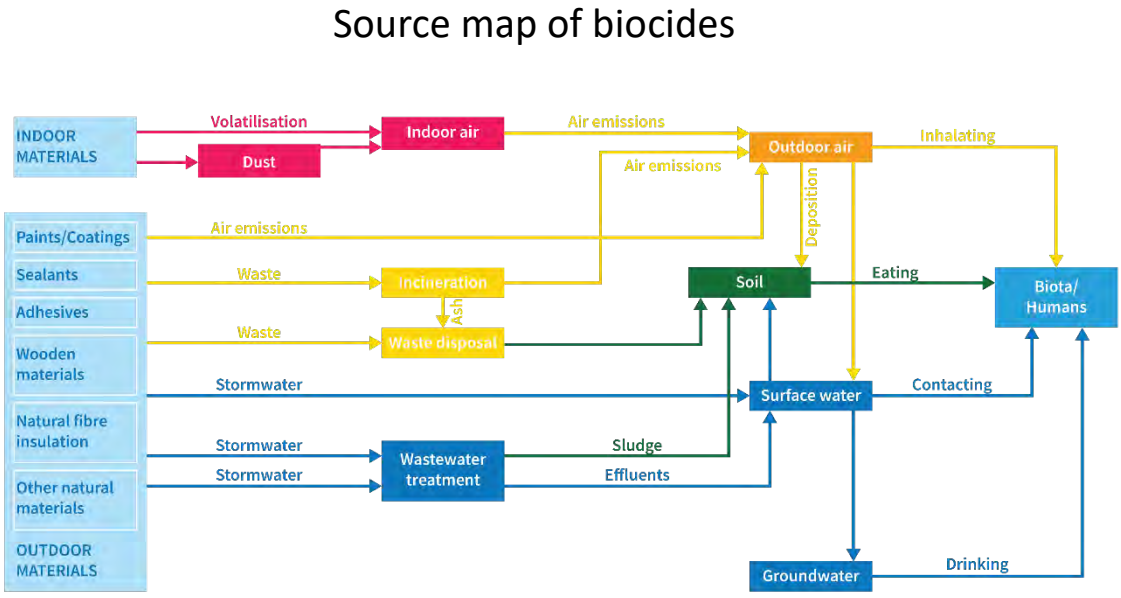


Figure 8. A Source map showing the sources of biocides in construction products and the pathways into different reservoirs in the indoor and outdoor environment.

Figure 8 shows how a source map can illustrate the spread of biocides from construction products. The grey boxes show common sources of these substances in construction products in Europe. Biocides are found in various matrices such as indoor dust, indoor air, and freshwater.

Results from the sampling

In short, biocides like Diuron, Propiconazole, and Mecoprop were found in stormwater samples in this investigation across different cities, including Turku, Helsinki, and Västerås, in varying quantities and distributions across the cities. For more details see the section Results and relevant appendices.

Chlorinated paraffins

Use

As described in the Catalogue (NHC3, 2023), chlorinated paraffins are typically used as plasticizers and flame retardants, as well as additives to various chemical products such as paints, sealants, adhesives, and many other items. There are many different substances within this group, with varying toxic properties. Overall, they are of high concern due to their toxic properties and persistence in the environment. Mixtures of different chlorinated paraffin compounds are produced, making it difficult to analyse these substances and determine their hazardous properties more precisely.

Chlorinated paraffins are divided into three groups according to their chain lengths:

- SCCPs – short chain chlorinated paraffins
- MCCPs – medium chain chlorinated paraffins
- LCCPs – long chain chlorinated paraffins

In the construction sector, chlorinated paraffins are found especially in plastics, rubber, and chemical products. They are common in PVC plastics such as flooring or wood panels, in the rubber of tracks and playgrounds, and in chloroprene rubber products such as joint insulations and membranes used for roof waterproofing. In chemical products, they can be found in adhesives, sealants, paints, spray polyurethane foams, and more.

Adverse effects

SCCPs are carcinogenic as well as persistent, bioaccumulative, and toxic to aquatic life, and have been banned under the Stockholm Convention and the EU POPs regulation since 2013. These substances should therefore not be found in construction materials produced today. MCCPs have been included in ECHA's candidate list for authorisation since 2021 due to their persistent, bioaccumulating, and toxic properties. However, it is worth noting that SCCP occur and are permitted under EU regulation in low concentrations in MCCP and LCCP mixtures.

MCCPs are used as alternatives to SCCPs and are much more common in the environment due to high production volumes.

Exposure

As mentioned in the Catalogue (NHC3, 2023), chlorinated paraffins are commonly found in indoor dust and air as they are released from various articles and construction materials. Inhaling dust is one of the main pathways of human exposure.

Source mapping and measured occurrence

Scientific papers have found chlorinated paraffins mainly in the indoor environment, in dust and air. However, they have also been found when sampling snow or sediment. Several examples of papers showing these findings are listed in Table 7. Studies measuring the substances in stormwater have been hard to find.

Table 7. Examples of studies that have detected chlorinated paraffins in indoor air, dust, snow, sediment and wastewater sludge.

Matrix	Substances analysed	Reference	Comment	Country
Dust in preschools	SCCP, MCCP	Langer et al. 2020	Much higher concentrations of MCCP than SCCP.	Sweden
Dust	SCCPs, MCCPs, LCCPs	Yuan et al. 2021	All three found. Highest levels detected was from MCCPs	Norway
Dust	SCCPs, MCCPs	Hilger et al. 2013	Both found. Highest levels detected was from MCCPs	Germany

Indoor air in preschools	SCCP, MCCP	Langer et al. 2020	Higher concentrations of SCCP than MCCP.	Sweden
Indoor air	SCCPs, MCCPs, LCCPs	Yuan et al. 2021	All three found. Highest levels detected was from SCCPs	Norway
Urban snow	No information in the abstract	Björklund et al. 2011	Chlorinated paraffins were detected in some snow samples.	Sweden
Sediment	SCCPs, MCCPs	The Swedish Environmental Protection Agency, 2005.	Low concentrations found in sediment	Sweden
Wastewater sludge	SCCPs, MCCPs	The Swedish Environmental Protection Agency, 2005.	Low concentrations found in wastewater sludge	Sweden

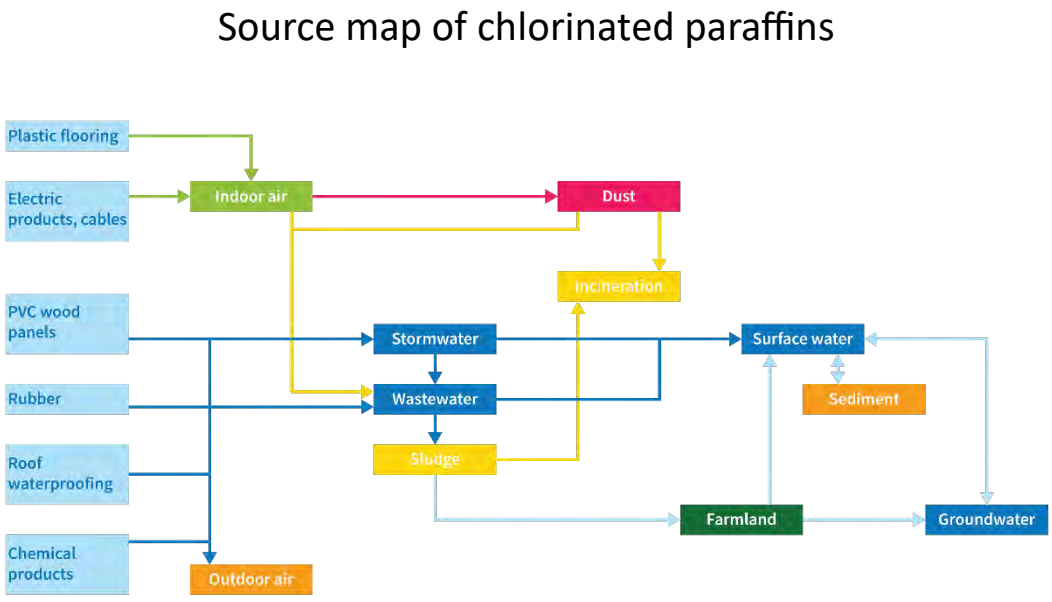


Figure 9. A Source map showing the sources of chlorinated paraffins in construction products and the pathways into different reservoirs in the indoor and outdoor environment.

Figure 9 shows how a source map can illustrate the spread of chlorinated paraffins from construction products. The grey boxes show some common sources of chlorinated paraffins in construction products in Europe. Chlorinated paraffins are found in dust and indoor air but might also spread to stormwater from roof products and rubber in the outdoor environment. Typically, dust is vacuumed or cleaned and ends up in wastewater or is incinerated.

Results from the sampling

In short, sampling of chlorinated paraffins was conducted in this investigation in wastewater and dust in Stockholm. In wastewater, sampling of SCCP and MCCP was conducted in three wastewater treatment plants, and both SCCP and MCCP were present in all three. The concentration of MCCP was the highest, with a concentration of 0.4-0.7 µg/L. In dust, SCCP, MCCP, and LCCP were quantified in all eight samples, with a range from 1.86-108 µg/g.

VOC

Use

Volatile Organic Compounds (VOCs) is an umbrella term for chemicals that are volatile at room temperature, but the chemicals within this group are not closely related. Indoors, sources of VOCs may include solvent residues that emit from chemical products such as paints, coatings, adhesives, sealants, finishing plaster, stone and masonry treatments, and finished products containing such chemical products.

VOCs are naturally occurring in wood materials and may emit from engineered wood products such as panels, chipboards, fibreboards, plywood, Oriented Strand Board (OSB), Medium Density Fibreboards (MDF), gypsum boards, ceiling and flooring materials. Polymer materials, insulation materials, electronic equipment, and textiles are other product groups that may emit VOCs.

The focus in this NonHazCity 3 project is on buildings and construction materials, so VOCs from industries and road traffic will not be discussed further in this report. However, VOCs from traffic and industries are significant sources of VOCs in the environment.

Adverse effects

Among the 13 most common VOCs in residential indoor air, almost all adversely affect the respiratory system. VOCs can also be carcinogenic, cause headaches, dizziness, sensitisation, and affect the cardiovascular and nervous systems (WHO 2021).

Legislation

The VOC Directive 2004/42/EG regulates the content of VOCs in paints and varnishes.

The EU List of “Lowest Concentration of Interest” (LCI) values (2023) publishes health-based guidance values for emissions of hazardous chemicals from building materials intended for indoor use.

A voluntary limit value for total VOC concentration (TVOC) in indoor air is recommended as 300 µg/m³ by the German authority UBA (Umweltbundesamt), which is lower than the LCI values.

Exposure

VOCs are gradually released from indoor materials, continuously contaminating indoor air. Over time, from months to years, the “source materials” become exhausted of VOCs, and the VOC concentration in indoor air decreases. Newly built or newly renovated buildings usually have higher concentrations of VOCs than older buildings, though efficient ventilation can reduce the VOC concentrations. For example, a Swedish study by Langer et al. (2020) shows that TVOC levels in a preschool increased fivefold after renovation. After one year, the VOC concentration had decreased by almost 50%.

Folkhälsomyndigheten (2018) refers to several studies showing the correlation between allergic symptoms and home renovations. VOCs and nitrogen oxides can form ground-level ozone, which is also harmful to the environment and health.

VOCs and nitrogen oxides can form ground-level ozone, which is also harmful to the environment and health.

Source mapping and measured occurrence

VOCs can be solvent residues that emit from chemical products such as paints, coatings, adhesives, sealants, finishing plaster, and stone and masonry treatments. Engineered wood products, such as chipboards, fibreboards, plywood, ceiling and flooring products, are some examples. Gypsum boards, polymer materials, insulation materials, electronic equipment, and textiles are other product groups that may emit VOCs.

VOC concentrations are usually higher indoors than outdoors. VOCs from traffic and industrial pollution can contaminate groundwater but are not discussed in this report. In scientific papers, VOCs are mainly studied in indoor environments, including homes, schools, preschools, and offices.

There are few studies describing the distribution of VOCs from indoor air to outdoor environments. Correlations are found between new products and renovations and higher levels of VOCs in indoor air. Langer et al. (2020) describe how the VOC levels increased in a preschool after renovation and decreased one year after the renovation. Some examples of papers showing these findings are listed in Table 8. Studies measuring VOCs in stormwater have been hard to find.

Table 8. A selection of studies that have detected VOCs in indoor air.

Matrix	Substances analysed	Reference		Comment	Country
Indoor air in preschools and schools	Alcohols, aldehydes, alkanes, Aromatic hydrocarbons, ester alcohols, esters, glycol ether, halogenated hydrocarbons, ketones, siloxanes terpenes.	WHO 2021		Aldehydes,alkanes, aromatic hydrocarbons most frequent	Europe
Indoor air in schools and homes	Aldehydes, aromatic hydrocarbons (BTEX), terpenes, chlorinated VOCs, 2E1H, Texanol, TXIB, glycol ethers	Folkhälsomyndigheten 2018		Aldehydes, terpenes, BTEX, 2E1H, TXIB most frequent	Sweden
Indoor air in preschools		Langer et al. 2020		Terpenes and glycol ethers highest	Sweden
Indoor air in homes	aromatic hydrocarbons, alkane hydrocarbons, aldehydes, aliphatic hydrocarbons, terpenes, chlorinated hydrocarbons, glycol and glycol ethers and esters	Halios et al. 2022		aromatic hydrocarbons, alkane hydrocarbons, aldehydes most frequent	Europe and UK

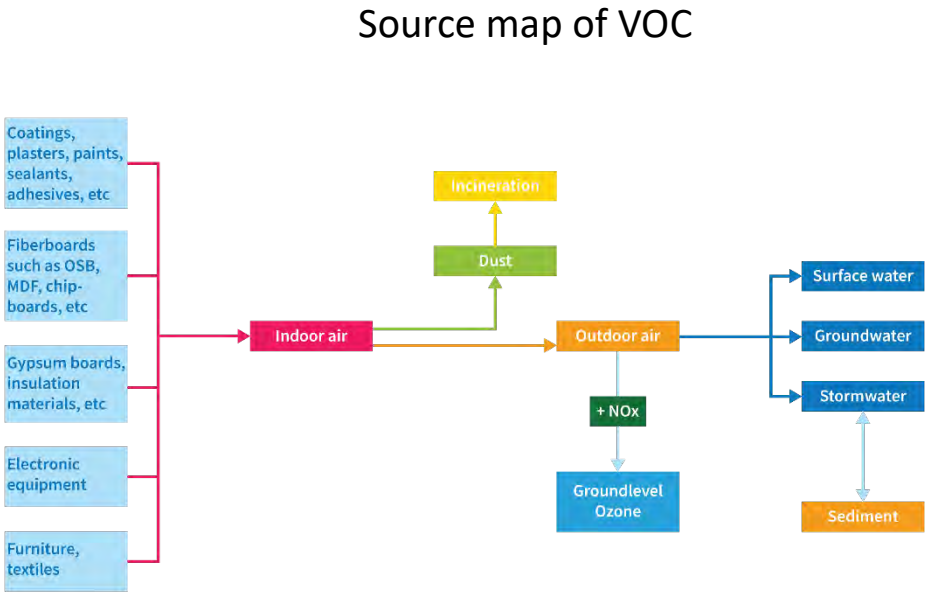


Figure 10. A Source map showing the sources of VOCs in construction products and the pathways into different reservoirs in the indoor and outdoor environment.

Figure 10 illustrates how a source map can depict the spread of VOCs from construction products. The grey boxes show some common sources of the substances in construction products in Europe. VOCs are mainly found in indoor air.

Results from the sampling
In short, in this investigation VOCs were sampled only in Västerås in indoor air in four preschools. Several substances were detected, and the concentrations were about 20-60 µg/m³.

Zinc and copper

Metals are naturally occurring elements widely used in different construction materials, including exterior and indoor finishings and supportive structures.

Some are essential trace elements which are important for the well-being of organisms when present in the proper amount. However, in larger amounts metals can cause acute and chronic toxicity.

As said in the Catalogue (NHC3, 2023), metals are durable, malleable, and recyclable. Some metal salts or other metal compounds are used as additives in chemical products, such as coatings. Metals in construction materials often occur as alloys, such as steel and brass. These alloys can contain metals such as lead (Pb) and cadmium (Cd) as additives or impurities.

Metals can be found in many types of construction products such as metal roofing, gutters and rain pipes, window frames, construction beams, piping foils, sheets and finishings, faucets, concrete and cement, and coatings.

Non-essential metals, such as lead, cadmium and mercury, may cause toxic effects even when present in trace amounts. Also, essential metals such as zinc or copper are toxic in high concentrations. Common health effects of metals are for example damage to lungs, liver, kidneys

and other internal organs, carcinogenicity, reproductive problems, damage to fish gills and acute toxicity. Main concerns related to heavy metals in construction and building materials are related to leaching to the environment and toxicity to especially aquatic biota.

Humans can be exposed to metals in construction materials mainly through dust and fumes. Workers are especially at risk of harmful exposure to metals through dust inhalation and contaminated air. Also, metals like zinc and copper can leach into the environment, for example from metal roofs during heavy rain and can end up in soil and aquatic environments such as rivers, lakes and stormwater.

The following metals were analysed in the NonHazCity 3 project: chromium (Cr), copper (Cu), zinc (Zn), nickel (Ni), cadmium (Cd) and lead (Pb). Cadmium and lead compounds are included in the REACH candidate list because of their particular toxic properties. Since 2015, chromium compounds have been included in the REACH restriction list (Annex XVII) with a requirement that it shall not occur in leather articles other than in very low concentrations. In this chapter the focus is on zinc and copper.

Source mapping of zinc and copper

Zinc and copper are mainly found in metal sheets used as tood and facade coatings. Zinc is also found in corrosion protection paints and copper is also found in water pipes. In the literature zinc and copper have been mainly measured in runoff from metal sheets, mainly spreading to the stormwater and outdoor environment. Some examples of papers showing these findings are shown in Table 9.

A study made by Luleå technical University in Sweden have found correlation between zinc sheets and zinc leaching to stormwater and between copper sheets and copper leaching to stormwater. Both metal content in the material and in the storm water runoff was measured. The results of the study is shown in table X.

Table 9. A selection of studies that have detected copper and zinc in storm water and dust.

Matrix	Substances analysed	Reference	Country and comment	
Stormwater	Copper from copper sheet	Müller et al. 2022	In runoff from copper sheets the concentration of copper was much higher than all other metals masured.	Sweden
Stormwater	Zinc from galvanised steel sheet	Müller et al. 2022	In runoff from galvanised steel sheets the concentration of zinc was much higher than all other metals masured.	Sweden
Stormwater	Zinc from titanium zinc sheet	Müller et al. 2022	In runoff from titanium zinc sheets the concentration of zinc was much higher than all other metals masured.	Sweden
Dust	Cr, Ni, Mn, Zn, Ba, Cu, Co, Rb	Barrio-Parra et al. 2018	Household floor dust, the metals found in highest concentrations were zinc, manganese, barium and copper.	South Arabia

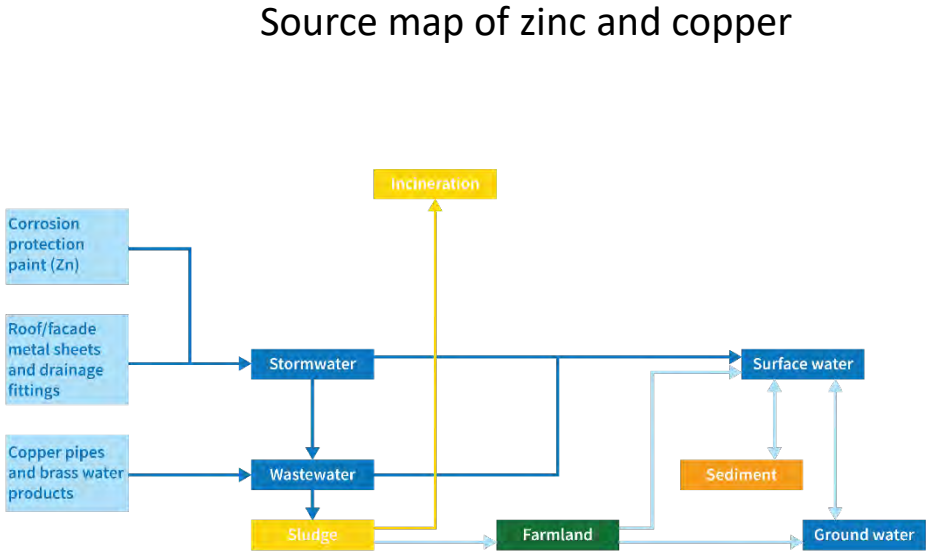


Figure 11. A Source map showing the sources of zinc and copper in construction products and the pathways into different reservoirs in the indoor and outdoor environment.

Figure 11 shows how a source map can illustrate the spread of zinc and copper from construction products. The grey boxes show some common sources of zinc and copper in construction products in Europe. Zinc and copper are found mainly in stormwater and wastewater.

Results from the sampling

In short, in this investigation metals analyses were conducted on storm water samples collected from Stockholm, Västerås, Turku, and Helsinki. Metals were detected in all samples.

Methodology – sampling

Our methods included targeted screening of pollutants in five different matrices: construction materials, stormwater, indoor dust and air from preschools, and wastewater from residential areas. Screening took place in five cities by six project partners in the Baltic Sea Region: Turku, Helsinki, Tallinn, Västerås, and Stockholm. In total, approximately 140 samples were taken. The distribution of the type of samples was as follows:

Turku: Stormwater (Appendix 1).

Helsinki: Stormwater and construction material (from a construction site) (Appendix 2).

Tallinn: Construction material (from a hardware store) (Appendix 3).

Västerås: Stormwater, preschool air and dust, construction material (floor material from preschools) (Appendix 4).

Stockholm: Preschool dust (Appendix 5A), stormwater (Appendix 5B), wastewater (Appendix 5C), construction material (paint for outdoor use and roof material from a hardware store (Appendix 5D), sheet material from a construction site (Appendix 5E), and floor material from schools and preschools (Appendix 5F).

Sampling methods generally followed established routines. For example, the procedure for sampling dust is described in Giovanoulis et al. (2019) and Langer et al. (2021). Stormwater was sampled using a manual sampling approach, which provides a snapshot of the stormwater quality at that specific moment. This is a practical and cost-effective method for assessing stormwater quality by collecting water samples directly from discharge points. By analysing these samples, we get a better understanding of the substances present in stormwater.

Sampling and chemical analyses of construction material included over 50 items used in construction. The following table provides an overview of the types and quantities of construction materials analysed. For details on the substances screened, see the screening reports in Appendices 2, 3, 4, and 5.

Table 10. Construction materials, number of samples and substances analysed.

Construction material group	Total no of samples	Substance (samples) analysed
Paints	12	Biocides (12) Metals (12) Phthalates and alternatives (4) PFAS (4) OPEs (3) SCCP (2) MCCP (2)
Roofing materials Ex: roofing felt, shingel	5	Phthalates and alternatives (1) Biocides (2) PFAS (1) Metals (5) OPEs (1)
Flooring materials Ex: PVC	9	Phthalates and alternatives (9) PFAS (4) Metals (2) OPEs (2)

		SCCP (2) MCCP (2)
PVC tunnel sheet	1	Phthalates and alternatives (1) PFAS (1) OPEs (1)
Mansonry material Ex: mortar and bricks	4	PFAS (3) Metals (4)
Wood for terraces or façades	3	Biocides (3) PFAS (3) Metals (3) OPE (3) SCCP (2) MCCP (2)
Boards Ex. Gypsum, plywood, MDF board	9	Isothiaszolinones (1) PFAS (4) Metals (3) OPEs (5)
Coatings/surface treatments	4	Phthalates and alternatives (2) PFAS (3) Metals (3) Biocides (3) OPEs (2) SCCP (2) MCCP (2)
Flame retardant coating for wood	2	Phthalates and alternatives (2) PFAS (2) Metals (2) Biocides (2) OPEs (2) SCCP (2) MCCP (2)
Synthetic insulation material	2	OPEs (2) Styrene (1) Acrylonitrile (1) HBCD (1)
Tile grout	1	Metals (1)
Plaster	1	Biocides (1)

Samples were sent to commercial laboratories for chemical analysis according to standardised methods. The selection of pollutants for analysis (by target analytical methods) was decided collectively by the working group. Each screening project partner also had specific priorities based on political/local chemical management plans and financial limitations. A brief summary of the distribution of pollutant groups, matrices, and screening cities is presented in Table 11.

Table 11. Overview summary of targeted screening performed by project partners. Water refers to stormwater except for Stockholm where both stormwater and wastewater were included in the investigation.

	PE[1]	**PFAS[2]**	**BP[3]**	**OPEs[4]**	**BFR[5]**	**Biocides[6]**	**CP[7]**	**VOC[8]**	**Elements[9]**
Stockholm	Dust, material, water	Dust, material, water	Dust, material, water	Water	Dust	Material, water	Dust, water		Dust, material
Västerås	Dust, material, water	Dust, material, water	Dust	Dust, material, water	Dust, material, water	Dust, Water	Dust	Air	Water
Helsinki	Water, material	Water, material		Water, material		Water, material	Water, material		Water, material
Turku	Water	Water		Water		Water	Water		Water
Tallinn	Material	Material		Material	Material	Material	Material		Material

1. Phthalates and alternatives
2. Per- and Polyfluoroalkyl Substances (PFAS)
3. Bisphenols
4. Organophosphate esters (OPEs)
5. Brominated organic substances
6. Diuron, triazines, and isothiazolinones (biocides in/on wood and façade coatings)
7. Chlorinated paraffins
8. Volatile Organic Compounds (VOCs)
9. Metals and elements, focus copper and zinc

The analytical results received from the laboratories were organised and sorted into a master Excel file and subsequently processed as required. Data processing was then performed to visualise the quantities, frequency of quantification, differences, and similarities within the large dataset. The results are presented in tables and diagrams in the results section. Diagrams were created in Excel and/or using R software.

All materials and methods are further described in each partner's report, see Appendices 1-5.

Results and discussion

In this project, a number of interesting observations were made. Due to the differing goals and objectives of the five participating cities, a broad spectrum of hazardous substances was investigated upon, and found. In the appendices, all results are described per partner (i.e. city that performed screening activities), along with individual hypotheses, instrumental and methodological setups, lists of findings, and interpretations.

Given the abundance of results, most relevant findings were highlighted and selected for interpretation. As the presented results are from chemical analyses of construction materials, stormwater, wastewater, and preschool air and dust, the concentrations are presented in different units, depending on the hazardous substance and sample type.

The results will be presented in following order (*explanation within brackets*):

-**Hazardous substances found in construction material** (*construction materials are the focus of this project, which is why these have been screened for respective substances. In addition to construction material, other media (water dust etc) have been screened in order to get an idea about how substances spread from these materials. This data was complemented by data from previous projects*)
-**The bigger picture** (*combining the results from different cities and different matrices, a bigger picture emerges*)

- The cocktail of pollutants in dust
- Biocides in wood treatment and leakage to the environment
- PFAS forever, wherever
- TCPP – a potential PMT
- Metals

-**Additional results** (*In addition to the points mentioned above, some results could not be compared across cities or different matrices. However, following topics and observations are still important findings resulting from our investigations*)

- Chlorinated paraffins
- Direct leakage of phthalates to drain water
- Effects on hazardous substances after renovating floors
- Trends of DEHP in wastewater

Hazardous substances found in construction materials

In total, 51 samples of construction material were sampled and chemical analyses of a range of hazardous substances was conducted (Table 12 and Appendices 2-5). The main results are presented in table 12.

*Table 12. Findings on the occurrence of hazardous substances are presented. Numbers in bold indicate relevant findings. Compounds are found under the respective substance groups. In case of further grouping (e.g. Isothiazolinones under biocides) the compounds as well as their respective values are separated by / . Values below LoQs are indicated by *. Compounds not analysed for the respective construction material group are indicated by -. All values represent maximum values found for this group of construction material.*

Content mg/kg (max) *means <LOQ -means not analysed	Coatings/ surface treatments	Flame retardant coating for wood	Flooring material	Masonry material	Paint	Plaster	Roofing material	Synthetic insulation	Tile grout	Tunnel sheet	wooden terrace/ façade material
Biocides											
BIT/CIT/DCOIT/MIT/OIT	*/0.38/*/*/0.44/*	7.4/7/*/3.6/*	-	-	**220**/0.17/160/3.6/*	-/6.4/-/0.32/-	130/0.76/*/3.2/8.1	-	-	-	0.42/-/0.18/2.6/15.1
Diuron	-	-	-	-	**780**	-	*	-			*
IBPC	-	-	-	-	**7589**	-	1384	-	-	-	-
Isoproturon	-	-	-	-	0.0019	-	*	-	-	-	*
Triazoles (Ppz/Tbz)[1]	-	-	-	-	*/*	-	*/*	-	-	-	8.3/8.7
Terbutryn	-	-	-	-	40	-	*	-	-	-	*
Metals											
Cd/Cr/Cu/Pb/Zn	-	-	0.2/3.8/1.6/*/-	*/0.113/0.057/*/*	*/110/8.6/15/8	-	*/380/**1400**/30/20	-	*/23/*/0.9/*	-	*/*/0.228/*/*
Styrene	-	-	-	-	-	-	-	**410**	-	-	-
OPEs											
TBEP/TMCP	*/*	*/*	35/17	*/*	*/*	-/-	*/*	*/*	-/-	0.016/0.72	*/*
TCPP/TEP	*/*	*/*	*/*	*/*	*/*	-/-	*/*	**37000**/23	-/-	0.016/0.01	*/*
PFAS											
5:3 FTCA	0.0066	*	*	*	*	*	*	*	*	*	*
6:2 FTOH	**20**	*	*	*	*	*	*	*	*	*	*
PFBA	0.012	*	*	*	*	*	*	*	*	*	*
PFHxA	0.054	*	*	*	*	*	*	*	*	*	*
PFPeA	0.0047	*	*	*	*	*	*	*	*	*	*
Sum of PFAS			**3.183**								
Plasticizers											
DEHA	*	*	**4100**	-	*	-	*	-	-	0.14	-
DEHP	*	*	**17753**	-	*	-	*	-	-	1.51	-
DEHT	*	*	**5300**	-	*	-	*	-	-	14.7	-
DIDP	*	*	11091	-	*	-	*	-	-	**91725**	-
DINCH	*	*	**200000**	-	*	-	*	-	-	317	-
DINP	*	*	39612	-	*	-	*	-	-	**353677**	-

Relevant findings highlighted in table 12

Paints for exterior use contained biocides such as IBPC, diuron, and isothiazolinones, as well as metals. Most of the substances found in screening activities were also reported on in respective safety data sheets (SDS) of the respective product, were also quantified in the analyses. Some analyses were performed on the dry (cured) paint, allowing for comparison between the concentrations in the cured paint and those reported in the SDS. Due to evaporation, the biocide concentration in the cured paint was higher than that reported in the SDS for the wet paint. When quantifying leakage of biocides from a painted area, this factor needs to be considered to avoid miscalculations. The results from the chemical analyses of paints are an important part of understanding the bigger picture; e.g. when comparing stormwater results from diverse catchment areas, some using the paints analysed. Additionally, these results are useful for providing advice on tox-free construction.

Roof felt contained biocides, for example, IBPC, diuron, isothiazolinones as well as metals (copper) The results from chemical analyses of roof felts are valuable when comparing storm water results from catchment areas having different kinds of roof materials. In addition, the results are valuable for back-tracking pollutants found in the environment (source tracking), but also in the sense of giving advises for tox – free construction.

Construction materials made from PVC contained various plasticisers to a large extent, up to 44% (sum of 35% DINP and 9% DIDP). The analysed PVC materials included PVC floors sampled in existing buildings, PVC flooring purchased directly from the construction hardware store, and a PVC sheet

used for water protection in a tunnel construction. The newly purchased floor-coverings contained alternative plasticizers that commonly replace phthalates, while, in the old flooring materials, one phthalate was predominant in mixture of plasticisers, with several of the others appearing at lower concentrations. The new PVC tunnel sheet contained mainly two phthalates, and only traces of others. These results provide insights into the extent of which plasticizes are distributed to, both, indoor environments (by comparing levels with those measured in dust) and outdoor environments (by comparing levels in runoff water).

The Polyurethane insulation for exterior use contained OPEs, specifically TCPP and TEP, in quantities suggesting diffusing into surrounding media. These findings are significant since TCPP was detected in stormwater, dust, and wastewater. To get a better understanding of why this substance appears in products and different environments, we need more facts on its use, regulations, risk assessments, etc. These are presented and discussed in the "Bigger Picture" section about TCPP, along with this project´s observations. It is important for construction management to note that current EU regulations (REACH) do not require the content of TCPP to be declared in construction materials, as TCPP is not on the candidate list. This means it can be added to products without informing downstream users, potentially leading to widespread use of this hazardous substance.

Other insulation materials analysed in this project did not contain these substances. Therefore, the presence of TCPP in polyurethane insulation may only be interpreted as a snapshot, and further investigations are needed to establish the relevant sources of TCPP.

Wooden panels for terraces and facades contained biocides, which are added to extend the wood's lifespan. However, their toxicity necessitates careful evaluation of wood construction for trade-off decisions. Biocides were also found in stormwater samples. The chemical analysis results of wooden panels are valuable for comparing stormwater data from areas with different construction materials and for providing guidance on tox-free construction.

Coatings and surface treatments were found to contain PFAS. This project aimed to track widespread pollutants, particularly PFAS, in various construction materials, whether intentionally or unintentionally added. Only one product from this group of construction materials, a surface treatment for stone and concrete, was found to contain PFAS. Additionally, an old PVC flooring was also found to contain PFAS. Identifying and tracing the sources of PFAS in construction material remains an ongoing challenge.

Results on substance groups below LOQ

A number of construction materials did not contain substances which were expected to be found such as heavy metals, phthalates, PFAS, and chlorinated paraffins. Substances and chemicals are often added to construction materials to obtain certain properties; thus the producer has a specific intention behind their use. Some hazardous chemicals were expected due to historical usage patterns and the need to meet certain functional criteria. However, their absence can be attributed to several factors including substitution, legislation, and increased awareness. The substitution of hazardous substances with safer alternatives has become a common practice, driven by stricter legislation and a growing emphasis on circularity. The REACH regulation, in particular, has played a significant role in phasing out harmful chemicals. REACH requires the registration, evaluation, authorisation, and restriction of chemicals, compelling manufacturers to seek safer alternatives.

Furthermore, the push for circularity in the construction sector necessitates the use of materials that can be safely reused or recycled. This has led to a reduction in the use of toxic substances, as they pose significant challenges to recycling processes. Increased awareness among consumers and industry stakeholders about the health and environmental impacts of hazardous chemicals has also driven demand for safer products. Chemical demand in procurement processes has become more stringent, with many organisations specifying the exclusion of certain hazardous substances in their procurement criteria. This proactive approach ensures that materials used in construction projects meet high safety standards from the start.

In conclusion, the absence of expected hazardous substances in certain construction materials can be attributed to a combination of legislative pressure, the drive for circularity, heightened awareness, and stringent chemical demands in procurement processes. These factors collectively contribute to a safer and more sustainable built environment.

The bigger picture

A broad spectrum of hazardous substances was investigated and found in the different matrices investigated. Combining the results from different cities and different matrices, a bigger picture can be seen. In this section, we will describe five such bigger pictures in-depth namely:

- The cocktail of pollutants in dust
- Biocides in wood treatment and leakage to the environment
- PFAS forever, wherever
- TCPP – a potential PMT
- Metals

These in-depth examples are followed by several important but briefly described examples. For more detailed information from each partner (city), substance, or matrix, please refer to the appendices.

The cocktail of pollutants in dust

As many scientists have proven previously, dust serves as a carrier for an uncountable number of hazardous substances. Dust matrices are hence known for reflecting the specific chemical cocktail of the respective indoor environment.

Phthalates and alternative plasticizers in dust in relation to plasticizer in PVC-flooring

We hypothesised that there is a relationship between plasticizers in PVC materials and dust. The following connections were investigated:

- In construction, PVC is often used as flooring material. Presence of plasticizer in flooring material can also affect dust levels. This is due to the fact that many plasticisers migrate into neighbouring materials, especially when they come into contact with lipids and are exposed to higher temperatures than 21°C.

The results from this study contributed to the large number of PVC-samples and dust samples taken in previous investigations performed in Stockholm (Larsson and Berglund, 2016). The number of samples helped us to prove our hypothesis that plasticizers added to PVC migrate into the indoor environment and adhere to dust particles (Table 13&14 and Appendix 4 and 5A). By comparing median content of plasticizer in dust sampled from rooms with confirmed plasticizer-containing floors (DINP (row i), DEHP (row *j*) and DINCH (row k)), with median content of plasticizer in dust from rooms with non-PVC floors (row l), the content of plasticizer was found to be 5 times larger or more.

Table 13. Plasticizer in dust in comparison to other studies.

	Year Country [ref]	N	Plasticizer, median *µg/g*								
			DEHP	BBzP	DnBP	DINP	DIDP	DEHT	DEHA	ATBC	DINCH
a	2006-07 Sweden [1]	10	1600	31	150						
b	2008-09 Denmark [2]	151	500	17	38						
c	2011-12 Germany [3]	63	888	6	21	302	34	40	49	24	302
d	2013 Sweden [4]	3	560		26	660	260				
e	2015 Sweden [5]	100	290	9	21	380	50	86	9,7	6,2	49
f	2018 Stockholm [6]	20	117	6	13	390	57	100	9	5	57
g	2023 Stockholm [7]	19	35	2	4	90	21	99	4	3	109
h	2023 Västerås [8]	8	53	2	3	31	22	538	4	6	17

Table 14. Plasticizer in dust in relation to floor plasticizer content.

	Year Country [ref]	N	Plasticizer, median *µg/g*								
			DEHP	BBzP	DnBP	DINP	DIDP	DEHT	DEHA	ATBC	DINCH
i	DINP - flooring (average content 22%) [5, 6, 7, 9, 10]	12	66	3	3	975	53	126	11	7	32
j	DEHP-flooring (average content 27%) [5, 6, 7, 9, 10]	8	703	14	20	165	43	69	6	10	31
k	DINCH-flooring (average content 9%) [5, 6, 7, 9, 10]	14	61	5	9	135	26	88	6	6	476
l	non PVC [5, 6, 7]	6	125	7	20	125	50	108	3	6	86

References: 1. Bergh et al. 2011, 2. Langer et al. 2010, 3. Fromme et al. 2013 and 2016, 4. KEMI 2013, 5. Larsson and Berglund 2016, 6. Giovanoulis, 2018, 7. Öhman, 2023 (Appendix 5A), 8. Larsson 2024 (Appendix 4), 9. Ekberg-Österdahl, WSP 2015, 10. Langer et al. 2020

In a previous study conducted in the City of Stockholm, air samples were taken in rooms with PVC flooring, and plasticizers (often phthalates) were also detected in the air (Langer et al., 2021).

Phthalates and alternative plasticizers in dust – a comparison between Stockholm and Västerås

In figure 12, all the dust samples (from individual preschools) are visualised by having different colours on the bars that correspond to an individual phthalate or alternative plasticizer. Apparently, the pattern among the plasticizer content in dust differ, not only between the cities but also within

the city. Due to the knowledge found and proved in tables 13 and 14 (above), the pattern is strongly influenced by the type of plasticizer in the floor material. For Västerås, it is known that the PVC floor has DEHT (light green) as plasticizer as it is registered and assessed in BVB (full content declaration) and documented in the construction management's logbook (sample id Västerås 3-6). The same applies for Stockholm except here DINCH (dark green) has been used (sample id Stockholm 8-9, 13-15, 17, 19).

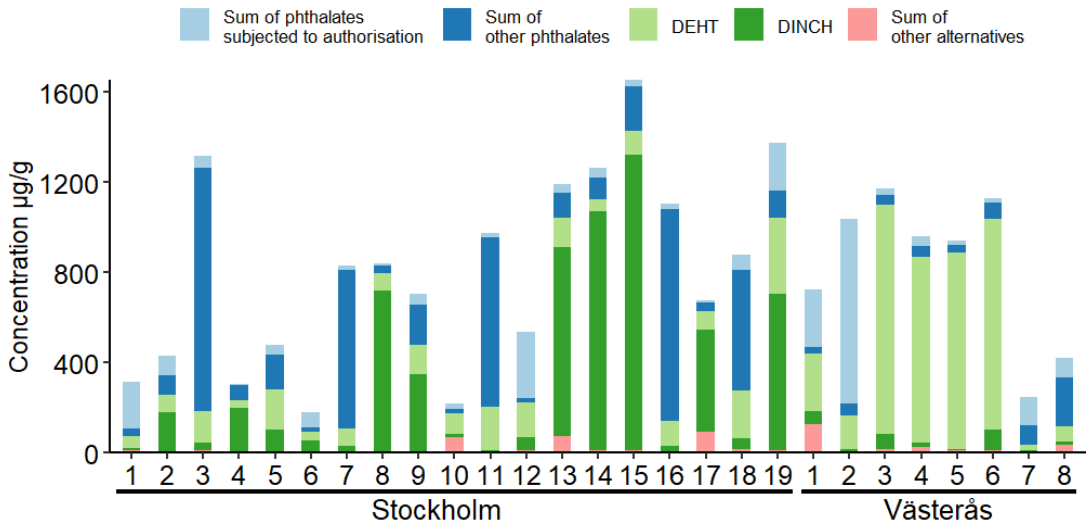


Figure 12. Group of Plasticizer in dust from 19 preschools in Stockholm and 4 preschools in Västerås, two samples from each preschool. Phthalates subjected to authorisation (DiBP, DnBP, BBzP,DEHP), Other phthalates (DMP, DEP, DiNP, DiDP, DPHP), other alternatives other alternatives, (ATBC, DEHA, TOTM).

Phthalates and alternative plasticizers in dust - trends

The content of pollutants in dust can also serve as a history book of old mistakes as well as maps of regrettable substitutions. The figure 13 shows an example of old mistakes (and happy news) where we can see the trend for DEHP (which was restricted 2008[1]) as well as DINP (added to SIN-list[2] 2014) decreasing drastically from 2015 to 2018 and continuing the trend from 2018 to 2023. In addition, new emerging plasticizers are increasing (DEHT and DINCH). The results indicates that legislation is efficient in reducing DEHP.

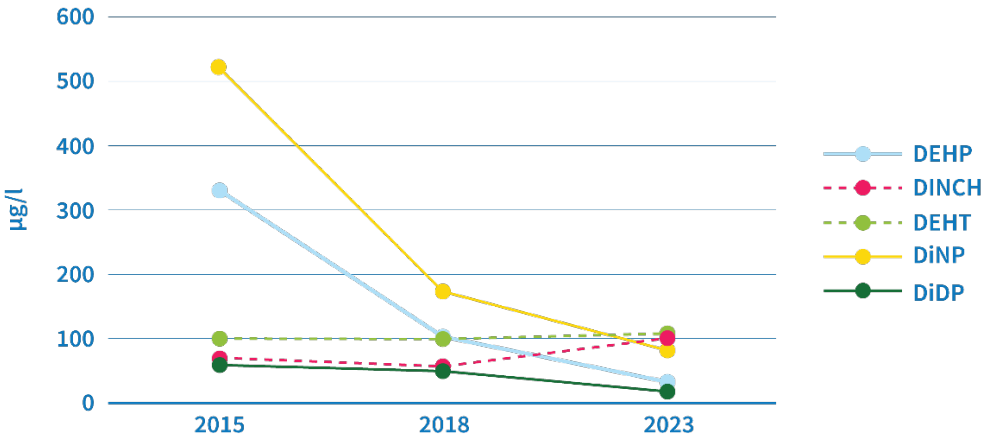


Figure 13. Trends of plasticizer in preschool dust in Stockholm.

[1] DEHP was added to the REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) Candidate List of Substances of Very High Concern (SVHC) for authorisation on October 28, 2008. It was later included in Annex XIV of the REACH Regulation, which lists substances subject to authorisation. The sunset date for DEHP, after which its use is generally prohibited without authorisation, was February 21, 2015.

[2] SIN-list, Substitute It Now List by ChemSec uses the criteria in REACH to identify Substances of Very High Concern (SVHC).

PFAS in dust

PFAS analysis was conducted on preschool dust samples collected in Stockholm and Västerås, with a total of 26 samples taken. The distribution of PFAS compounds is depicted in Figure 14. A broad range and distribution of PFAS substances were observed. Generally, Stockholm exhibited the highest concentrations of PFAS in the category of "sulfonates and carboxylic acids" (PFHxA 766 ng/g), while Västerås recorded the highest concentrations in the category of "telomers" (8:2 PAP 682 ng/g). Among the preschools included in this study, there appeared to be a few samples or preschools that had levels of certain substances that were three times as high as others. In this study, we observed an indication about relationship between PFAS in dust and the PVC flooring material used in a preschool in Västerås (Appendix 4). As a result, by supplier's dialogue in Västerås, we retrieved information on the use of floor polish. In general, floor/ furniture polish products may contain PFAS. Therefore, further investigation is needed to back track from where the PFAS comes from and therefore take measures on how to avoid PFAS in preschools.

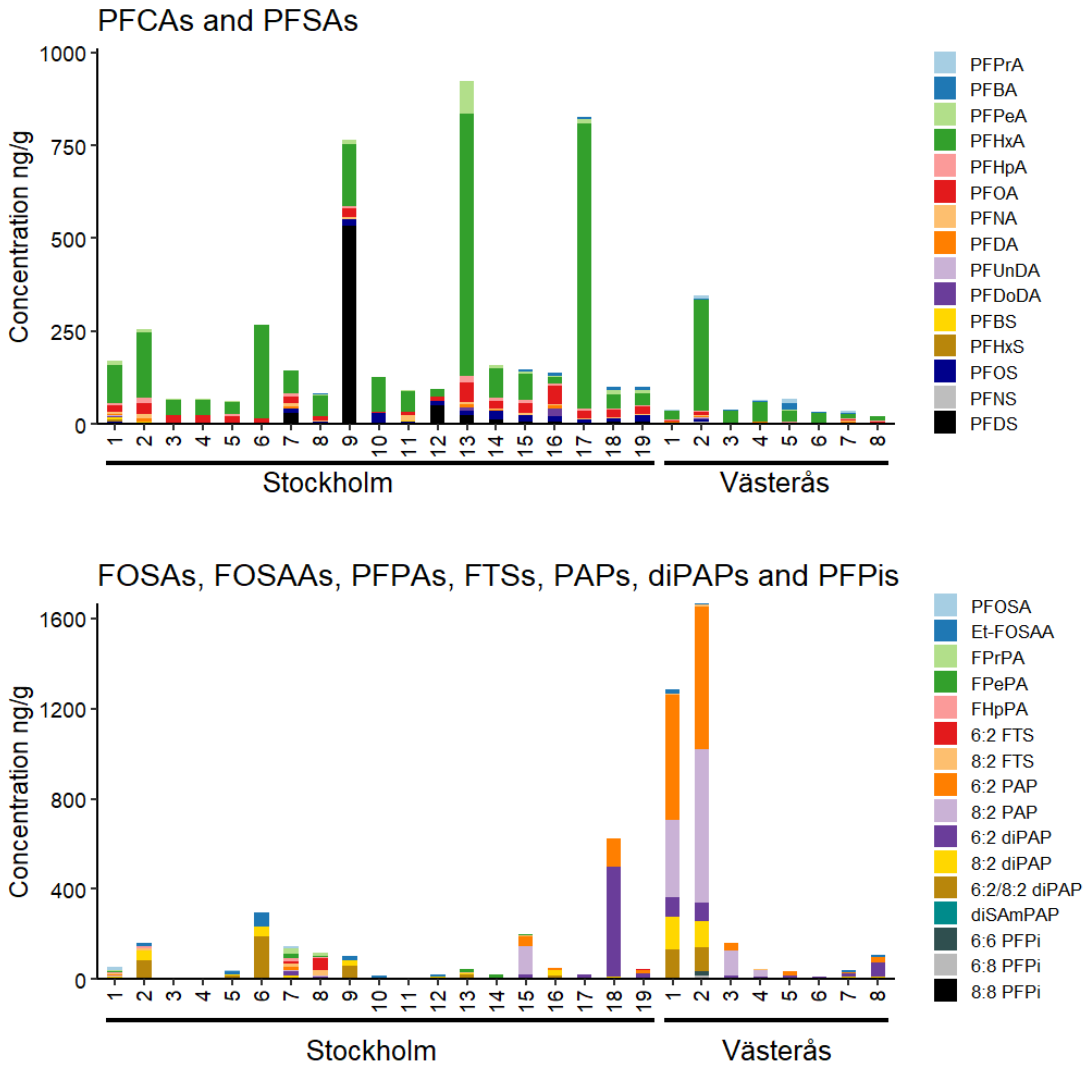


Figure 14. PFAS in preschool dust in Stockholm and Västerås. PFAS in preschool dust in Stockholm and Västerås. The upper diagram shows perfluorinated carboxylic PFCA) and sulphonic acids PFSA), and the lower diagram shows other investigated PFAS, many of which so called precursors, meaning they can degrade into persistent PFCAs or PFSAs.

Bisphenols in dust

Bisphenol analysis was conducted on preschool dust samples collected in Stockholm and Västerås, with a total of 26 samples being taken. The distribution of bisphenols is depicted in Figure 15. Generally, Stockholm exhibited the highest concentrations of BPA (2600 ng/g) and BPS (792 ng/g), while Västerås recorded the highest concentrations of TBBPA (1015 ng/g).

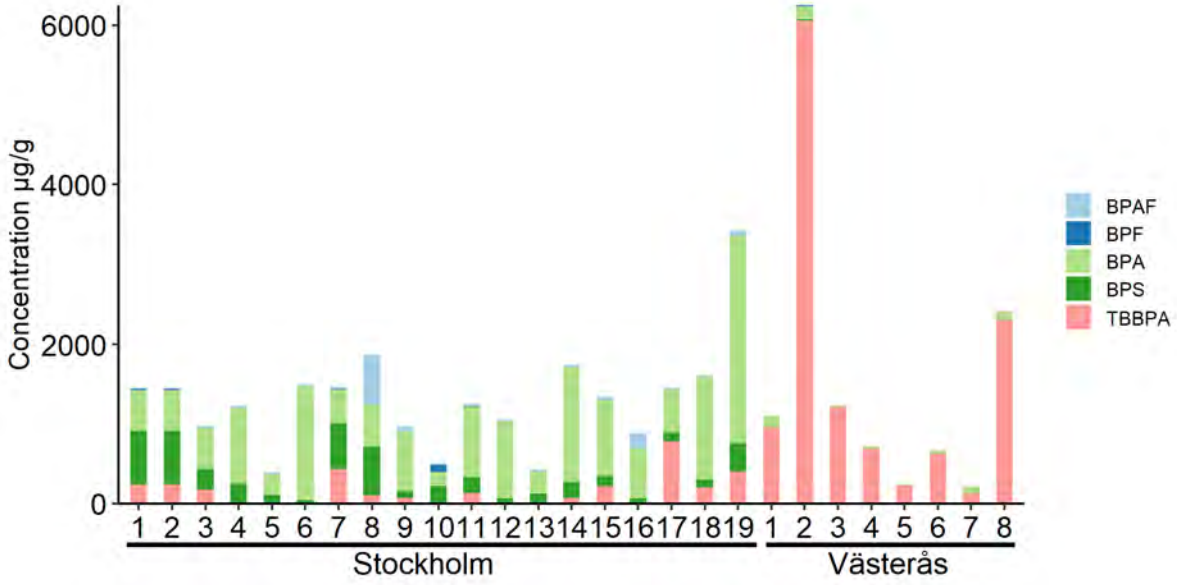


Figure 15. Bisphenols in preschool dust in Stockholm and Västerås.

Sample Västerås 2 reflects dust samples of one room in a preschool. Exceptionally high values were found for TBBPA, a brominated bisphenol used as a flame retardant in electronic devices. The room was observed to have a high number of tables that include integrated lights, one potential source. Typically, TBBPA is bound to the polymer material and is not genuinely released to neighbouring areas. A possible explanation could be the over-use of TBBPA in the material: excess amounts of TBBPA molecules cannot react with the polymer and in turn migrates out of the material.

Conclusions on pollutants in indoor dust

Our study confirmed that indoor dust serves as a significant carrier for various pollutants, including plasticizers from PVC materials, PFAS, brominated compounds (TBBPA) and bisphenols, some of them often used in construction materials. The presence of these hazardous substances in dust was strongly linked to the type of materials used in the indoor environment, with higher concentrations found in areas with PVC flooring and treated surfaces, indicating that the studies substances are mobile and emitted from materials in these environments. These results highlight the importance of safer material choices and stricter regulations to reduce health risks from exposure to these contaminants in indoor environments. Further research is essential to understand the long-term effects and develop strategies to reduce pollutant levels in indoor dust.

Biocides in wood treatment and leakage to the environment

Another group of substances which we investigated was biocides. With the trend towards construction with wood, which is considered eco-friendly and fashionable, comes a downside: because wooden construction materials need protection against weathering and decay, they are often treated with biocide containing wood-treatment products. The biocides may be lurking in the

wooden construction material itself, such as the wooden cladding, but also paints and varnishes, used for extending the lifespan.

The biocides used can be emitted into the environment, especially when they get into contact with water. With a functional purpose, biocides are intended to have a negative effect on their target organisms. However, most often biocides are not species-specific and are often toxic to aquatic organisms. In the frame of our screening activities, it was discovered that stormwater from areas with predominantly new wooden claddings on buildings contains higher levels of biocides compared to stormwater from other areas (Appendix 1 Turku UAS). All found biocides and their concentrations are given in Appendix 1-2, 4-5.

Biocides in stormwater

The results of the biocides in analysed stormwater samples are presented in the Table 15, showing max and min values of measured concentrations and detection frequencies. Two of the eleven samples collected in Turku were in non-urban areas, where biocides were not found, which means that the detection frequency for urban areas in Turku was in fact higher. The different ranges of detection frequencies are indicated as follows to visualise the abundancy:

0-24%	25-49%	50-74%	75-100%

Table 15. Frequency and range of biocide concentration, analyzed in stormwater samples in four cities.

Biocides	Turku	Helsinki	Västerås	Stockholm
Diuron				
Detected/analysed	4/11	0/5	0/3	1/12
% of detection	36%	0%	0%	8%
Min - Max [µg/L]	<0.01-1.9	<0.05	<0.01	<0.01-0.01
Propiconazole				
Detected/analysed	5/11	3/5	1/3	0/12
% of detection	45%	60%	33%	0%
Min - Max [µg/L]	<0.01-0.17	<0.05-0.88	<0.01-0.011	<0.01
Mecoprop				
Detected/analysed	2/11	2/5	0/3	1/12
% of detection	18%	40%	0%	8%
Min - Max [µg/L]	<0.01-0.18	<0.05-0.38	<0.01	<0.01-0.06
BAM (2,6-dichlorobenzamide)				
Detected/analysed	2/11	-	0/3	4/12
% of detection	18%	-	0%	33%
Min - Max [µg/L]	<0,002-0.017	-	<0.01	<0.01-0.02

2-hydroxyterbutylazine				
Detected/analysed	2/11	-	1/3	3/12
% of detection	18%	-	33%	25%
Min - Max [µg/L]	<0.005-0.026	-	<0.01-0.011	<0.01-0.02

Across different cities, including Turku, Helsinki, and Västerås, biocides like diuron, propiconazole, and mecoprop were found in stormwater samples in varying quantities and distributions across the cities. Propiconazole was the most prevalent, with detection rates of 45%, 60%, and 33% in Turku, Helsinki, and Västerås, respectively, with concentrations ranging from 0.011 to 0.88 µg/L, whereas BAM was the most frequently detected in Stockholm (up to 0.02 µg/l).

Mecoprop was detected in 18%, 40%, and 8% of samples from Turku, Helsinki and Stockholm, respectively, with concentrations ranging from 0.06 to 0.38 µg/L. Diuron was found in stormwater from Turku (36% of samples) and Stockholm (8% of samples), with concentrations ranging from 0.01 to 1.9 µg/L, falling within previously reported ranges in stormwater of up to 12 µg/L (<0.005 - 12 µg/L) (Paijens et al., 2020).

These biocides are recognised as additives in construction materials, see the results in the section concerning construction materials, further linking their presence in stormwater to urban infrastructure. Notably, concentrations of diuron and mecoprop were higher in combined sewer overflows (CSOs) compared to wastewater, suggesting a significant contribution from stormwater runoff, with buildings identified as potential primary source (Paijens et al., 2020).

Degradation products of pesticides that are not commonly used for construction material, were also observed: BAM (dichlorobenzoamide), a derivative from the plant treatment of the PFAS fungicide fluopikolide (identified in Stockholm and Turku), and 2-hydroxyterbutylazine, derived from terbutylazine (noted in Turku, Stockholm, Västerås).

Biocides in stormwater from areas with predominantly wooden buildings

In Turku, storm water samples from a residential area (labelled "IL"), having mostly wooden detached houses, contained higher concentrations of biocides typically utilised for wood preservation or paints compared to locations with predominantly non-wooden materials ("KA" and "PV").

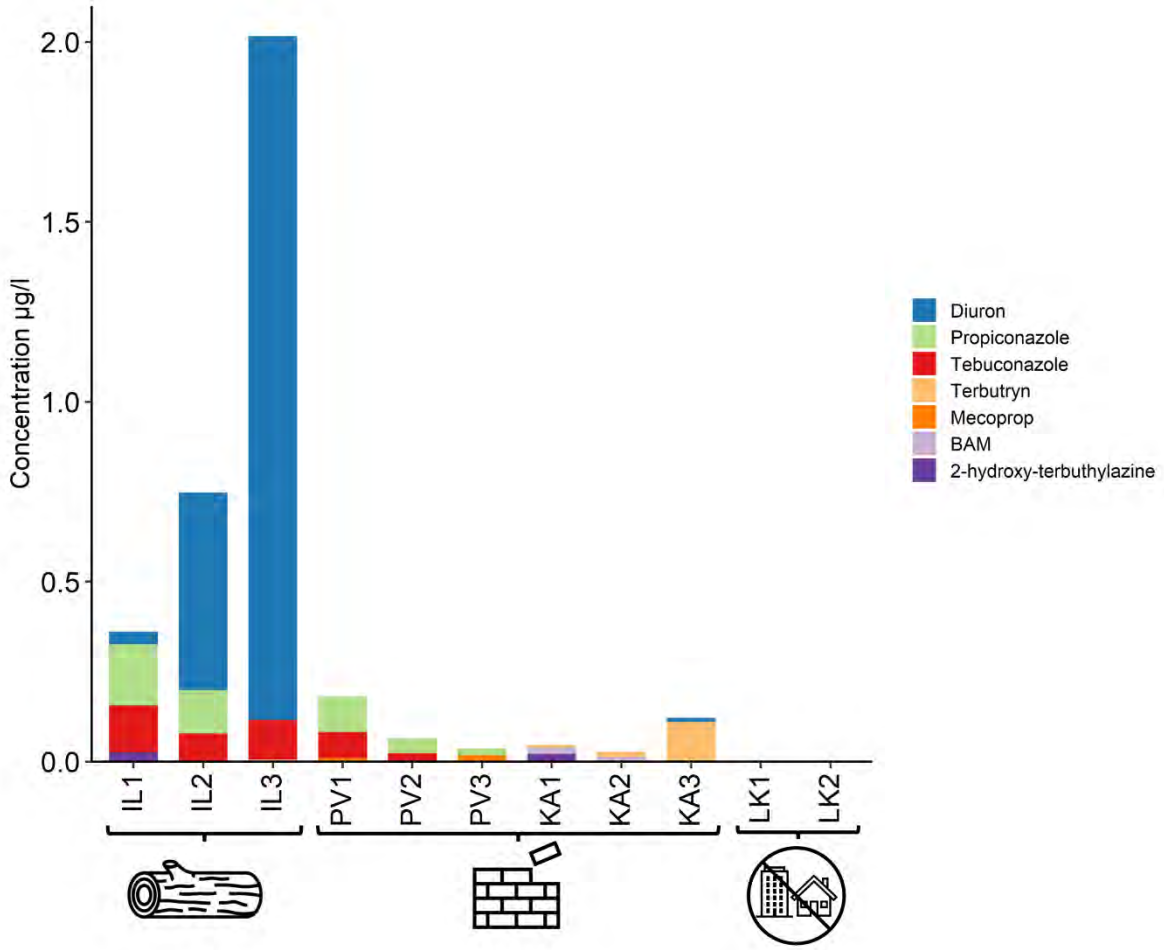


Figure 16. Selected biocides in storm water sampled in Turku area (µg/L). Symbols on the x-axis signify (from left to right) area with wooden buildings, are with non-wooden buildings and area without any buildings.

Biocides were found in all sampling sites except for a control area without any buildings ("LK"), showing a clear contrast between sites with and without buildings. The total concentrations of construction-related biocides were highest in IL (figure 16).

The highest individual biocide concentration was 1.9 µg/l for diuron in IL, being more than 10 times higher than the concentrations of other analysed biocides. In other sites, diuron was either found only in low concentrations or not found at all. The highest concentration of diuron also exceeded the Maximum Allowed Concentration Environmental Quality standard (MAC-EQS) for inland waters of 1.8 µg/l, given in the Water Framework Directive (Directive 2000/60/EC and 2013/39/EU). Currently, update of WFD is under preparation, and for diuron, a new, lower MAC- EQSs of 0.27 µg/l has been proposed. Two samples from IL exceeded the new proposed MAC-EQS. The results indicate that biocides from construction materials can leach and end up in stormwater, even concentrations at these levels are environmentally relevant. Note, that measured concentrations in stormwater and

EQS for surface water cannot be directly compared, as they are different types of waters. However, a comparison with EQS values can be used for benchmarking.

In addition to the concentrations being higher in the wooden vs. non-wooden building areas, the profiles of different biocides differed between sites, probably due to differences in the used materials. While in both IL and PV propiconazole and tebuconazole were commonly found, in neither substance was found in the samples from KA. Instead, terbutryn was found in every sample from KA, while in IL it was found only in one sample, and not found in other sites. Mecoprop, used commonly as herbicide but also reported in literature in construction materials, was found only in one site (PV). Out of the biocide transformation products, 2-hydroxyterbuthylazine, metabolite of terbuthylazine, was found in one sample from IL and from KA in low concentrations.

Biocides in paints for outdoor use

In the partner report by Stockholm (Appendix 5D), biocides in cured paint were analysed to verify their content. The findings confirmed the information listed in the supplier's safety data sheet (SDS), but also revealed that the actual concentration after curing was significantly higher than reported in the SDS, which was expected. However, the findings in cured/dried paint is not common sense and should be taking into account when calculating on risk and in making choices among different paints. Among the paints analysed, IPBC was the most prevalent biocide (maximum of 7589 mg/kg), followed by diuron (maximum 780 mg/kg).

Biocides in other construction material (excl paints)

Roof felt material purchased in Stockholm contained the biocide IPBC at a concentration of 1384 mg/kg. Additionally, two samples (out of four) from construction sites in Helsinki contained biocides. Wooden panels for terraces and facades were found to contain propiconazole (8.3 mg/kg and 0.07 mg/kg) and tebuconazole (8.7 mg/kg and 0.05 mg/kg).

Biocides leakage to water in a laboratory set-up

In parallel with the findings of this investigation, the Luleå University of Technology conducted a laboratory set-up to measure the direct leakage of biocides in construction material into water. Preliminary findings support the hypothesis that biocides leak to a certain extent.

Conclusions regarding biocides and wooden construction

Stormwater samples from areas with predominantly new wooden claddings showed higher levels of biocides, with substances like diuron, propiconazole, and mecoprop detected across various cities. Notably, concentrations of these biocides were significantly higher in stormwater runoff, particularly in areas with wooden buildings, highlighting a substantial environmental impact. Further, biocides in cured paint were found at higher concentrations than reported in the SDS, emphasizing the need for better management and monitoring of these substances in construction materials.

PFAS – forever, wherever

PFAS (Per- and polyfluorinated alkyl substances) have been called “forever chemicals” because of their extreme persistence. As in many other investigations we found these substances almost “everywhere”, that is in stormwater, wastewater, indoor dust and in construction material. However, we could also see a distribution and range of concentrations among all the sampling matrices that gave us some hints of the environmental fate and possible sources. PFAS substances have valuable properties of being water repellent as well as having special surfactant properties but they are also undegradable in addition to having hazardous properties. To make use of their performance characteristics in industry only a very low amount of chemicals is needed. Therefore, it is seldom declared neither in consumer products nor in construction material.

PFAS in stormwater

The concentrations of PFAS in stormwater in the four cities is depicted in Figure 17 and Table 16.

Västerås samples were taken from storm water ponds/ditches receiving water from residential areas with mainly private houses. The EL catchment area is the largest with some traffic included. GO, KA and ST represent smaller catchment areas in residential areas with less traffic. GO and KA areas were under development and construction was still going on during the time for sampling. Turku samples were taken from a residential area (labelled "IL"), having mostly wooden detached houses, whereas “KA” and “PV” are locations with predominantly non-wooden materials. Stockholm and Helsinki samples are taken from areas with a mix of traffic and residential areas catchments.

The main message is that the pollution pattern differs among the cities, but also between sample sites and sampling occasions. The high PFAS concentration in site KT1 in Helsinki does not have an obvious explanation, but the city will continue to search for potential sources. In Turku area, there are also indications on a certain pattern depending on which type of buildings appearing in the area, as there was an effect on the PFAS pattern for the district IL (predominately wooden buildings). The wooden building areas tend to have lower PFAS concentrations in stormwater compared to areas with less wooden buildings (Figure 17: TURKU, PV1 and Appendix 1).

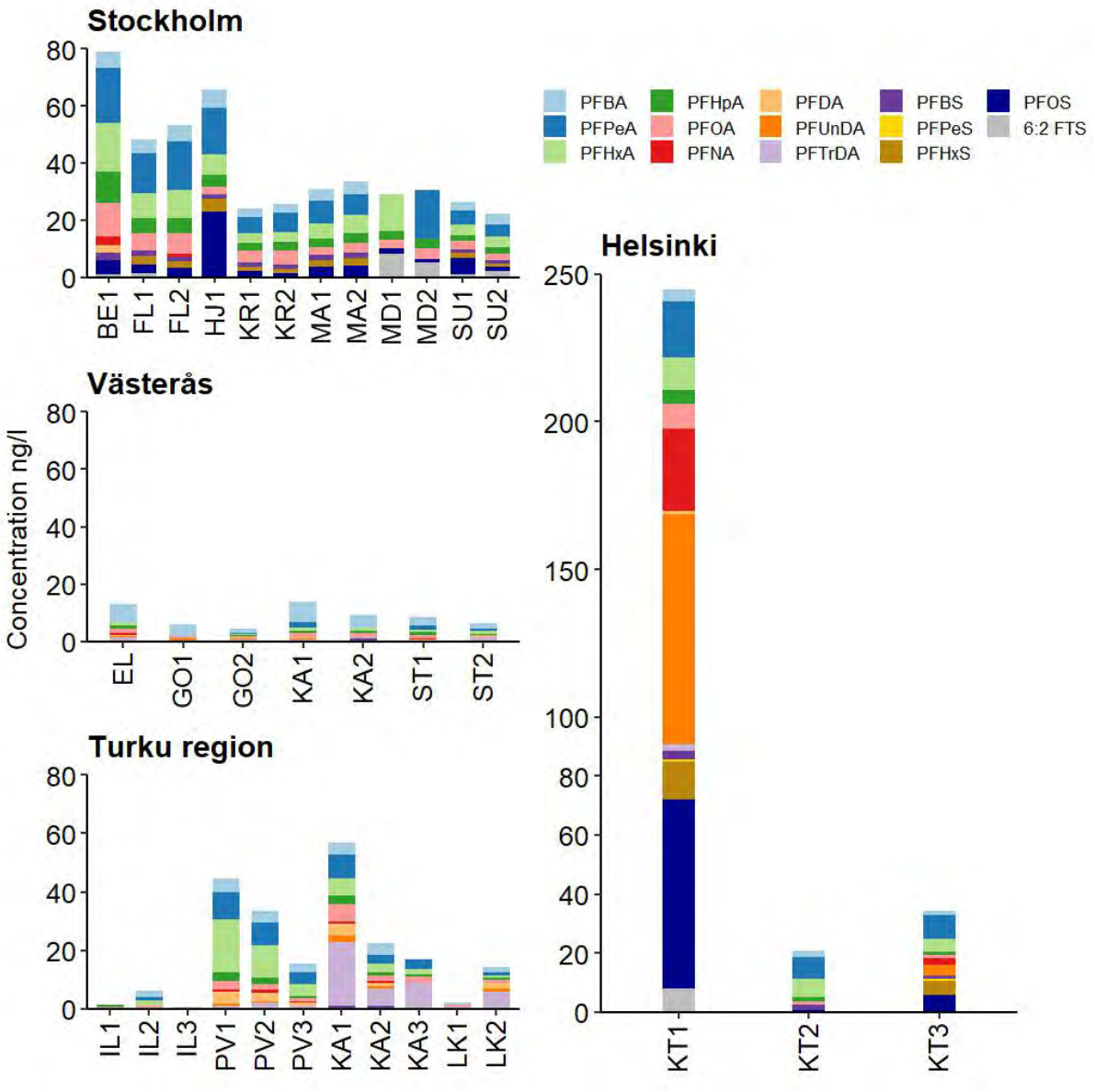


Figure 17. PFAS concentration in stormwater. Figure includes only those substance, which were analysed from all locations and found in at least one sample above LOQ. For information about the sampling locations see the text.

The results of the PFAS in analysed stormwater samples is presented in the following tables, showing max and min values of measured concentrations and detection frequencies. The different ranges of detection frequencies are indicated as follows:

0-24%	25-49%	50-74%	75-100%

Table 16. Summary of results of the screening PFAS in stormwater samples from four cities. The table includes a description of the frequency with which each substance was detected and the range of concentrations. LOQ for the individual PFAS substances ranged fro m <0.3 to <1 ng/L in Helsinki and Västerås samples, in Stockholm samples the range was <1 to <20 ng/L. PFOS in stormwater was above EQS avg. limit for inland waters of 0.65 ng/L in all samples where it was detected, Maximum Allowed Concentration, MAC-EQS of 36 000ng/l was not exceeded. Note, that measured concentrations in stormwater and EQS for surface water cannot be directly compared, as they are different types of waters. However, a comparison with EQS values can be used for benchmarking. Se appendices 1, 2, 4-5A for further details.

PFAS	Turku	Helsinki	Västerås	Stockholm
PFBA				
Detected/analysed	9/11	5/5	7/7	10/12
% of detection	82%	100%	100%	83%
Min - Max [ng/L]	<LOQ-5	1.3-4	1.4-7.3	<LOQ-6.6
PFPeA				
Detected/analysed	8/11	5/5	4/7	11/12
% of detection	73%	100%	57%	92%
Min - Max [ng/L]	<LOQ-9	4.3-19	<LOQ-1.8	<LOQ-19
PFHxA				
Detected/analysed	8/11	5/5	6/7	11/12
% of detection	73%	100%	86%	92%
Min - Max [ng/L]	<LOQ-18	3.9-11	<LOQ-1.2	<LOQ-11
PFHpA				
Detected/analysed	8/11	5/5	6/7	12/12
% of detection	73%	100%	86%	100%
Min - Max [ng/L]	<LOQ-3	1.1-4.8	<LOQ-1.2	2.1-11
PFOA				
Detected/analysed	10/11	5/5	7/7	12/12
% of detection	91%	100%	100%	100%
Min - Max [ng/L]	<LOQ-9	0.94-8.2	0.42-1.6	2.3-12
PFNA				
Detected/analysed	5/11	3/5	2/7	2/12
% of detection	45%	60%	29%	17%
Min - Max [ng/L]	<LOQ-1	<LOQ-28	<LOQ-0.5	<LOQ-2.7
PFDA				
Detected/analysed	0/11	1/5	0/7	1/12
% of detection	0%	20%	0%	8%
Min - Max [ng/L]	<LOQ	<LOQ-0.89	<LOQ	<LOQ - 2.9
PFUnDA				
Detected/analysed	0/11	3/5	0/7	0/12
% of detection	0%	60%	0%	0%
Min - Max [ng/L]	<LOQ	<LOQ-78	<LOQ	<LOQ
PFTrDA				
Detected/analysed	0/11	1/5	0/7	0/12
% of detection	0%	20%	0%	0%
Min - Max [ng/L]	<LOQ	<LOQ-2.1	<LOQ	<LOQ
PFSB				

Detected/analysed	6/11	5/5	5/7	10/12
% of detection	55%	100%	71%	83%
Min - Max [ng/L]	<LOQ-4	0.6-3	<LOQ-0.5	<LOQ-2.4
PFPeS				
Detected/analysed	0/11	2/5	0/7	0/12
% of detection	0%	40%	0%	0%
Min - Max [ng/L]	<LOQ	<LOQ-1.5	<LOQ	<LOQ
PFHxS				
Detected/analysed	5/11	3/5	4/7	9/12
% of detection	45%	60%	57%	75%
Min - Max [ng/L]	<LOQ-2	<LOQ-13	<LOQ-1	<LOQ-4.5
PFOS				
Detected/analysed	9/11	5/5	6/7	12/12
% of detection	82%	100%	86%	100%
Min - Max [ng/L]	<LOQ-22	0.56-64	<LOQ-1.4	1.4-23
6:2 FTS				
Detected/analysed	2/11	2/5	1/7	6/12
% of detection	18%	40%	14%	50%
Min - Max [ng/L]	<LOQ-1	<LOQ-7.9	<LOQ- 1.1	<LOQ-8.3

PFAS in wastewater

There was no apparent trend in the result from the investigation on domestic wastewater in Stockholm (Figure 18 and Appendix 5C). Previous survey from 2014-2016 (internal report by SVOA) shows similar results. Even though PFOS and PFOA are regulated by the POPs regulation since 2009 and 2019 respectively, there is no reduction in levels in either domestic wastewater or incoming wastewater.

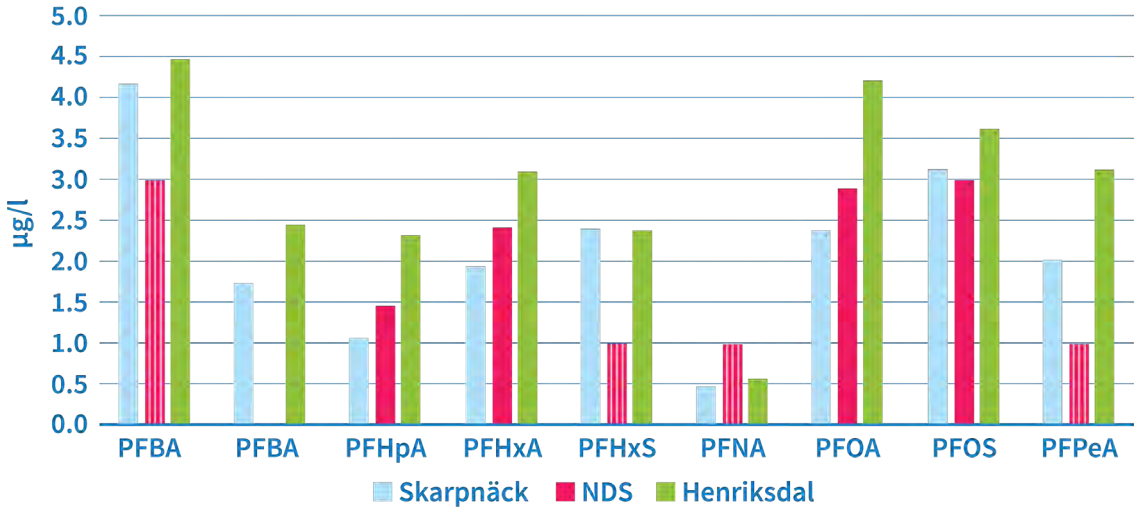


Figure 18. The concentration of PFAS in domestic wastewater from Skarpnäck, NDS and influent wastewater to Henriksdal WWTP 2020-2023. The striped bars show the limit of quantification (LOQ). For PFBS in wastewater from NDS 4 out of 7 samples were <LOD.

PFAS in indoor dust

In this study, we observed an indication about a relationship between PFAS in dust and materials used in a preschool in Västerås. This is described in the section about dust.

PFAS in construction material

Previous reports have shown that construction materials can be a source of PFAS as this was reported from Miljøstyrelsen (2024). In this study, only a few construction materials were found to contain quantifiable amounts of PFAS (such as the PVC flooring in Västerås discussed above (~3 µg/g)and a surface treatment agent for stone and concrete (20 000 µg/g) sampled by Helsinki). However, neither the outdoor paints (and roofing felts) analysed in Stockholm nor the materials analysed in Tallinn, did contain PFAS and the PFAS in flooring material in Västerås could be explained by the flooring polish treatment, so the challenge remains to determine where these PFAS substances are coming from and how we can stop their spread in our environment.

By extracting data from the assessment system “Byggvarubedömningen” (BVB) one can obtain information about which types of construction materials contain specific hazardous substances. The content list and assessments are based on the supplier's product declarations. Results from such an investigation reveal that, according to the suppliers' knowledge, PFAS is rarely an additive in construction materials at levels exceeding of 0.01% by weight, except in cases where polymer PFAS are used.

Conclusions on PFAS in urban environment

PFAS, known for their water-repellent and surfactant properties, were detected across various matrices including stormwater, wastewater, indoor dust, and construction materials. Our study

found significant variations in PFAS concentrations among different cities, with notable occurrences in certain areas with specific types of buildings. The presence (however scarce) of PFAS in construction materials, such as PVC flooring and surface treatment agents, underscores the need for further research to trace specific sources and pathways of PFAS contamination and develop effective strategies to prevent their spread.

TCPP – a potential PMT

The flame retardant TCPP is suspected to have hazardous properties. It is used with a purpose is to make materials less flammable. Flame retardants like TCPP are added to materials such as insulation boards, which are often made from oil-based products (synthetic insulation material) that would otherwise burn quickly. These materials are commonly used in buildings because they are energy-efficient, lightweight, cost-effective, and easy to work with.

Several studies have compiled results that suggest that TCPP could have adverse effects and pose a potential risk for humans and other living organisms, especially aquatic organisms. This comes as a result from the wide utilization of TCPP and the consequent release of the substance into the environment. Since TCPP is considered ubiquitous in the environment, exposure can occur through inhalation, skin contact and incidental ingestion. There is a range of undesired effects, from toxicological alterations of micro-organisms to different genotoxicological damages in higher organisms such as humans (Giannakopoulou et al., 2023). A generally shared understanding among many researchers though is that further studies regarding TCPP are required to evaluate and determine more specific risks. The results of these studies also highlight the need for measures to control the introduction of TCPP into the environment (National Center for Biotechnology Information, 2021). The Danish Environmental Protection Agency (2023) have already concluded through substance evaluation the need for a harmonised classification for TCPP due to the substance's clear carcinogenic effects. Other regulatory action needed at EU level include identification of TCPP as a substance of very high concern (SVHC) and restriction of the substance.

According to the Fact Sheet on Triphosphates by the Umweltbundesamt of Austria, TCEP has been increasingly substituted by TCPP since the 1960s. We believe this substitution to be a regrettable one, as TCPP is suspected to be carcinogenic, reprotoxic, teratogenic, and embryotoxic for humans. TCPP is regulated via the Toys Directive (EC, 2014) and is also on the SIN-List due to its vPvM properties. The SIN-list, Substitute It Now List by ChemSec, uses the criteria in REACH to identify Substances of Very High Concern (SVHC).

Therefore, we expected to find this substance in newer construction materials that have been fireproofed, such as synthetic insulation boards. Due to its migration potential (vapour pressure of about 10^-3 Pa and water solubility of about 1g/L) and mobility, we also expected it to be found in stormwater, sewage waters, and indoor dust. Suspected to have PMT properties, we anticipated that TCPP would be widespread. Hence, this investigation analysed samples from different sites and different matrices. These hypotheses were confirmed, as TCPP was found in insulation material (3.7%, material purchased in Tallinn), stormwater (Turku, Stockholm, Västerås, Helsinki), wastewater (Stockholm), and dust (Västerås). For benchmarking, we also used information about the types of construction materials containing TCPP, as data collected in BVB showed TCPP in about 50 products at concentrations of 3-20%, mostly in foam/polyurethane products such as foam plastic insulation, joint foam, and intumescent sealant.

TCPP in stormwater

To present the results of TCPP in analysed stormwater samples, the data is shown in tables displaying the maximum and minimum values of measured concentrations and detection frequencies. The different ranges of detection frequencies are indicated to visualise the abundance.

0-24%	25-49%	50-74%	75-100%

Table 17. Frequency and range of TCPP concentration, analysed in stormwater samples in four cities. LOQ was 0.1 µg/L for the stormwater samples except for samples taken in Västerås with generally LOQ <0.02 µg/L, but one sample with LOQ <0.028 µg/L.

OPE	General presence in stormwater	Turku	Helsinki	Västerås	Stockholm
TCPP					
Detected/analysed	13/35	6/11	2/5	0/7	5/12
% of detection	37%	55%	40%	0%	42%
Min - Max [µg/L]	<0.02-0.52	<0.1-0.52	<0.1-0.18	<0.02	<0.1-0.44

The analyses of OPE compounds in stormwater samples collected from Stockholm, Västerås, Turku, and Helsinki provide valuable insights into environmental contamination across different urban areas. TCPP was detected in the samples, although at relatively low concentrations of 0.12-0.52 µg/L. Compared to the environmental levels found in the Baltic Sea (3-28 ng/L) by Bollmann et al. (2019), these levels are significantly higher, which is expected. In comparison, PNEC values for TCPP in freshwater is around 500 µg/L (REACH). Overall, TCPP was found in 37% of the analysed stormwater samples, see Table 17. In the stormwater samples collected in Turku, TCPP was detected in 55% of the analysed samples, in all of the investigated locations. In Helsinki and Stockholm, TCPP was found at one and four different locations respectively, with a detection frequency of approximately 40% in both cities.

TCPP in wastewater

Residential wastewaters contain 5.5 µg /L, compared to inlet to WWTP 3.6 µg/L and outlet 1.5 µg/L (only one sample), indicating that residential areas are a major source for TCPP to wastewater treatment plants. Among the OPEs monitored in wastewater, TCPP was the predominant substance.

TCPP in preschool dust

In this study OPEs were analysed in eight samples of preschool dust in Västerås, and the median value was 0.665 µg/g. It is worthwhile to make a comparison to previous investigations in Stockholm, where TCPP was analysed but not detected in a study from 2015 (Larsson and Berglund, 2015), but in the study from 2020, where it ranges 0.9 – 5.4 µg/g in dust and <LOQ - 30 ng/m^3 in air (Langer et al., 2020).

TCPP in different matrices (comparison to other and previous results)

The findings of TCPP in storm water, construction material and dust raised the question if there was data from previous studies (NHC1, among others performed by the city of Stockholm) to compare with. In table 18, results from this study (2023, all three) were compared to previous investigations in Stockholm (2015 and 2020) and an external investigation from the Baltic Sea (Bollmann et al., 2019).

Table 18. TCPP in different matrices. "n" designates the number of samples TCPP was quantified in. "t" designates the number of samples TCPP was analyzed (total number of samples).

Median Year ref	Air (n/t) ng/m³	Dust (n/t) µg/g	WWRA (n/t) µg/l	WWTP IN (n/t) µg/l	WWTP EF (n/t) µg/l	Storm water (n/t) µg/l	Surface water (n/t) µg/l
2015 1		<LOQ (0/100)					
2020 [2]	18.0 (15/18)	1.45 (20/20)					
2023 [3]		0.665 (8/8)					
2023 [4]			5.5 (3/3)	3.0 (4/4)	1.0 (2/2)		
2023 [5]						0.05 (13/35)[6]	
2019 [7]							0.028 (1/1)

References: [1]Larsson and Berglund 2016. [2]Langer et al. 2020. [3] Appendix 4 (Västerås). [4]Appendix 5C (Wastewater, SVOA Stockholm). [5]Calculation of median value from all storm water samples taken in this study, Appendix 1,2,4,5B. [6]In 13 of the samples TCPP was quantified (average/min/max 0,24/0,12/0,52 µg/l). In 22 of the samples TCCP was below LOQ .[7] Bollmann et al.,2019.

In addition to above results, there were also investigations on TCPP in material (toys, PVC-flooring etc) which is presented in table 19. TCPP ranges from below limit of quantification to 160 µg/g.

Table 19. TCPP in material. The material samples were taken and analysed in a previous project performed by the City of Stockholm and IVL (Langer et al., 2020), except for the PU insulation from Tallinn. Except for the PU insulation, all other concentrations indicate that the TCCP was not used in these materials as a functional additive.

TCPP in material	µg/g
Preschools in Stockholm[1]	
Linoleum	<LOQ
old plastic floor (kork-o-plast)	<LOQ
PVC floor (old)	<LOQ
carpet	<LOQ
PVC cover (old)	160
Foam rubber (old)	53
PVC cover (old)	1.8
Foam rubber (old)	4.1
Flooring (new PVC) H2	14
Heavy duty tape	0.19
Insulation (Armaflex?)	1.7
Projector screen	0.86
Toy (soft dino)	0.068
Phthalate-free vinyl glove	<LOQ
anti slip material	4.3
resting madress	<LOQ
PVC flooring	<LOQ
TCPP in construction material, purchased in Tallinn [2]	
Polyurethane Insulation for external use	37 000

References: [1] Langer et al. 2020. [2] Appendix 3. Tallinn/BEF Estonia.

TCPP – need for source tracking?

Previous mentioned studies have shown that TCPP was not commonly used in consumer goods / materials from the last century. Comparing these previous results on TCPP to the values found in this study (insulation board for external use, TCPP was quantified in 3.7% in this material) indicates a change in chemical composition of materials. However, the diversity of construction materials we were able to sample is not high. More sampling initiatives are needed to extend our knowledge on where TCPP exposure originates. Bluntly put, we lack information on the diversity of the potential sources.

TCPP is suspected to be persistent (Arp and Hale, 2019), as well as mobile, physiochemical properties that enables migration through matrices into neighboring materials and spaces. Nevertheless, further research on relevant sources of TCPP is needed. The data indicates that indoor materials may not be the predominant source of TCPP, as the values found are low but widespread. However, there appears to be a small but consistent emission into the indoor environment, as both air and dust contain this substance. It is unlikely that indoor materials are contributing to outdoor contamination. Specifically, insulation foams, which are used indoors, do not seem to be the main source. However, there is a suspicion that outdoor sources, possibly involving water contact, are the primary contributors. Further analysis is needed to confirm this hypothesis.

The use of BVB as information source is important for source tracking since we were able to collect information in BVB about TCPP. It was found in about 50 products in a concentration of 3-20 %, mostly in foam/polyurethane products such as foam plastic insulation, joint foam and intumescent sealant.

Conclusions on findings regarding TCPP

Our study confirmed the presence of TCPP in various matrices, including stormwater, wastewater, and indoor dust across multiple urban areas, indicating widespread contamination. TCPP, commonly used as a flame retardant in construction materials, such as PU insulation foams, was detected in stormwater samples, suggesting potential sources in urban areas. This widespread contamination is typical for a high-tonnage functional additive with comparably high vapour pressure, water solubility, and low biodegradability. The regulatory concern is heightened by its carcinogenic properties. Monitoring and managing the use of flame retardants, particularly in construction materials, is crucial to mitigate contamination and reduce OPEs release into urban environments and water bodies. Identifying specific sources and pathways of TCPP release can aid in targeted mitigation strategies. Further research is needed to comprehensively understand and address the sources of TCPP contamination.

Metals

Metals in stormwater in four cities

In Turku, Helsinki, Stockholm and Västerås, metals were analysed in stormwater. The concentration of Ni, Cu, Zn, Pb are depicted in figure 19. A notable result is the slightly higher concentration of metals in one site in Turku, compared to almost all other sample sites. For Stockholm sites there will also be a comparison of stormwater, groundwater and wastewater samples.

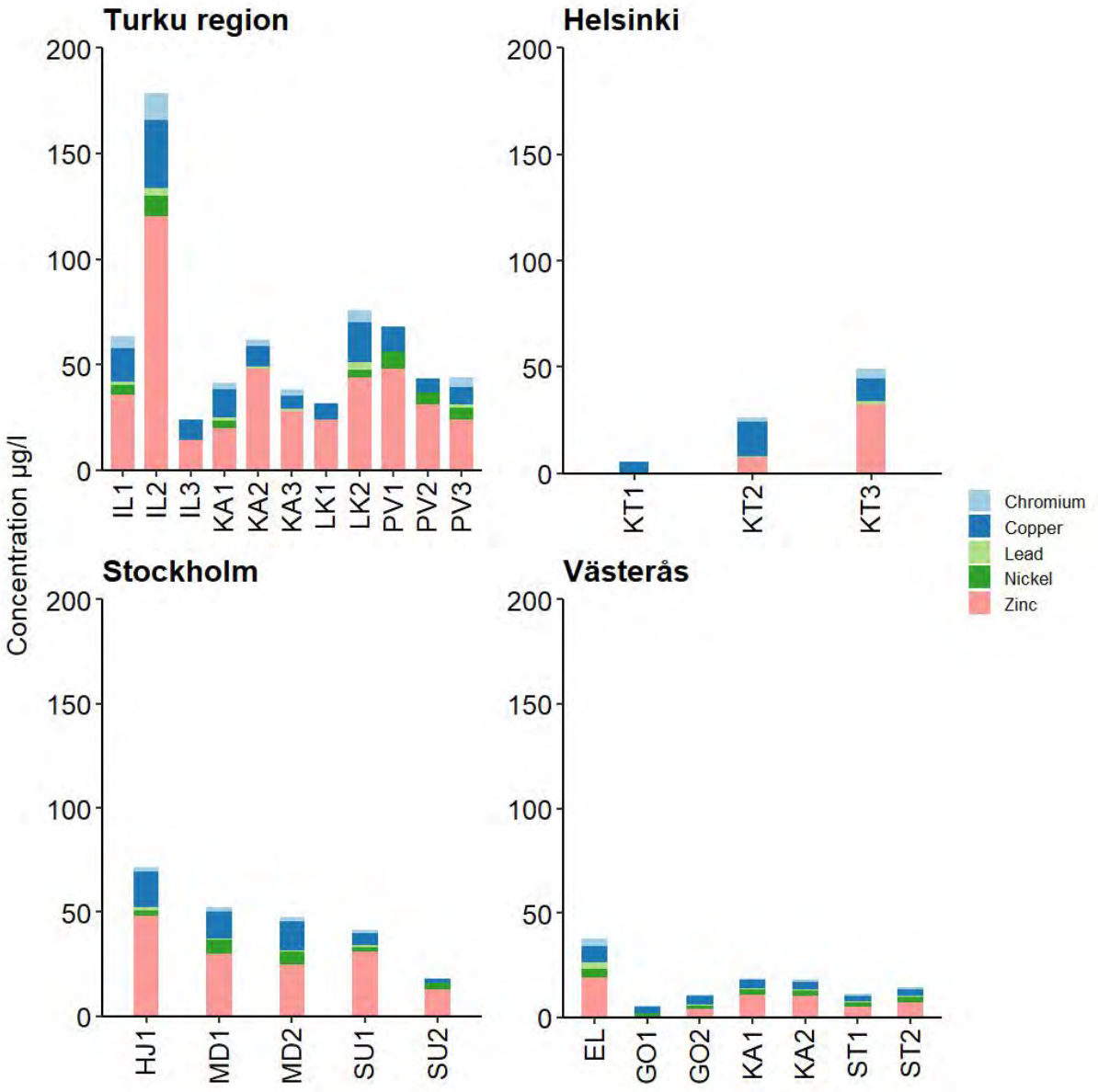


Figure 19. Metals in stormwater in Turku, Helsinki, Stockholm, Västerås. The x-axis designates different sample sites explained in Appendices 1,2,4,5A.

Metals in groundwater and wastewater

In the results from Stockholm, a comparison of groundwater and wastewater samples was possible due to accessible data from the environmental monitoring program. Figure 20 clearly shows that wastewater from residential areas is contaminated with metals, but also that these metals are efficiently removed in the wastewater treatment plant (WWTP). Additionally, groundwater has a very low concentration of metals.

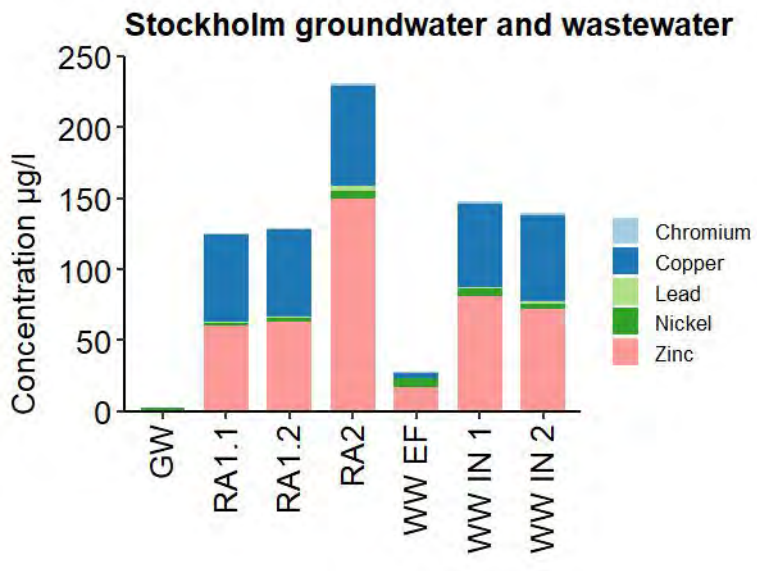


Figure 20. Metals in groundwater and wastewater in Stockholm. GW-groundwater, RA-wastewater from residential areas, WW-wastewater (treatment plant), EF – effluent, IN-inlet.

Additional results

In this section we present several important but only briefly described results. For more detailed information from each partner (city), substance, or matrix, please find the respective appendices.

Chlorinated paraffins

Chlorinated paraffins in dust and construction material

Chlorinated paraffins were measured in indoor dust from preschools in both Västerås and Stockholm (see Tables 20 and 21). This investigation analysed short-chain chlorinated paraffins (SCCP), medium-chain chlorinated paraffins (MCCP), and long-chain chlorinated paraffins. Compared to other pollutants in indoor dust (see dust section), the levels and distribution of these hazardous substances suggest an indoor source of chlorinated paraffins. However, chlorinated paraffins were not detected in any of the construction materials sampled and analysed.

In a previous investigation in Stockholm, chlorinated paraffins were analysed, and the results indicated a 5-7 times higher concentration compared to those found in the NHC3 screening activities. In another investigation, where the focus was on following-up on the city's chemical demands, a specific building material product (a black condensation insulation) was found to contain 9.1-12% by weight of MCCP and 0.011-0.021% by weight of SCCP (Bohman 2021). This material is prevalent in buildings with strict energy standards due to its efficient insulation properties and its ability to reduce condensation on cold surfaces. Additionally, a polyurethane foam was found to contain 0,77 % by weight of MCCP (Bohman 2021). Dust from a small room, with observed and numerous pipes covered by the insulation material, contained 30 times higher concentration of MCCP in dust than the mean value in three adjacent rooms (table 22).

Table 20. Chlorinated paraffins in indoor dust in preschools in Stockholm, this study (Appendix 5A).

Substance (µg/g)	Mean	Median	Minimum	Maximum
∑SCCPs (C10-C13)	8.20	3.34	1.23	32.40
∑MCCPs (C14-C17)	37.50	23.10	8.45	108.40
∑LCCPs (C18-C21)	11.39	7.67	4.44	23.40

Table 21. Chlorinated paraffins in indoor dust in preschools in Västerås, this study (Appendix 4).

Substance (µg/g)	Mean	Median	Minimum	Maximum
∑SCCPs (C10-C13)	28,41	33,20	1,45	47,80
∑MCCPs (C14-C17)	54,87	49,05	7,48	118,00
∑LCCPs (C18-C21)	12,93	8,82	4,52	23,40

Table 22. Preschool dust. Previous results from Stockholm, Langer et al., 2020 (three playing room) and unpublished results (small room).

Substance (µg/g)	Mean value (3 playing room)	Small room[3]
∑SCCPs (C10-C13)	3,00	5,00
∑MCCPs (C14-C17)	5,00	150,00

Chlorinated paraffins in wastewater

Short-chained chlorinated paraffins (SCCP) and medium-chained chlorinated paraffins (MCCP) were analysed in wastewater. The results show levels of similar SCCP concentrations in domestic wastewater in both residential areas Skarpnäck and NDS (Figure 21). Comparing the NHC3 screening results to previous studies from 2018 and 2014 (not shown), the values are steadily decreasing. This is likely to be due to, to the ban that was introduced through the POPs regulation in 2017.

[3] A room with a number of pipes covered by a black condensation insulation

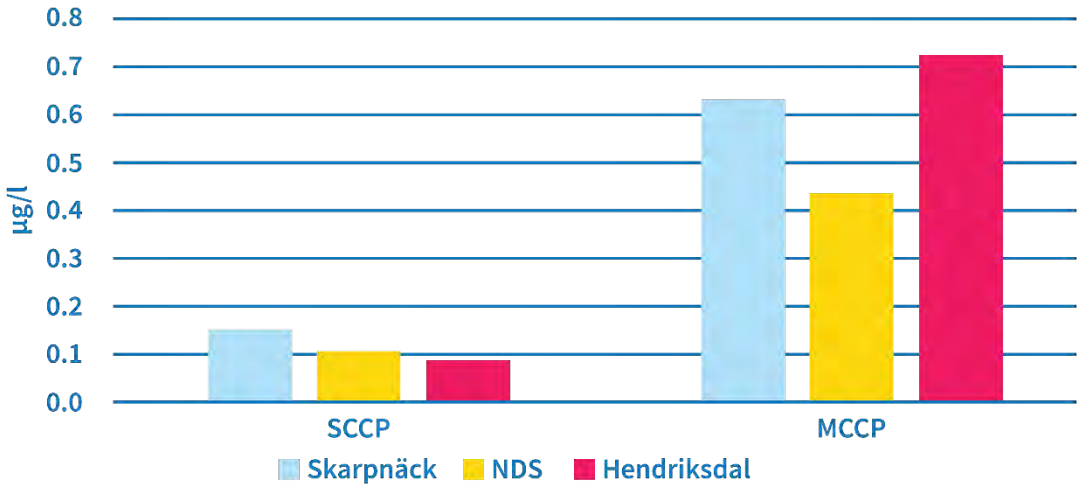


Figure 21. Chlorinated paraffins in wastewater. Skarpnäck and NDS is domestic waste water from residential areas and Henriksdal is inlet to the WWTP.

Direct leakage to the drain water run-off-Tunnel sheet investigation

In this investigation the safety of using PVC-sheet in tunnel construction, focusing on Protan 554 supplied by Protan AB, was examined. Results showed that, while phthalates like DiNP and DiDP were present in the PVC-sheet, their leaching into water was quantifiable but trace amount, especially at lower temperatures, and no PFAS were detected. Although some hazardous chemicals were identified, their limited leaching suggests a low environmental and health impact, though continued monitoring is recommended due to the extensive use of material across many kilometres of tunnel. See Appendix 5E.

Renovating the floor lowers the content in dust

The study investigated potentially harmful substances in a school, focusing on dust and materials, to evaluate the impact of floor treatments on the indoor environment. Measurements taken before and after the floor treatments showed a decrease in the concentrations of most of the analysed substances, suggesting that these treatments can support the City of Stockholm's efforts toward a more tox-free school environment. However, long-term risks associated with floor treatments remain uncertain, emphasizing the need for ongoing research and continuous environmental toxicity monitoring to ensure chemical safety, especially for children. See Appendix 5F.

Trends of pollutants in WW (RA & inlet)

For some data there are possibilities to draw conclusion on trends and effects of regulation of hazardous substances. One example is the concentration of DEHP in wastewater, which is steadily decreasing from 2014 to 2023, Figure 22. The sunset date for DEHP, after which its use is generally prohibited without authorisation, was February 21, 2015.

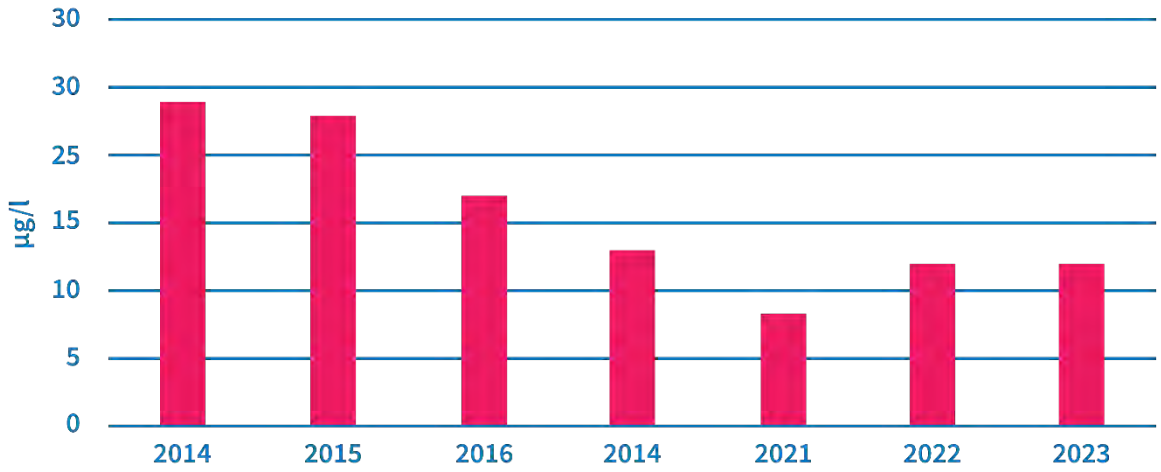


Figure 22. The concentration of DEHP in residential area wastewater from a residential area in Stockholm, Skarpnäck 2014-2023.

HS avoidance in construction and sites

This chapter partly refers to Chapter 9 in The NonHazCity 3 Building Material Catalogue for tox free construction (NHC3, 2023). The content is a fusion of environmental routines and requirements in construction process originating from administration and municipal companies / real estate owner / developers in the City of Stockholm (SISAB, Familjebostäder AB, Svenska Bostäder AB, Stockholmshem AB, City Development Department, and Real Estate Department).

Solutions for managing procedures for HS in construction materials and sites at municipal entity

To control and limit hazardous chemical substances used in construction, the chemicals that are allowed need to be determined already in the procurement stage. This is achieved by using assessment tool (based on chemical criteria and a digital logbook) for example Byggvarubedömningen (BVB). In the procurement process, formulation of requirements for the digital logbook, documenting the materials used as well as their chemical composition. A logbook facilitates substitution of hazardous materials, products, and substances. It also provides valuable information if the knowledge of what is considered non-hazardous today changes in the future.

To get a better understanding of the power to influence selection of non-hazardous construction- and building materials, it is necessary to understand the construction process where materials are selected and when procurement and purchase of materials take place. It is important with knowledge and management through the construction process. A success factor is that the project is staffed with committed people. Therefore, in a construction project, there are different crucial responsibilities that need to be staffed:

Construction project manager: The construction project manager (CPM) is responsible for delivering information to the BVB manager. In addition, a CPM must ensure that designers and contractors fulfil their mission in BVB.

Designer: Responsible for ensuring that the chosen products and goods meet the requirements and are recorded in the logbook in BVB during the detailed design.

Contractor: Responsible for ensuring that all goods and chemical products used in the building as well as consumable products meet the requirements and are recorded in the logbook in BVB.

BVB manager: Administers the work in BVB and handles deviations. This includes creating logbooks, inviting designers and contractors to logbooks as well as training and attending construction meetings as needed.

Head of unit, environmental unit (client's side): Approves or rejects deviations in planning and production. Is the owner of all logbooks in BVB.

Planning and programming

The developer should at an early stage decide levels of ambitions and tools for verification, to ensure the selection of materials without hazardous substances used in the construction process. At this stage, decisions need to be taken about target levels and verification, tools for documentation (logbook) and verification of chemical content, preferred product groups. These requirements shall be incorporated in the specifications for the procurement of contractors and designers.

Design (architectural and engineering design)

The contract between developer and consultant should indicate that the consultant undertakes to comply with the requirements and objectives that the developer set, in relation to chemical substances in construction materials. During the design phase, it is possible to choose design and functions, but it is also important to control that chosen construction material fulfils requirements of non-hazardous content.

In the design phase, the BVB manager creates a logbook in BVB and invites relevant actors, assists with training, creates licenses, and distributes routines. The BVB manager is also available for questions about material selection during the detailed design. The construction project manager informs the BVB manager about quantities of goods for registration. The BVB manager reviews the logbook in BVB prior to construction start.

Construction

During construction, the contractor´s purchasing organization has an important role to play in relation to selection of non-hazardous construction material and compliance with requirements in the agreement with the developer. At the end, the BVB manager reviews the logbook within the framework of the final inspection and reports back to the responsible construction project manager.

Management

Management of buildings in relation to non-hazardous materials is not very common. Chemical considerations in the management process may be important to consider because a large volume of products could be used for maintenance during the user phase. Subcontractors in municipalities often perform maintenance.

Table 23. Examples of aspects to consider.

Nr.	Aspects to consider	Yes/No
1.	Are **responsibilities defined** at municipality on who will follow implementation of toxfree, circular and climate neutral aspects during the construction/refurbishment/extension project?	
2.	Is organisation of a **market consultations** with design/architectural companies considered prior to elaboration of procurement documentation and launching a procurement procedure?	
3.	Is application of **innovation-friendly procurement procedure** e.g. design contest considered?	
4.	Is **collaboration** procedure between the architect/designer and municipality specialists established to ensure elaboration of a building design meeting the targets for tox free, circular, climate neutral construction?	
5.	Is an (electronic, online) **logbook** created to identify potential materials to be used for construction/extension/refurbishment of a building?	
6.	Are options for application of materials containing reduced amount or **no hazardous substances** considered at the design stage?	
7.	Are options for using locally produced (e.g., wood, clay) and/or **eco certified materials** considered in the design of the building?	

8.	Are options to use **reusable, recyclable materials** and easy to repair solutions considered in the design?	
9.	Are options for application of materials having **low embodied energy** considered?	
10.	Is the new design so **flexible**, that it can serve for other needs than the original planned, to save reconstruction in case of the change of the need?	
11.	Are options for **increasing energy performance** of the building considered avoiding “hot spots” e.g., thermal bridges at the design stage?	
12.	Are options for use of **renewable energy sources** considered at the design stage?	

Assessment of products and goods (BVB)

In the agreement with a contractor, it is necessary to use the chosen chemical products and construction products that are registered in the project-specific logbook in the BVB-system. Consultants and contractors must have the skills and routines necessary to ensure that products, chemicals, and materials are assessed, and with an overall accepted level of assessment in BVB. Chemical products and goods that do not meet the municipality’s requirements are handled as deviations, as described below.

Material requirements

Assessment of construction products in BVB

The party that specifies or intends to use a product is responsible for ensuring that it is assessed in accordance with BVB's criteria, and that the product meets the following assessment levels:

• Products that have gotten the overall assessment Recommended or Accepted are approved for use. The higher level Recommended must be prioritized over the assessment Accepted.

• Products with the overall assessment To be Avoided may only be used after approval from the customer before use. Products with this assessment must be handled as a deviation (see Deviation management below).

To ensure that products and goods fulfil the requirements, they must be verified according to BVB's criteria in the design phase and before purchase and use. The criteria of BVB are updated regularly. This means that even if a product previously met the requirement for an assessment level, the assessment could have changed. Therefore, the current assessment of a product must always be confirmed prior to use.

A hired consultant or contractor is responsible for documenting goods on BVB's web portal before they are purchased and used. The customer reimburses the verified license cost for BVB for one user per consulting company or contractor per project. Prior to final reporting, the consultant or contractor must notify the customer when registration of all included goods is completed.

Handling of unassessed products and goods

The priority is to use products and goods that are assessed in BVB. If the desired product is not assessed in BVB, the consultant or contractor must search for an alternative product. The product should have the overall assessment Recommended or Accepted. If there is no satisfactory alternative, the consultant or contractor must contact the supplier of the initial product to request an assessment of the product. The supplier must bear the cost for the assessment.

The priority order for a situation where a product is not assessed in BVB is shown below.

1. The consultant or contractor contacts the supplier of the desired product and asks them to submit the goods for assessment in BVB.

2. During the assessment period for the product, the consultant or contractor can enter the product in BVB with a placeholder ("Own product").

3. The consultant or contractor asks the supplier to be notified of the BVB identification number (BVB ID) when the product is assessed in BVB.

4. When the product is assessed, "Own product" must be replaced with the assessed product in the logbook (BVB ID required).

The product may not be used until all steps above have been completed and the product has been published with its assessment in the BVB system.

If the supplier cannot assess the product and there are no alternative products that meet the specified requirements, the product must be registered in BVB as an "Own product" and handled as a deviation. The consultant or contractor must be able to confirm that the supplier has been contacted before a deviation can be established.

Deviation management

All products, materials, and goods must be logged before they are used or installed. Designers and contractors must document and justify deviations from material requirements in a deviation report in BVB. The BVB manager from the contractor’s side is responsible for the deviation management.

Deviations must be reported to the customer. The decision whether a product with a deviation should be used or not must be made by the person responsible for the project prior to use of the product on the construction site. Quantity and location of products that have received the assessment To be Avoided or products that are not assessed at all (“Own products”) must be declared as deviations in BVB. If the deviation routine is not followed and thereby prevents the correct actions, this may become an inspection remark.

When a deviation is registered in BVB, the attempts that have been made to find an alternative product as well as a summary of the dialogue with the supplier must be submitted alongside the deviation.

If the product has the assessment To be Avoided due to a lack of documentation, the person who proposed the product must contact the supplier and ask them to update the documentation for reassessment of the product.

The following deviations cannot be approved:

Products that lack complete or correct assessment documentation.

Products that are logged in the logbook after they have been installed or used.

Follow-up processes

Depending on the requirements set in the procurement documents, different follow-up processes can be used. Below are some examples:

Follow-up meetings with the contractor and/or material supplier.

Measurement of quality through indicators or key figures.

Randomized verification of invoices.

Survey submitted to suppliers, clients or third parties (e.g., residents).

Follow-up of self-reporting from suppliers.

Follow-up of management systems for environment and quality.

Notified or unannounced follow-up visits to the supplier.

Planned or randomized audits of a supplier.

Summary and conclusions

The findings highlight both progress and challenges in the construction sector's approach to chemical management and sustainability. The widespread use of various chemicals across different material groups underscores the complex composition of construction materials and the potential risks associated with their use.

The analysis of construction materials revealed significant insights into the presence of various chemicals and substances, as well as the absence of certain hazardous compounds. Key findings from the analysis include:

In exterior paints, high levels of biocides such as Iodocarb and Diuron were detected, particularly in samples collected from Stockholm. Additionally, significant concentrations of metals like titanium, aluminium, and chromium pose potential environmental and health risks.

Flooring materials exhibited a diverse range of plasticizers, with varying concentrations across different samples from Stockholm, Västerås, and Tallinn. The presence of DEHP, DiNP, and other plasticizers raises concerns about their impact on indoor air quality and human health. PFAS compounds are a major issue because of their ubiquitous presence in the environment. They have previously been shown to be widely used in construction materials. However, in this screening only a few products were found to contain PFAS. Further work is needed to identify the sources of PFAS.

The absence of certain hazardous substances, such as HBCDD and organophosphate flame retardants, is encouraging. However, concerns remain regarding the presence of biocides, plasticizers, and PFAS compounds in construction materials,.

Dust reflects the chemical composition of the indoor environment. The samples analysed in this study contained organic pollutants such as plasticizers, PFAS, and chlorinated paraffins, with some samples having up to 0.1% by weight of these pollutants. Although levels of some hazardous substances have decreased compared to earlier studies, dust still contains a significant number of pollutants. The presence of these hazardous substances in dust was strongly linked to the type of materials used in the indoor environment. These results highlight the importance of better material choices and stricter regulations to reduce health risks from exposure to these contaminants in indoor environments.

Stormwater acts as a conduit between the built environment and the natural environment, transporting several pollutants, including biocides, organophosphate esters, metals, and PFAS. There were notable differences in urban stormwater contamination between the cities included in the study.

Contamination of stormwater by biocides used in construction materials was evident. Stormwater samples from areas with predominantly new wooden claddings showed higher levels of biocides such as Diuron, Propiconazole, and Mecoprop across various cities. These concentrations were significantly higher in stormwater runoff, particularly in areas with wooden buildings.

PFAS were detected across various matrices, including stormwater, wastewater, indoor dust, and construction materials. Significant variations in PFAS concentrations among different cities were noted, with notable occurrences in certain areas with specific types of buildings. Further research is essential to trace specific sources and pathways of PFAS contamination and develop effective strategies to prevent their spread.

Our investigation confirmed the presence of TCPP in various matrices, including stormwater, wastewater, and indoor dust across multiple urban areas, indicating widespread contamination. TCPP, commonly used as a flame retardant in construction materials, such as PU insulation foams, was detected in stormwater samples, suggesting potential sources in urban areas. This widespread contamination is typical for a high-tonnage functional additive with comparably high vapour pressure, water solubility, and low biodegradability. The regulatory concern is heightened by its carcinogenic properties. Monitoring and managing the use of flame retardants, particularly in construction materials, is crucial to mitigate contamination and reduce OPEs release into urban environments and water bodies. Identifying specific sources and pathways of TCPP release can aid in targeted mitigation strategies. Further research is needed to comprehensively understand and address the sources of TCPP contamination.

Final remarks

Both the objective of a non-toxic environment and the work for true circularity in the construction sector require the elimination of hazardous chemicals from products. The presence of these substances hinders efforts towards sustainable resource management and recycling practices. Stakeholders must adopt a holistic approach prioritising the elimination of hazardous substances, promoting the use of safer alternatives, and encouraging transparency and collaboration across the supply chain. Regulatory frameworks play a crucial role in driving industry-wide change, ensuring compliance with standards, and fostering innovation in chemical management.

While there is still much work to be done to achieve a truly sustainable and circular construction sector, progress has been made in reducing the presence of certain hazardous substances in construction materials. By prioritising chemical safety, promoting transparency, and fostering collaboration, stakeholders have already started, and can continue to work towards a future where construction materials are safe, environmentally friendly, and conducive to circularity.

These observations and recommendations underscore the need for continued vigilance, further research, and regulatory oversight to ensure the safe and sustainable use of construction materials in the built environment.

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Appendices

Partner reports overview

Appendix 1. Storm water Turku UAS

Appendix 2. Storm water and construction material Helsinki

Appendix 3. Construction material Tallinn/BEF Estonia

Appendix 4. Dust & air in preschools, storm water Västerås

Appendix 5. Stockholm

- 5A. Dust in preschools Sthlm (Goodpoint)
- 5B. Storm water Sthlm
- 5C. Wastewater Sthlm (SVOA)
- 5D. Biocides and other additives in building material Sthlm (Goodpoint)
- 5E. Tunnel sheet investigation Sthlm (Goodpoint)
- 5F. Floor renovation measure Sthlm (Goodpoint)

Occurrence of substances of concern in Baltic Sea Region buildings, construction materials and sites

Storm water

Turku University of Applied Sciences

Appendix 1

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Contents

Abbreviations

AA-EQS annual average environmental quality standard
Al aluminium
COD chemical oxygen demand
Cr chromium
Cu copper
DBP dibutyl phthalate
DEHP diethylhexyl phthalate
DiBP diisobutyl phthalate
DIDP diisodecyl phthalate
DINCH 1,2-cyclohexane dicarboxylic acid diisononyl ester
DINP diisononyl phthalate
DMP dimethyl phthalate
DNOP di-n-octyl phthalate
EQS environmental quality standard
LCCP long-chain chlorinated paraffins
MAC-EQS maximum allowed concentration environmental quality standard
MCCP medium-chain chlorinated paraffins
Ni nickel
OPFR organophosphate flame retardant
Pb lead
PBDE polybrominated diphenyl ether
PFAS per- and polyfluoroalkyl substances
PFBA perfluorobutanoic acid
PFBS perfluorobutanesulfonic acid
PFCA perfluorocarboxylic acid
PFHpA perfluoroheptanoic acid
PFHxA perfluorohexanoic acid
PFHxS perfluorohexanesulfonic acid
PFNA perfluorononanoic acid
PFOA perfluorooctanoic acid
PFOS perfluorooctanesulfonic acid
PFPeA perfluoropentanoic acid
PFSA perfluorosulfonic acid
PP polypropylene
PVC polyvinyl chloride
SCCP short-chain chlorinated paraffins
TCPP tris(2-chloro-1-methylethyl) phosphate
WFD Water Framework Directive
Zn zinc
6:2 FTS 6:2 fluorotelomer sulfonate

Introduction

Building materials used both indoors and outdoors may contain chemical substances that pose harm to the health of humans and the environment. Hazardous substances used in outdoor materials can leach from the material into rainwater and end up in waterbodies or soil with run-off.

In Europe, some studies have investigated the occurrence of building material associated substances in stormwaters. For example, several biocides (Paijens et al. 2020), chlorinated paraffins (Birch et al. 2011) and flame retardants (Mertens et al. 2018) have been found in European stormwaters. In Finland however, the occurrence of hazardous substances from building materials in stormwater is largely unknown.

We analysed different groups of chemicals associated with outdoor building materials from storm water in the Turku region, southwest Finland. Our aim was to compare the screening results of sampling areas with different main building materials, i.e., between wooden construction and other materials (e.g. concrete, tile). We expected to find more biocides associated with wood (wood preservatives, biocides used in paints) in the wooden building areas compared to other sampling locations. We also included a sampling site to account for the possible impact of traffic and air pollution on the results.

Substance screening

We investigated the leakage of harmful chemicals from building materials into stormwater. The substances were chosen based on discussions with experts and information from studies on chemical content of building materials and their occurrence in stormwater. The list of analysed substances included wide variety of biocides, metals, phthalates, organophosphate flame retardants, PFAS and chlorinated paraffins.

Biocides

Biocides are used especially on the exterior surfaces of buildings to prevent the growth of microorganisms and damage to materials. Often wood used in exterior parts of building includes wood preservative biocides. In addition, biocides, e.g. isothiazolinones, can be used as in-can preservatives of chemical products, such as paints. Biocides can be mixed with the material or added as a surface treatment (Paijens et al. 2020). Most products contain more than one biocide to increase effectiveness. The biocides analysed by Turku UAS in NHC3 included variety of different biocides approved for use as wood and in-can preservatives.

Many biocides do not have a specific target species, and thus also affect other species in the environment. The effect depends on the specific compound. Several biocides used in construction materials are toxic to aquatic organisms. Some are also carcinogenic, mutagenic and toxic to reproduction (Building material catalogue for tox-free construction 2024).

Phthalates

Phthalates are used as plasticizers, and their source from building materials is especially various PVC materials. In exterior building materials, PVC is found, for example, in PVC roofs, skylights on terraces and in various pipes, such as sewer pipes and rainwater wells. For example, DNOP, DEHP, DIDP and DINP have been observed to leach from PVC roof materials (Müller et al. 2019).

While phthalates degrade easily in the environment, they are used in high quantities and often found prevalently. Many phthalates have endocrine disrupting qualities and some a toxic to aquatic organisms (Building material catalogue for tox-free construction 2024).

Metals

Metals can leach into the environment from various metallic building materials. However, metals also have many other environmental sources, such as e.g. traffic. Among building materials, sources of metals are, for example, metal roofing materials (tin roofs) and rainwater eaves and downspouts made of metal. Zinc, copper, nickel, aluminum, chromium and lead have been found to be leached from metallic exterior building materials (Wicke et al. 2022, Müller et al. 2020, 2019).

Per- and polyfluoroalkyl substances

PFAS are a large group of substances used in variety of products e.g. for their grease, water and dirt repellent properties. In building materials, PFAS (including fluoropolymers) are used among other uses are coatings in roofing materials, waterproof membranes, gutters, coatings of windows, different wood-based products like plywood and fibre boards and in solar panels. In addition, PFAS compounds are found in some paints, metal coatings, wood varnishes, plastic coatings, sealants, crystals, adhesives, tapes and electrical wires and cables used in construction (The Green Science Policy Institute 2021). In this screening, a broad target-analysis of PFAS was done for the storm water samples.

PFAS are very persistent in the environment, and they either do not degrade, or they degrade into persistent PFAS. Some PFAS are also bioaccumulative. The adverse effects of many PFAS are poorly studied, but certain PFAS are known to e.g. be reprotoxic, carcinogenic and immunosuppressive (Building material catalogue for tox-free construction 2024).

Chlorinated paraffins

Chlorinated paraffins are used as plastic softeners and flame retardants, e.g. in plastics (mostly PVC), rubbers, paints, sealants and polyurethane foams (Danish Environmental Protection Agency 2014b, Brandsma et al. 2021). Short-chain chlorinated paraffins (SCCPs) belong to the Stockholm Convention's list of substances to be phased out (UNEP/POPS/SC-8/11). The ban on SCCPs has led to their replacement by medium chain chlorinated paraffins (MCCP) with a carbon chain length of C14-17 or containing 45% chlorine by weight. MCCPs are on the candidate list of substances to be added to the Stockholm Convention (UNEP/POPS/POPRC.17/6). In addition, long chain chlorinated paraffins (LCCPs) with a carbon chain length of >C18 are in use on the market. The leaching of chlorinated paraffins into storm water is largely unstudied. In this screening, SCCPs, MCCPs and LCCPs were analysed from the storm water samples.

Chlorinated paraffins are persistent and toxic (Building material catalogue for tox-free construction 2024).

Organophosphate flame retardants

Organophosphate flame retardants (OPFRs) are added to products to decrease their flammability and slow down spreading of fire. OPFRs have been used to replace harmful brominated flame retardants. Some OPFRs are also used as plasticizers. In building materials, OPFR is used e.g. in sealing and insulating foams, plastic and rubber products, sealants and adhesives. (Blum et al. 2019).

OPFRs have been associated with e.g. neurotoxicity, developmental toxicity, damage to the reproductive function, endocrine disruption and carcinogenicity. OPFRs are less persistent than the brominated flame retardants they have been used to replace, but they are often found in the environment in higher concentrations than the brominated compounds (Building material catalogue for tox-free construction 2024).

Methodology

Sampling sites

Illoinen (IL)

In the catchment area of the Illoinen sampling site, there are detached houses, some of which were under construction at the time of sampling, while others were already completed. All the houses in the catchment area were built after 2019. The exterior cladding of the houses is wood, except for two houses with a stone surface. Almost all houses have metal roofs. The roads in the area are asphalted, but the yards of the houses are unpaved. The catchment area has moderately green areas and permeable surfaces. The catchment area is approximately 5 hectares. Sampling is conducted from a stormwater pipe that collects water from the yards of the buildings in the catchment area. The material of the stormwater pipes is PVC.

Kaarina (KA)

The sampling site is in the city centre of Kaarina. The catchment area primarily consists of apartment buildings and various commercial spaces. About half of the building stock in the area was completed in the last 10 years, while the remaining buildings are much older and built in a traditional style. In newer buildings, the roof structures are made of metal, while older buildings have tiled roofs. Solar panels are installed on the roof of the city hall. Most surfaces in the catchment area are asphalted, and there are only a few green areas. The catchment area is approximately 23 hectares. Samples are taken from a stormwater pipe that collects runoff water from the central area.

Pääskyvuori (PV)

The catchment area of the Pääskyvuori sampling site has plans for the construction of seven apartment buildings, of which five were completed at the time of sampling. Construction of the remaining buildings had not started at the time of sampling, except for some ground works. The completed apartment buildings feature brick cladding, glass balconies, and metal roofs. Waste sheds in the yards have wooden cladding and green roofs. Yard areas and roads are paved. The catchment area is approximately 5.5 hectares. Sampling was carried out from a stormwater wetland that collects runoff water from the catchment area. The material of the stormwater pipes is unknown.

In the upper part of the catchment area, there was military activity from 1930 to 2012, suspected to have caused soil contamination. In 2018, soil classified as contaminated with metals and PAH compounds was removed from the area. Soil investigations were conducted at the site in 2020, revealing elevated levels of zinc, individual PAH compounds, and arsenic. The detected contaminants are not highly mobile and are poorly volatile. Additionally, some areas of the soil contain construction waste. As a remediation measure for the contaminated soil, mass exchange has been done.

Länsikeskus (LK)

The sampling site in Länsikeskus is entirely on asphalted roads. The drainage area is very small, only about 560 square meters, and does not have any buildings. The sampling site has been selected as a control point for atmospheric deposition and traffic. The material of the stormwater pipes is at least partly polypropylene, but the material of all pipes is not known.

Sample collection

11 storm water samples and one blank sample were collected from September to November of 2023. In locations with stormwater pipes, one hour composite sample was collected during rain, while in locations with stormwater ponds, samples were collected after rain.

Table 1. Sampling locations and information on the sampling

Sampling location	Number of samples	Sample collected from
Illoinen	3	stormwater pipe
Kaarina	3	stormwater pipe
Pääskyvuori	3	stormwater pond/pool
Länsikeskus	2	stormwater pond/pool

Each sampling location was assigned its own sampling gear, used to collect samples only that location to avoid cross-contamination. Material of all sampling gear was food-grade polypropylene (PP). Before sampling, all sampling equipment was washed first using tap water, and then rinsed first with MilliQ water and finally ethanol. All sampling gear was transported lid closed or in closed containers to the sampling location and was rinsed using the water from the sampling location before starting to collect the sample. To avoid contamination from e.g. clothing fibres, protective cotton coats, low-linting hair nets and nitrile gloves were worn when handing sampling gear or samples.

For samples collected from storm water pipes (sites IL and KA), 2 l subsamples were collected during a rain event using PP water scoops every 10 minutes for an hour, i.e., at 0-, 10-, 20-, 30-, 40-, 50- and 60-minute marks, into a 30 l bucket. Between taking sub samples, the water scoop was stored in another PP bucket with the lid closed to avoid contamination. For samples collected from storm water ponds (sites PV and LK), water from the pond close to the stormwater pipe was collected after a rain event into a 30 l bucket using 2 l water scoops without disturbing the bottom of the pond. Total sample volume using both methods was 14 l.

After collecting the full volume, the sample was mixed thoroughly with the scoop for 30 seconds without making a vortex. After mixing, the sample was transferred into the bottles provided by the laboratory using a PP jug. Sample bottles were transported in polystyrene cooler boxes containing freezer packs to keep the sample temperature low. The samples were sent to the analysis laboratory via mail as soon as possible.

Possible contamination from the sampling gear and sampling method was tested by taking a blank sample of MilliQ water. Blank sample was taken in similar way to the one-hour composite sampling, i.e., 2 l of MilliQ water was taken into 30 l bucket every 10 minutes for an hour, mixed, and transferred to the sample bottles. MilliQ water was transported to the field location in a Nalgene PP-container.

In the blank sample, DEHP (0,4 ug/l), DiBP (0,1 ug/l), zinc (0,0065 mg/l) and nitrogen (180 mg/l) were found. DEHP and DiBP were not found in most of the storm water samples, so contamination from the sampling gear seems unlikely. Similarly, concentrations of Zn and N in the storm water samples were notably higher than in the blank. Instead, contamination in the blank sample probably originated from the MilliQ equipment, as it includes both plastic and metal parts.

Table 2. Analysed substance groups, sample volumes and material of bottle.

Substance analysis package	Analysed from	Bottle volume/ml	Bottle material
Biocides	All samples, blank	500	glass
Phthalates	All samples, blank	1000	glass with Telfon cap
Elements	All samples, blank	100	plastic
Perfluorinated compounds	All samples, blank	500	plastic

Medium chain chlorinated paraffins (MCCPs)	All samples, blank	1000	plastic
Organophosphate flame retardants	All samples, blank	1000	plastic
Isothiazolinones	First sample from each location, blank	100	plastic
Biocidal transformation products	First sample from each location, blank	100	plastic
Quaternary ammonium compounds	First sample from each location, blank	500	plastic
Short chain chlorinated paraffins (SCCPs)	First sample from each location, blank	1000	plastic
Long chain chlorinated paraffins (LCCPs)	First sample from each location, blank	1000	plastic
Fluorotelomer alcohols	First sample from each location, blank	100	plastic
Solids, conductivity, total phosphorus and nitrogen, COD	All samples, blank	2 x 1000	plastic

Table 3. Temperature and rain conditions during sampling

Sample	**Method**	**Date**	**Av. temp. of previous 24 h/°C**	**Max. temp. of previous 24 h/°C**	**Min. temp. of previous 24 h/°C**	**Temp. during sampling/°C**	**Rain previous 24 h/mm**	**Rain during sampling (for composite samples)/mm**	**Comment**
IL1	1h composite	19.9.2023	12,70	16,4	9,1	16,2	2,25	4,16	Taken during rain
IL2	1h composite	31.10.2023	2,20	7,4	-0,1	6,2	9,44	0,96	Taken during rain
IL3	1h composite	22.11.2023	-2,30	3,6	-7,4	1,8	7,65	3,18	Taken during rain
PV1	storm water pond	20.9.2023	15,30	17,8	12,4	12,8	18,27	-	Taken after rain in following morning
PV2	storm water pond	11.10.2023	9,70	12,5	6	12,5	5,7	-	Taken after rain in following morning
PV3	storm water pond	23.11.2023	1,70	3,6	-6,2	3,2	19,86	-	Taken after rain in following morning
KA1	1h composite	4.10.2023	10,90	14	8,2	9,4	20,9	0	Taken after rain when there was still flow
KA1	1h composite	31.10.2023	1,80	7,3	-0,1	6,7	9,44	0	Taken after rain when there was still flow
KA3	1h composite	22.11.2023	-1,70	3,6	-7,4	2	14,05	2,79	Taken during rain

LK1	storm water pond	20.9.2023	15,30	17,8	12,4	12,9	18,27	-	Taken after rain in following morning
LK2	storm water pond	1.11.2023	3,40	7,4	0,6	0,6	15,1	-	Taken after rain in following morning

Results

PFAS

PFAS were found in every sample from all locations. Most commonly found compound was PFOA, which was found in all samples except one, followed by PFBA and PFOS.

Compared to the site with wooden house (IL) and control site (LK), the sum concentrations of PFAS were clearly higher in locations with non-wooden construction (PV, KA), where the mean of total sum of PFAS was more than double those in the other two sites. Although the means of total sum of PFAS were similar between the PV and KA sites, the profiles of the PFAS compounds differed between them. In PV site, PFCAs dominated over the PFSAs, while in KA, the mean sum of PFCAs and PFSAs were on similar level. This was due to high concentrations of PFOS compared to other PFAS found in KA site. In PV, the individual PFAS substances with the highest concentrations were PFHxA, PFPeA and PFBA.

The mean sum concentrations of PFAS were lowest in the wooden housing area IL. While concentrations in IL were on otherwise on similar level to the control site LK, in LK higher concentrations of PFOS and PFBS were found compared to IL.

Table 4. TUAS results for PFAS in stormwater samples

µg/l	**IL1**	**IL2**	**IL3**	**PV1**	**PV2**	**PV3**	**KA1**	**KA2**	**KA3**	**LK1**	**LK2**
PFBA	<0,0025	**0,002**	**0,0006**	**0,005**	**0,004**	**0,003**	**0,004**	**0,004**	<0,0005	**0,0009**	**0,002**
PFPeA	<0,0005	**0,001**	<0,0005	**0,009**	**0,008**	**0,004**	**0,008**	**0,003**	**0,003**	<0,0005	**0,0009**
PFHxA	<0,0025	**0,002**	<0,0005	**0,018**	**0,011**	**0,004**	**0,006**	**0,003**	**0,002**	<0,0005	**0,001**
PFHpA	**0,001**	<0,0005	<0,0005	**0,003**	**0,002**	**0,001**	**0,003**	**0,001**	**0,0008**	<0,0005	**0,0007**
PFOA	**0,0006**	**0,0006**	<0,0005	**0,003**	**0,002**	**0,001**	**0,006**	**0,002**	**0,002**	**0,0006**	**0,0009**
PFNA	<0,0005	<0,0005	<0,0005	**0,001**	**0,001**	**0,0005**	**0,0007**	**0,0006**	<0,0005	<0,0005	<0,0005
PFBS	<0,0005	<0,0005	<0,0005	**0,004**	**0,003**	**0,001**	**0,004**	**0,001**	<0,0005	<0,0005	**0,002**
PFHxS	<0,0005	<0,0005	<0,0005	**0,0007**	**0,0006**	<0,0005	**0,002**	**0,0008**	<0,0005	<0,0005	**0,001**
PFOS	<0,0005	**0,0005**	<0,0001	**0,001**	**0,002**	**0,001**	**0,022**	**0,006**	**0,009**	**0,0008**	**0,006**
6:2 FTS	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005	**0,001**	**0,001**	<0,0005	<0,0005	<0,0005
Sum total	0,0016	0,0061	0,0006	0,0447	0,0336	0,0155	0,0567	0,0224	0,0168	0,0023	0,0145
Sum PFCAs	0,0016	0,0056	0,0006	0,039	0,028	0,0135	0,0277	0,0136	0,0078	0,0015	0,0055
Sum PFSAs	0	0,0005	0	0,0057	0,0056	0,002	0,029	0,0088	0,009	0,0008	0,009

Elements

Metals were found in all samples. Generally, both concentrations and profiles of investigated metals were similar between all sites. Concentrations of Al were highest, followed by Zn and Cu. Ni, Pb and Cr were also commonly found. There were no differences in the metal concentrations of the built and unbuilt sites, as the concentrations of metals were similar between KA, PV and control site LK. In IL, however, metal concentrations were about double those of the other sites.
In addition to metals, boron was also analysed, as boron based biocidal products are commonly used in e.g. roofings. Boron was found from one sample per sampling location. Concentrations were highest in LK (control), concentration being double those found in other sampling locations.

Table 5. TUAS results for elements in stormwater samples

mg/l	**IL1**	**IL2**	**IL3**	**PV1**	**PV2**	**PV3**	**KA1**	**KA2**	**KA3**	**LK1**	**LK2**
Nickel	**0,0042**	**0,0098**	<0,0030	**0,0081**	**0,0056**	**0,0055**	**0,0037**	<0,0030	<0,0030	<0,0030	0,0036
Copper	**0,016**	**0,032**	**0,01**	**0,012**	**0,0069**	**0,0082**	**0,013**	**0,0096**	**0,006**	**0,0075**	**0,019**
Zinc	**0,036**	**0,12**	**0,014**	**0,048**	**0,031**	**0,024**	**0,02**	**0,048**	**0,028**	**0,024**	**0,044**
Aluminium	**1,5**	**6,2**	**0,61**	**1,4**	**0,86**	**2,6**	**1,7**	**1,1**	**1,4**	**0,26**	**2,8**
Lead	**0,0016**	**0,0039**	<0,0010	<0,0010	<0,0010	**0,0018**	**0,0015**	**0,001**	**0,0011**	<0,0010	0,0034
Chromium	0,0055	**0,013**	<0,0030	<0,0030	<0,0030	**0,0044**	**0,0031**	**0,0033**	**0,0033**	<0,0030	0,0057
Boron	<0,050	**0,08**	<0,050	**0,07**	<0,050	<0,050	<0,050	**0,071**	<0,050	<0,03	**0,16**

Biocides and their transformation products

Biocides were found in all sampling sites except for the control site in LKs showing clear contrast between the sites with and without buildings. Sum concentrations of biocides in focus (used in construction materials) were highest in IL, where most buildings are made with wood-based materials. Highest individual biocide concentration of 1.9 µg/l was found for diuron in IL, being more than 1 µg/l higher than concentrations of other biocides. In other sites, diuron was either found only in low concentrations or not found at all.

The biocides profile in focus differed between sites. While in both IL and PV propiconazole and tebuconazole were commonly found, in neither substance was found in the samples from KA. Instead, terbutryn was found in every sample from KA, while in IL it was found only in one sample, and not found in PV. Mecoprop, used commonly as herbicide but also reported in literature in construction materials, was found only in one site, PV. Out of the biocide transformation products, 2-hydroxyterbuthylazine, metabolite of terbuthylazine, was found in one sample from IL and from KA in low concentrations.

In addition to the biocides in focus (used in construction materials), we also found biocides used in other purposes, such as weed and pest control and repelling, including prosulfocarb, MCPA, diethyltoluamide and imidacloprid. Isothiazolinones and quaternary ammonium compounds were not found in any samples.

Table 6. TUAS results for biocides in stormwater samples

µg/l	**IL1**	**IL2**	**IL3**	**PV1**	**PV2**	**PV3**	**KA1**	**KA2**	**KA3**	**LK1**	**LK2**
Propiconazole	**0,17**	**0,12**	<0,010	**0,099**	**0,042**	**0,019**	<0,010	<0,010	<0,010	<0,010	<0,010
Tebuconazole	**0,13**	**0,078**	**0,11**	**0,072**	**0,023**	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010
Terbutryn	<0,050	<0,005	**0,006**	<0,005	<0,005	<0,005	**0,008**	**0,014**	**0,11**	<0,005	<0,005
Diuron	**0,035**	**0,55**	**1,9**	<0,010	<0,010	<0,010	<0,010	<0,010	**0,011**	<0,010	<0,010
Mecoprop	<0,010	<0,010	<0,010	0,01	<0,010	0,018	<0,010	<0,010	<0,010	<0,010	<0,010
MCPA	<0,010	<0,010	<0,010	0,081	0,015	0,049	<0,010	<0,010	<0,010	<0,010	<0,010
Imidacloprid	**0,034**	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010
BAM (2,6-dichlorobenzamide)	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	**0,017**	**0,013**	<0,010	<0,010	<0,010
Prosulfocarb	<0,010	<0,010	<0,010	<0,010	0,048	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010
2-hydroxy-terbuthylazine (terbutylazine m.)	**0,026**	-	-	<0,005	-	-	**0,021**	-	-	<0,005	-
N,N-dimethylsulfamide (dichlofluanid m.)	<0,02	-	-	<0,02	-	-	**0,052**	-	-	<0,02	-
Anthraquinone	<0,10	**0,018**	**0,013**	<0,010	<0,010	<0,010	<0,010	**0,014**	<0,010	<0,010	<0,010

Diethyltoluamide (DEET)	<0,050	**0,008**	**0,007**	<0,005	<0,005	<0,005	<0,005	**0,008**	<0,005	<0,005	<0,005
Fluroxypyr	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	**0,011**	<0,010	<0,010	<0,010

Phthalates

Against expectations, phthalates were found only in some samples. In total, only four individual phthalates were found: DMP, DEHP, DiBP and DBP. The concentrations of all compounds were in similar range and generally low. Highest phthalate concentration was found for DMP in Illoinen. Phthalates were found also in LK (control), possibly originating in the plastic stormwater piping, from which the water goes through before entering the pond. Similarly, in IL and KA plastic stormwater pipes are used in the area. In PV, phthalates were not found.

Table 7. TUAS results of phthalates in stormwater samples

µg/l	**IL1**	**IL2**	**IL3**	**PV1**	**PV2**	**PV3**	**KA1**	**KA2**	**KA3**	**LK1**	**LK2**
Dimethyl phthalate (DMP)	**0,4**	**0,2**	<0,1	<0,1	<0,2	<0,1	<0,1	<0,1	<0,2	<0,1	<0,1
Diethylhexyl phthalate (DEHP)	<0,1	**0,1**	<0,1	<0,1	<0,2	<0,1	<0,1	<0,1	**0,2**	0,1	<0,1
Diisobutyl phthalate (DiBP)	<0,1	<0,1	<0,2	<0,1	<0,2	<0,2	<0,1	**0,2**	**0,2**	<0,1	0,1
Dibutyl phthalate (DBP)	<0,1	<0,1	<0,1	<0,1	<0,2	<0,1	<0,1	**0,1**	<0,2	<0,1	<0,1

Organophosphate flame retardants

Out of the analysed organophosphate flame retardants, only compound found was tris(2-chloro-1-methylethyl) phosphate (TCPP). TCPP was found in at least one sample in each sampling site, also in LV (control). Highest TCPP concentration was found in KA, where TCPP was found in one sample with concentrations of 0.52 µg/l.

Table 8. TUAS results for organophosphate flame retardants in stormwater samples

µg/l	**IL1**	**IL2**	**IL3**	**PV1**	**PV2**	**PV3**	**KA1**	**KA2**	**KA3**	**LK1**	**LK2**
TCPP	**0,2**	**0,23**	<0.1	**0,13**	<0.1	<0.1	<0.1	**0,52**	<0.1	**0,12**	**0,12**

Chlorinated paraffins

Concentrations of chlorinated paraffins were below the laboratory reporting limit in all samples.

Interpretation and discussion of results

Metals

Lack of differences in the metal concentration between sampling sites, including the control site, indicates that the main sources of the studied metals is something other than building materials, such as emissions from traffics. The result was unexpected, as the study site have mainly metal roofs and rain gutters, which have been shown to leach metals into rainwater (Müller et al. 2019).

Biocides

The area with mainly wooden building had higher concentrations of biocides compared to the areas with tile and concrete buildings. No biocides were found in the LK control area, strongly indicating that traffic and air deposition is not a source of the investigated biocides. The result supports the hypothesis that wooden construction is a significant source of biocides.

Highest biocide concentrations were found for diuron in IL, where the mean concentration (xx) exceeded the substance's surface water AA-EQS of 0,2 µg/l, and the highest concentration (1,9 µg/l) also exceeded the MAC-EQS of 1,8 µg/l given in the Water Framework Directive (WFD; Directive 2000/60/EC). The EQSs for diuron have been proposed to be lowered in the updated WFD, the new AA-EQS being 0,049 µg/l for inland surface waters, 0,0049 µg/l for other surface waters, and new MAC-EQS being 0,27 µg/l and 0,054 µg/l, respectively. Two samples for IL exceeded the proposed lower MAC-EQSs. The results shows that construction materials can leach biocides in environmentally relevant concentrations, potentially posing harm to the ecosystem health. Diuron is not currently approved for use as wood preservative, but it is used as preservative in e.g. paints and construction materials (product categories 7 and 10, ECHA).

After diuron, the highest biocide concentrations were found for propiconazole and tebuconazole, highest concentrations in IL being 0,17 and 0,13 µg/l, respectively. Both substances were also found in PV, but concentrations were lower than in IL. Currently, propiconazole has been approved in EU for use as preservative of films, wood and fibre, leather, rubber, and polymerised materials (product categories 7, 8 and 9). Tebuconazole has been approved for use as preservative of films, wood, and construction materials (product categories 7, 8 and 10). No EQSs exist for either substance.

Mecoprop and 2-hydroxyterbutylazine (degradation product of terbutylazine) were also found in some of the samples. While use of neither substance is currently allowed for use as biocide for construction materials in EU, they might be present in some materials and leach into the environment (Paijens et al. 2020).

PFAS

Opposite to the result with the biocides, the concentrations of PFAS were higher in the areas with mainly non-wooden buildings, indicating that the wooden construction contributes less PFAS into the environment compared to other materials. PFAS were also found in the control areas, showing that PFAS may originate also from traffic or air deposition. However, the PFAS concentrations in the areas with buildings were higher than in the control area, indicating that building materials or other urban sources than traffic contributes to the environmental load of PFAS. The concentrations of PFAS were mostly similar to what has been found in Finnish urban storm waters previously (Vahtera et al. 2022).

The profile of the found PFAS substances varied between the study sites, suggesting differences in the source materials between the different sites. In KA and PV, the concentration profiles of PFAS did not show much variation between the samples from the same site, while in IL the profiles varied quite a lot. However, the concentrations in IL were also low. The profile of PFAS substances seemed similar between KA and control site LK. This might indicate that the source for these sites might be traffic, as these locations are also most heavily trafficked among the sampling sites. In both locations, PFOS was found in higher concentrations than the other individual PFAS substances. While use of PFOS is currently restricted, there are several precursor PFAS which can degrade into PFOS in the environment. In PV, PFPeA and PFHxA had the highest proportion of the total load of analysed PFAS.

Phthalates

Opposite to the expectations, phthalates were found only in few samples and in low concentrations. Sampling in the first NonHazCity project found phthalates in higher frequency, being present in 82 % of the stormwater samples (NonHazCity). Based on the result, it might be that phthalates have been replaces by other non-phthalate plasticizers in the plastic building materials currently in use. Use of

traditional phthalates has decreased in the last decades, while use of alternative plasticizers, such as DINCH (Bui et al. 2016).

Organophosphate flame retardants

Only OPFR found was TCPP. This compound is used as a flame retardant and plasticizer, and it can be found in e.g. insulation materials and plastics. OPFRs such as TCPP have been used to replace brominated flame retardants such as polybrominated diphenyl ethers (PBDEs), which are persistent, bioaccumulative and toxic. However, TCPP is suspected to be carcinogenic, toxic to reproduction and neurotoxic (Wang et al. 2020), making this a possibly regrettable substitution. The finding of this substance in all four sampling sites, also the control site, suggests that this contaminant is widespread in the environment. TCPP is currently regulated in toys in the EU, but otherwise unregulated despite the suspected adverse effects.

Possible sources of error

Although the substances targeted in the screening were substances that are known to be used in building materials e.g. based on studies and databases, contribution from other sources, such as soil, air deposition and traffic, cannot be ruled out. Also, we cannot draw a direct links to the building materials used in the study areas, as no material samples were analysed.

Conclusions

The results show substances with adverse health and environmental effects can be released from building materials into stormwaters. These substances can eventually end up in waterbodies, such as the Baltic Sea. Some substances, such as PFAS, are persistent, contaminating the environment possibly for a very long time after their initial release. While some substances might degrade faster, they can still have a harmful effect on the environmental health. For example, many biocides found in the samples are toxic to aquatic organisms.

The concentrations and profiles of investigated substances in the samples differed between sampling sites with different building materials or sites with and without buildings. Biocides used as wood and in-can preservatives were found in higher concentrations from the location with mainly wooden buildings, showing that wooden construction can be a significant source of these substances. On the contrary, the concentrations and number of PFAS found in the wooden house area was lower than in the other locations. The results show that the material choices made affect also the environment through difference in the burden of hazardous substances leached from them along run-off.

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Annexes

Table A1. Analysed PFAS, their CAS numbers and laboratory reporting limits (µg/l)

Substance	**CAS**	**RL**
Perfluoroundecanoic acid (PFUnA)	2058-94-8	0,0005
Perfluorotetradecane acid (PFTA)	376-06-7	0,0005
Perfluoropentane acid (PFPeA)	2706-90-3	0,0005
Perfluorononanoic acid (PFNA)	375-95-1	0,0005
Perfluoroheptane sulphonate (PFHpS)	375-92-8	0,0005
Perfluorheptanoic acid (PFHpA)	375-85-9	0,0005
Perfluorohexane sulfonate (PFHxS)	355-46-4	0,0005

Perfluorohexanoic acid (PFHxA)	307-24-4	0,0005
Perfluorododecane acid (PFDoA)	307-55-1	0,0005
Perfluordecanoic acid (PFDA)	335-76-2	0,0005
6:2 Fluorotelomer sulfonate (6:2 FTS) (H4PFOS)	27619-97-2	0,0005
1H,1H,2H,2H-Perfluorohexanesulfonic acid (4:2 FTS)	757124-72-4	0,0005
Perfluorobutanoic acid (PFBA)	375-22-4	0,0005
Perfluoropentanesulfonic acid (PFPeS)	2706-91-4	0,0005
Perfluorooctanoic acid (PFOA)	335-67-1	0,0005
Perfluorooctadecanic acid (PFODA)	16517-11-6	0,0005
Perfluorononanesulfonic acid (PFNS)	68259-12-1	0,0005
Perfluorohexadecanic acid (PFHxDA)	67905-19-5	0,0005
Perfluorbutansulfonate (PFBS)	375-73-5	0,0005
Henicosafluorodecanesulphonic acid	335-77-3	0,0005
8:2 Fluorotelomer sulfonate (FTS)	39108-34-4	0,0005
Perfluorooctane sulphonic acid (PFOS)	1763-23-1	0,0001
Perfluorotridecanoic acid (PFTrDA)	72629-94-8	0,0005
Perfluorododecanesulfonic acid (PFDoS)	79780-39-5	0,0005
2H-Perfluoro-2-decenoic acid (8:2 FTUCA)	70887-84-2	0,0005
perfluoro-n-tridecane sulfonic acid (PFTriDS)	791563-89-8	0,0005
Perfluoroundecane sulfonic acid	749786-16-1	0,0005
Perfluorooctane-sulfonamide (PFOSA)	754-91-6	0,0005
Perfluoro-1-hexanesulfonamide (FHxSA)	41997-13-1	0,0005
Perfluorobutane-sulphonamide (PFBSA)	30334-69-1	0,0005
Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	113507-82-7	0,0005
Nonafluoro-3,6-dioxaheptanoic acid (NFDHA/3,6-OPFHpA)	151772-58-6	0,0005
Perfluoro-4-methoxybutanoic acid (PFMBA/PF5OHxA)	863090-89-5	0,0005
Perfluoro-3-methoxypropanoic acid (PFMPA/PF4OPeA)	377-73-1	0,0005

Bis(1H,1H,2H,2H-perfluorooctyl)phosphate (6:2 DiPaP)	57677-95-9	0,0005
9H-Perfluorononanoic acid (9H-PFNA)	76-21-1	0,0005
Perfluoro-(2,5,8-trimethyl-3,6,9-trioxadodecanoic)acid (HFPO-TeA)	65294-16-8	0,0005
5H-Perfluoropentanoic acid (5H-PFPeA)	376-72-7	0,0005
HFPO-TA	13252-14-7	0,0005
8:2 Fluorotelomer phosphate diester (8:2 diPAP)	678-41-1	0,0005
11Cl-PF3OUdS	763051-92-9	0,0005
Perfluor-1-octanesulphonamide-EtAce (PFOSAA), sum of linear and branched	2991-50-6	0,002
N-methylperfluorooctanesulfonamidoacetic acid (MeFOSAA), sum of linear and branched	2355-31-9	0,002
Perfluorooctanesulfonamidoacetic acid	2806-24-8	0,005
9Cl-PF3ONS	756426-58-1	0,0005
P37DMOA (Perfluoro-3,7-dimethyloctanoic acid)	172155-07-6	0,0005
Perfluoro-4-ethylcyclohexanesulfonate	335-24-0	0,0005
ADONA	919005-14-4	0,0005
7H-Dodecafluoroheptanoic acid (HPFHpA)	1546-95-8	0,0005
HFPO-DA (GenX)	13252-13-6	0,0005

Table A2. Analysed biocides, their CAS numbers and laboratory reporting limits (µg/l)

Substance	**CAS**	**RL**
2,4-Methoxychlor	30667-99-3	0,005
Quintozene	82-68-8	0,005
Chlorothalonil	1897-45-6	0,005
Chloroneb	2675-77-6	0,005
Chlormephos	24934-91-6	0,005
Chlorfenson	80-33-1	0,005
Chlordecon	143-50-0	0,005
Chlordane, oxy-	27304-13-8	0,005
Chlordane, trans-	5103-74-2	0,005
Chlordane, cis-	5103-71-9	0,005
Heptachlor epoxide, trans-	28044-83-9	0,005
Isodrin	465-73-6	0,0025
Heptachlor epoxide, cis-	1024-57-3	0,005
Heptachlor	76-44-8	0,005
Chlorbenside	103-17-3	0,005
Captan	133-06-2	0,02
Hexachlorobutadiene	87-68-3	0,005

Hexachlorobenzene (HCB)	118-74-1	0,01
Lindane (gamma-HCH)	58-89-9	0,001
HCH, beta-	319-85-7	0,001
HCH, alpha-	319-84-6	0,001
Flucythrinate	70124-77-5	0,005
Fenvalerate	51630-58-1	0,05
Perthane	72-56-0	0,005
Phenothrin	26002-80-2	0,02
Esfenvalerate	66230-04-4	0,05
Endrin	72-20-8	0,0025
Endrin ketone	53494-70-5	0,005
Endrin-aldehyde	7421-93-4	0,005
Endosulfan sulphate	1031-07-8	0,005
Endosulfan, beta-	33213-65-9	0,0025
Endosulfan, alpha-	959-98-8	0,0025
Dicofol (Kelthane)	115-32-2	0,001
Dichlobenil	1194-65-6	0,005
Dieldrin	60-57-1	0,0025
Deltamethrin	52918-63-5	0,01
Diethyltoluamide	134-62-3	0,005
4,4'-DDT	50-29-3	0,001
Allethrin	584-79-2	0,1
Aldrin	309-00-2	0,0025
Acrinathrin	101007-06-1	0,005
4-Chloro-3-Methylphenol	59-50-7	0,005
4-Chloro-2-Methylphenol	1570-64-5	0,005
2,4-Dichlorophenol	120-83-2	0,005
Trans-Permethrin	61949-77-7	0,005
cis-Permethrin	61949-76-6	0,005
HCH, delta-	319-86-8	0,001
Ethofumesat-2-keto		0,01
Ethofumesate	26225-79-6	0,005
Chloropropylate	5836-10-2	0,005
Pyrimethanil	53112-28-0	0,005
Triclosan-Methyl	4640-01-1	0,005
Vinclozolin	50471-44-8	0,005
Triclosan	3380-34-5	0,005
Trifluralin	1582-09-8	0,005
Transfluthrin	118712-89-3	0,005
Tetramethrin	7696-12-0	0,005
Tetradifon	116-29-0	0,005
Terbutryn	886-50-0	0,005
Tecnazene	117-18-0	0,005
Tefluthrin	79538-32-2	0,005
Cyprodinil	121552-61-2	0,005
Cypermethrin (sum of isomers)	52315-07-8	0,005

Prochloraz	67747-09-5	0,2
Prometryn	7287-19-6	0,005
Cyhalothrin, lambda-(incl. Cyhalothrin, gamma-)	91465-08-6	0,01
Irgarol	28159-98-0	0,002
Cyfluthrin beta	68359-37-5	0,005
Pirimicarb	23103-98-2	0,005
Piperonyl butoxide	51-03-6	0,005
Pentachlorobenzene	608-93-5	0,005
Pentachloroanisole	1825-21-4	0,005
Oxadiazon	19666-30-9	0,005
S-Metolachlor	87392-12-9	0,005
Nonachlor, trans-	39765-80-5	0,005
Nonachlor, cis-	5103-73-1	0,005
Mirex	2385-85-5	0,005
2,4´-DDT	789-02-6	0,001
DDM	101-76-8	0,005
4,4´-DDD	72-54-8	0,001
4,4´-DDE	72-55-9	0,001
2,4'-DDD	53-19-0	0,001
DDE, o,p-	3424-82-6	0,001
Bifenthrin	82657-04-3	0,005
Bifenox	42576-02-3	0,01
Bifenazate	149877-41-8	0,01
Anthraquinone	84-65-1	0,01
Epoxiconazol	106325-08-0	0,005
4,4´-DDMU	1022-22-6	0,005
Methiocarb	2032-65-7	0,002
Mepanipyrim	110235-47-7	0,005
Methoxychlor, p,p'	72-43-5	0,005
Methoxychlor-olefin, p,p’	2132-70-9	0,005
BHC (Benzahex)	608-73-1	0,004
Permethrin (sum of isomers)	52645-53-1	0,005
Fluvalinate-tau	102851-06-9	0,05
β-Cyfluthrin	1820573-27-0	0,005
Fluazifop-P-butyl	79241-46-6	0,01
Florasulam	145701-23-1	0,01
Flonicamid	158062-67-0	0,01
Flamprop-isopropyl	52756-22-6	0,01
Fenhexamid	126833-17-8	0,01
Fenamidone	161326-34-7	0,01
Famoxadone	131807-57-3	0,01
Diuron	330-54-1	0,01
Dinoterb	1420-07-1	0,01
Dinoseb	88-85-7	0,01
Dimethomorph	110488-70-5	0,01
Diflufenican	83164-33-4	0,01

Dimethoate	60-51-5	0,01
Dichlofluanid	1085-98-9	0,01
Difenoconazole	119446-68-3	0,01
Atrazin, desisopropyl-	1007-28-9	0,01
Atrazine-desethyl-desisopropyl	3397-62-4	0,01
Atrazin, desethyl-	6190-65-4	0,01
Buprofezin	69327-76-0	0,01
2,6-Dichlorobenzamide	2008-58-4	0,01
Bentazone	25057-89-0	0,01
Boscalid	188425-85-6	0,01
Bromacil	314-40-9	0,01
Bromoxynil	1689-84-5	0,01
Amidosulfuron	120923-37-7	0,01
Alachlor	15972-60-8	0,01
Acetamiprid	135410-20-7	0,01
Thiamethoxam	153719-23-4	0,01
Thiacloprid	111988-49-9	0,01
Terbuthylazine, desethyl-	30125-63-4	0,01
Terbacil	5902-51-2	0,01
Tepraloxydim	149979-41-9	0,01
Teflubenzuron	83121-18-0	0,01
Tebuconazole	107534-96-3	0,01
Sulfotep	3689-24-5	0,01
Sulfosulfuron	141776-32-1	0,01
Cyazofamid	120116-88-3	0,01
Cymoxanil	57966-95-7	0,01
Propazine	139-40-2	0,01
Azinphos-methyl	86-50-0	0,01
Paclobutrazol	76738-62-0	0,01
Omethoate	1113-02-6	0,01
Nicosulfuron	111991-09-4	0,01
Napropamide	15299-99-7	0,01
Mevinphos	7786-34-7	0,01
Metsulfuron-methyl	74223-64-6	0,01
Metribuzin-desamino	35045-02-4	0,01
Metribuzin	21087-64-9	0,01
Metoxuron	19937-59-8	0,01
Methabenzthiazuron	18691-97-9	0,01
Metconazole	125116-23-6	0,01
Metazachlor	67129-08-2	0,01
Metamitron-Desamino	36993-94-9	0,01
Metamitron	41394-05-2	0,01
Metalaxyl	57837-19-1	0,01
MCPA	94-74-6	0,01
Mandipropamid (any ratio of constituent isomers)	374726-62-2	0,01
Malathion	121-75-5	0,01

Linuron	330-55-2	0,01
Quinmerac	90717-03-6	0,01
Quinoxyfen	124495-18-7	0,01
Clothianidin	210880-92-5	0,01
Chlorsulfuron	64902-72-3	0,01
Chlorpyrifos	2921-88-2	0,01
Chlorpropham	101-21-3	0,01
Chloroxuron	1982-47-4	0,01
Chloridazone	1698-60-8	0,01
Chlorfenvinphos	470-90-6	0,01
Kresoxim-methyl	143390-89-0	0,01
Quinoclamine	2797-51-5	0,01
Isoxaben	82558-50-7	0,01
Isoproturon	34123-59-6	0,01
Iprodione	36734-19-7	0,01
Hexythiazox (any ratio of constituent isomers)	78587-05-0	0,01
Hexazinone	51235-04-2	0,01
Furathiocarb	65907-30-4	0,01
Aclonifen	74070-46-5	0,01
Pronamide	23950-58-5	0,005
Triallate	2303-17-5	0,005
Terbuthylazine	5915-41-3	0,005
Cyanazine	21725-46-2	0,005
Carbofuran	1563-66-2	0,005
Azoxystrobin	131860-33-8	0,005
Atrazine	1912-24-9	0,005
Triasulfuron	82097-50-5	0,001
Dichlorvos	62-73-7	0,0005
Quizalofop-P-ethyl	100646-51-3	0,01
Dichloroctylisothiazolinon	64359-81-5	0,005
Fenoxaprop-p-ethyl	71283-80-2	0,01
Diflubenzuron	35367-38-5	0,01
Metribuzin-desaminodiketo	52236-30-3	0,01
2,4-D	94-75-7	0,01
2,4,5-T	93-76-5	0,01
Bronopol	52-51-7	0,2
Bitertanol	55179-31-2	0,1
Hymexazol	10004-44-1	0,1
Dalapon	75-99-0	0,1
Metribuzin-diketo	56507-37-0	0,05
MCPB	94-81-5	0,05
Imidacloprid	138261-41-3	0,01
Clopyralid	1702-17-6	0,05
Aminopyralid	150114-71-9	0,05
Picloram	1918-02-1	0,02
Cyproconazole	94361-06-5	0,01

Pyrethrin I	121-21-1	0,01
Pyridate	55512-33-9	0,01
Pyroxsulam	422556-08-9	0,01
Rimsulfuron	122931-48-0	0,01
Simazine	122-34-9	0,01
Spirodiclofen	148477-71-8	0,01
Pyraclostrobin	175013-18-0	0,01
Prosulfocarb	52888-80-9	0,01
Propoxycarbazone	145026-81-9	0,01
Propiconazole (sum of isomers)	60207-90-1	0,01
Penconazole (sum of constituent isomers)	66246-88-6	0,01
Pendimethalin	40487-42-1	0,01
Picoxystrobin	117428-22-5	0,01
Pinoxaden	243973-20-8	0,01
Primisulfuron-methyl	86209-51-0	0,01
Propachlor	1918-16-7	0,01
Propaquizafop	111479-05-1	0,01
Flutolanil	66332-96-5	0,01
Fluroxypyr	69377-81-7	0,01
Fludioxonil	131341-86-1	0,01
Carfentrazone-ethyl	128639-02-1	0,01
Fluazinam	79622-59-6	0,01
Fluopicolid	239110-15-7	0,01
Fenpyrazamine	473798-59-3	0,01
Cycloxydim	101205-02-1	0,05
Chloridazon, methyl-desphenyl-	17254-80-7	0,02
Chloridazon-desphenyl	6339-19-1	0,2
Metalaxyl Metabolite CGA 62826	87764-37-2	0,02
Metalaxyl CGA 108906	104390-56-9	0,01
Amisulbrom	348635-87-0	0,01
Benzovindiflupyr	1072957-71-1	0,01
Bixafen	581809-46-3	0,01
2-(4-chlorophenoxy)propionic acid	3307-39-9	0,01
Imazamox	114311-32-9	0,01
Phenmedipham	13684-63-4	0,01
Desmedipham	13684-56-5	0,01
Mesosulfuron-methyl	208465-21-8	0,01
Indoxacarb (sum, R+S isomers)	144171-61-9	0,02
Halauxifen-methyl	943831-98-9	0,01
Fuberidazole	3878-19-1	0,01
Foramsulfuron	173159-57-4	0,01
Fluxapyroxad	907204-31-3	0,01
Fluopyram	658066-35-4	0,01
Zoxamide	156052-68-5	0,02
Parathion-methyl	298-00-0	0,02
Parathion-ethyl	56-38-2	0,02

Fenitrothion	122-14-5	0,02
Dicamba	1918-00-9	0,02
Mecoprop + Mecoprop-P		0,01
Dichlorprop + Dichlorprop-P		0,01
Lenacil	2164-08-1	0,01
Chinomethionate	2439-01-2	0,01
Tritosulfuron	142469-14-5	0,01
Triticonazole	131983-72-7	0,01
Trinexapac-ethyl	95266-40-3	0,01
Trichlorfon	52-68-6	0,01
Triflusulfuron-methyl	126535-15-7	0,01
Trifloxystrobin	141517-21-7	0,01
Triadimenol	55219-65-3	0,01
Triadimefon	43121-43-3	0,01
Tralkoxydim	87820-88-0	0,01
Tolylfluanid	731-27-1	0,01
Tolclofos-methyl	57018-04-9	0,01
Thifensulfuron methyl	79277-27-3	0,01
Iodosulfuron-methyl Sodium	144550-36-7	0,01
Thiencarbazone-methyl	317815-83-1	0,02
Spirotetramat	203313-25-1	0,01
Sedaxane	874967-67-6	0,01
Pyriofenone	688046-61-9	0,01
Pymetrozine	123312-89-0	0,01
Proquinazid	189278-12-4	0,01
Prohexadione	88805-35-0	0,1
Penflufen	494793-67-8	0,01
Metaflumizone (sum of E- and Z- isomers)	139968-49-3	0,05

Table A3. Analysed Quaternary ammonium compounds, their CAS numbers and laboratory reporting limits (mg/l)

Substance	**CAS**	**RL**
Benzethonium Chloride	121-54-0	0,01
BAC C10 - Benzyldimethyldecylammonium chloride	965-32-2	0,01
Cetalkonium chloride (BAC-C16)	122-18-9	0,01
Miristalkonium chloride (BAC-C14)	139-08-2	0,01
Benzyldimethyldodecylammonium chloride (BAC-C12)	139-07-1	0,01
DDAC C8 - Dioctyldimetylammonium chloride	5538-94-3	0,01
DDAC C12 - Didodecyl dimethyl ammonium chloride	3401-74-9	0,01
BAC C18 - Benzyldimethyloctadecylammonium	122-19-0	0,01
DDAC C10 - Didecyldimethylammoniumchloride	7173-51-5	0,01
Benzyldimethyloctylammonium chloride (BAC C8)	959-55-7	0,01

Table A4. Analysed biocide transformation products, their CAS numbers and laboratory reporting limits (µg/l)

Substance	**CAS**	**RL**
Flumioxazin 482-HA		0,01
Chlorothalonil-4-hydroxy	28343-61-5	0,01
Metolachlor CGA 357704	1217465-10-5	0,02
Thiamethoxam CGA 355190		0,002
Metolachlor ethanesulfonic acid	171118-09-5	0,02
Metazachlor BH 479-9		0,005
Metazachlor ethanesulfonic acid	172960-62-2	0,02
Chloridazon, methyl-desphenyl-	17254-80-7	0,005
Chloridazon-desphenyl	6339-19-1	0,02
Tritosulfuron 635M02	1869-24-5	0,05
Tritosulfuron 635M01		0,02
1-(4-Isopropylphenyl)-urea	56046-17-4	0,05
iso-Chloridazon	162354-96-3	0,005
2-Hydroxy-terbuthylazine	66753-07-9	0,005
Simazine, 2-hydroxy-	2599-11-3	0,005
Terbuthylazine-Desethyl-2-hydroxy	66753-06-8	0,005
Atrazine, 2-hydroxy-	2163-68-0	0,005
Flufenacet oxalamic acid	201668-31-7	0,02
Flufenacet ethane sulfonic acid		0,02
Dimethenamid oxalamic acid	380412-59-9	0,02
Dimethenamid ethane sulfonic acid		0,02
2,6-Dichlorobenzamide	2008-58-4	0,002
Desmethyl-isoproturon	34123-57-4	0,01
Desmethyl-chlortoluron	22175-22-0	0,02
Atrazin, desisopropyl-	1007-28-9	0,005
Butachlor oxalamic acid		0,02
Butachlor ethane sulfonic acid		0,01
Bentazone-8-hydroxy	60374-43-8	0,02
2-amino-N-(isopropyl)benzamide	30391-89-0	0,002
Alachlor oxalamic acid	171262-17-2	0,02
Alachlor ESA	142363-53-9	0,02
Acetochlor SAA		0,02
Acetochlor oxalamic acid	194992-44-4	0,02
Acetochlor ESA	187022-11-3	0,02
4-Isopropylaniline	99-88-7	0,05
3,4-dichloroaniline	95-76-1	0,05
N-(3,4-Dichlorophenyl)urea	2327-02-8	0,05
1-(3,4-DICHLOROPHENYL)-3-METHYL UREA	3567-62-2	0,05
Atrazine-desethyl-desisopropyl	3397-62-4	0,02
Tritosulfuron	142469-14-5	0,002
Propachlor	1918-16-7	0,01
Dimethachlor	50563-36-5	0,005

Dimethachlor-metabolite CGA 354742	1231819-32-1	0,02
Trifloxystrobin metabolite CGA321113	252913-85-2	0,01
Metalaxyl CGA 108906	104390-56-9	0,02
Quinmerac BH518-5		0,02
Metazachlor oxanilic acid		0,02
Propazine 2-hydroxy	7374-53-0	0,01
Propachlor oxalamic acid	70628-36-3	0,02
Propachlor ethane sulfonic acid		0,02
Picoxystrobin M8		0,002
Picoxystrobin M3		0,005
Dimethachlor SYN 530561		0,02
Dimethachlor SYN 528702		0,005
Chlorthalonil M 5	142733-37-7	0,02
Chlorthalonil M 12		0,01
Azoxystrobin R234886	1185255-09-7	0,01
Metolachlor NOA 413173		0,02
Pethoxamid MET-42		0,005
Dimethyltolylsulfamid (DMST)	66840-71-9	0,02
N,N-Dimethylsulfamide	3984-14-3	0,02
Metalaxyl CGA 62826	87764-37-2	0,02
Metolachlor OA	152019-73-3	0,02
Dimethachlor-metabolite CGA 50266	1086384-49-7	0,02
Metolachlor CGA 50720	152019-74-4	0,01
Metolachlor CGA 50267	82508-03-0	0,02
Metolachlor CGA 37735	97055-05-5	0,02
Dimethachlor CGA 373464		0,005
Dimethachlor CGA 369873		0,01
Metolachlor CGA 368208		0,005
Metazachlor BH 479-12		0,02
Thiamethoxam CGA 353968	634192-72-6	0,02
Metolachlor Morpholinone	120375-14-6	0,01
metazochlor M11	1242182-77-9	0,002
Irgarol M1	30125-65-6	0,01

Table A5. Analysed phthalates, their CAS numbers and laboratory reporting limits (µg/l)

Substance	**CAS**	**RL**
Di-isobutyl phthalate (DiBP)	84-69-5	0,1
Dipentylphtalate	131-18-0	0,1
Phthalic acid, bis-iso-pentyl ester (DiPP)	605-50-5	0,1
Dinonyl phthalate (DNP)	84-76-4	0,1
Di-heptyl phthalate	3648-21-3	0,1
Phthalic acid, bis-hexyl ester (DnHP)	84-75-3	0,1
Diethylhexylphthalate (DEHP)	117-81-7	0,1
Diethylhexylphthalate (DEHP)	117-81-7	0,1
Diethyl phthalate (DEP)	84-66-2	0,1

Di-cyclohexyl phthalate	84-61-7	0,1
Di-n-octylphthalate (DNOP)	117-84-0	0,1
Diisononyl phthalate (DINP)	68515-48-0	5
Dimethylphtalate	131-11-3	0,1
Benzyl butyl phthalate (BBP)	85-68-7	0,1
Dibutyl phthalate (DBP)	84-74-2	0,1
Dipropylphthalate	131-16-8	0,1
Diisodecyl phthalate (DIDP)	68515-49-1	5
Diisopropyl phthalate (DiisopropP)	605-45-8	0,1

Table A6. Analysed elements, their CAS numbers and laboratory reporting limits (mg/l)

Substance	**CAS**	**RL**
Aluminium	7429-90-5	0,05
Boron (B)	7440-42-8	0,03
Cadmium (Cd)	7440-43-9	0,0001
Chromium (Cr)	7440-47-3	0,003
Copper (Cu)	7440-50-8	0,003
Lead (Pb)	7439-92-1	0,001
Nickel (Ni)	7440-02-0	0,003
Tin (Sn)	7440-31-5	0,001
Zinc (Zn)	7440-66-6	0,005

Table A7. Analysed isothiazolinones, their CAS numbers and laboratory reporting limits (µg/l)

Substance	**CAS**	**RL**
MIT	2682-20-4	10
CIT	26172-55-4	10
BIT	2634-33-5	10
OIT	26530-20-1	10
DCOIT	64359-81-5	10
BBIT	4299-07-04	10
MBIT	2527-66-4	10

Table A8. Analysed chlorinated paraffins and their laboratory reporting limits (µg/l)

Substance	**RL**
chlorinated paraffins (C10-C13)	1
chlorinated paraffins (C14-C17)	1
total chlorinated paraffins (C10-C20)	1

Table A9. Analysed organophosphate flame retardants, their CAS numbers and laboratory reporting limits (µg/l)

Substance	**CAS**	**RL**
TCEP	115-96-8	0,1
TCPP	13674-84-5	0,1

TCDPP	13674-87-8	0,1
tricresyl phosphate (mixed isomers)	1330-78-5	0,5
TBEP	78-51-3	0,5
triphenylphosphate	115-86-6	0,1
tris(2-ethylhexyl) phosphate	78-42-2	0,5
2-ethylhexyl diphenyl phosphate (Octicizer)	1241-94-7	0,1
tributylphosphate	126-73-8	0,1
triisobutylphosphate	126-71-6	0,1
triethylphosphate	78-40-0	0,1
diphenylkresylphosphate		0,5
phenyldikresylphosphate		0,5
tri-o-kresylphosphate	78-30-8	0,1
trimethylphosphate	512-56-1	0,1

Table A10. Analysed fluorotelomer alcohols, their CAS numbers and laboratory reporting limits (µg/l)

Substance	**CAS**	**RL**
6:2 FTOH (Fluorotelomer alcohol)	647-42-7	0,050
8:2 FTOH (Fluorotelomer alcohol)	678-39-7	0,010
10:2 FTOH (Fluorotelomer alcohol)	865-86-1	0,002

Occurrence of substances of concern in Baltic Sea Region buildings, construction materials and sites

Storm water & Construction material

City of Helsinki

Appendix 2

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NHC3 GoA2.1. Deliverable D.2.1

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Contents

Abstract

The scope of the construction material and stormwater sampling in Helsinki was to compare the analysis results of the most commonly used hazardous chemicals and substances in pure exterior construction materials, in material samples taken from the construction sites and in stormwater. Based on the analysis results it was estimated which construction materials and hazardous chemicals are potential pollutants of stormwater and environment.

Material sampling in Helsinki was implemented by actual field sampling and by analyzing construction materials purchased from the material manufactures or hardware stores. Materials for laboratory analysis were selected based on the original material lists used in two residential construction sites (Postipuisto area and Kuninkaantammi area) built by City of Helsinki Housing Production. Material samples included facade brick and mortar, fiber cement board, bitumen membrane used for roofing, wooden terrace and facade boardings, concrete, coating cement, paints and flame retardants for wood and concrete surfaces and protective agents for stone and concrete surfaces. Besides the material samples five stormwater samples were collected from Kuninkaantammi stormwater catchment area.

Chemicals analysed from material and stormwater samples included biocides and transformation products of biocides, phthalates, metals (aluminum, cadmium, chromium, copper, lead, nickel, zinc and tin), isothiazolinones, PFAS (perfluoro and polyfluoroalkyl substances), short-chain and medium-chain chlorinated paraffins and organophosphate flame retardants.

Based on the study biocides, chlorinated paraffins, metals, phosphorus flame retardants and phthalates are not used in construction materials in such a scale that they pose a significant risk to the environment and surface waters.

The potential pollutants based on the concentrations found in pure construction materials are isothiazolinones used as biocides in exterior paints, flame retardants and surface treatment agents for stone and concrete. Though high concentrations of isothiazolinones were detected in pure agents, the concentrations in material samples and in stormwater were considerably lower. In fact, in stormwater the concentrations were below laboratory's reporting limit. Isothiazolinones are soluble to water, and they present high volatility. They are also sensitive to thermal and pH conditions leading to transformation/degradation of them. On what scale these characteristics have effect on the zero result in stormwater is an open question and an object of interest.

Potential pollutants of the environment and surface waters are also PFAS compounds. They were detected only in one material sample, but widely in stormwater, which proves the fact – PFAS is everywhere.

Abbreviations

Al	aluminum
B	boron

BBIT	butylbenzisothiazolinon
BBP	bentsylbutylphthalate
BIT	benzylisothiazolinone
°C	degrees Celsius
Cd	cadmium
CIT	methylchloroisothiazolinone
Cr	chromium
Cu	copper
DCOIT	dichloroisothiazolinone
DEHA	bis(2-ethylhexyl)adipate
DIDP	diisodecylphthalate
DINP	diisononylphthalate
e.g.	exempli gratia, for example
et.al.	et alii, and others
EU	European Union
I	iodine
ID	identifier
kg	kilogram
l	litre
LCCP	long chain chlorinated paraffin
m	meter
MBIT	methylbenzoisothiazolinon
MCCP	medium chain chlorinated paraffin
mg	milligram
min	minute
MIT	methylisothiazolinone
µg	microgram
NE	north-east
N-EtFOSAA	N-ethyl perfluorooctane sulfonamido acetic acid
ng	nanogram
Ni	nickel

O	oxygen
OIT	octylisothiazolinone
OPFR	organophosphate flame retardant
Pb	lead
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFECHS	perfluoroethylcyclohexane Sulfonate
PFDA	perfluorodecanoic acid
PFHpS	perfluoroheptanesulfonic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFHxSA	perfluorohexanesulfonamide
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOD	perfluorooctyl dichloride
PFOS	perfluorooctanesulfonic acid
PFOSA	perfluorooctanesulfonamide
PFPeA	perfluoro-n-pentanoic acid
PFPeS	perfluoropentanesulfonic acid
PFPpA	perfluoropentyl-phosphonic acid
PFPrS	perfluoropropanesulfonic acid
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoroundecanoic acid
POP	persistent organic pollutant
PVC	polyvinyl chloride
REACH	registration, evaluation, authorisation and restriction of chemicals
s	second
SCCP	short-chain chlorinated paraffin
Si	silicon

Sn	tin
SVHC	substances of very high concern
TCCP	tris(2-chloro-1-methylethyl) phosphate
UNEP	United Nations' environment programme
Zn	zinc
6:2 FTS	6:2-fluorotelomersulfonic acid
8:2 FTS	8:2 fluorotelomer sulfonic acid

Introduction

The use of hazardous chemicals and substances in construction materials is controlled by national and EU (European Union) level legislation. Despite the control, hazardous chemicals and substances used especially in exterior materials may leach from the materials and end up in waterbodies or soil with run-off.

In Europe there have been carried out some studies concerning the occurrence of hazardous chemicals and substances in constructions materials and their leakage into stormwaters. For example, several biocides /1/, chlorinated paraffins /2/ and flame retardants /3/ have been found in European stormwaters. However, in Finland the occurrence of hazardous chemicals and substances related to building materials in stormwater is largely unknown.

The scope of the construction material and stormwater sampling in Helsinki was to compare the analysis results of the most commonly used hazardous chemicals and substances in pure exterior construction materials, in material samples taken from the construction sites and in stormwater. Based on the analysis results it was estimated which construction materials and hazardous chemicals are potential pollutants of stormwater and environment.

Substance screening

The chemicals and substances for the study were selected based on discussions with experts and information from studies on chemical content of building materials and their occurrence in stormwater. The list of analysed chemicals and substances included variety of biocides, chlorinated paraffins, metals, organophosphate flame retardants, PFAS (per- and polyfluoroalkyl substances) and phthalates.

The materials for the study were selected based on the material lists of two residential sites (Postipuisto and Kuninkaantammi) built by City of Helsinki Housing Production. The materials included e.g. facade brick, fiber cement board, paints for wood and concrete surfaces, flame retardants for wood, wooden terrace and facade boarding and bitumen membrane used for roofing.

Biocides

Biocides are used especially to protect the exterior surfaces of buildings to prevent the growth of micro-organisms (mold, fungi and algae) and to damage the materials. Biocides can be mixed with

the material or added as a surface treatment. /1/ Wood used in exterior parts of buildings are often treated with wood preservatives including biocides. Also paints for wood and concrete surfaces and protective agents for concrete surfaces may include biocides. Most products contain more than one biocide to increase the effectiveness. The biocides analysed by City of Helsinki included variety of different biocides approved for use as wood and in-can preservatives, rodenticides, insecticides and repellents.

Several biocides used in construction materials are toxic to aquatic organisms. Some of them are also carcinogenic, mutagenic and toxic to reproduction /4/.

Chlorinated paraffins

Chlorinated paraffins are used as plasticizers (softeners) for PVC, extreme-pressure additives in metal-machining fluids, as additives to paints, coatings, polyurethane foams and sealants to improve their resistance to chemicals and water, and as flame retardants for plastics, fabrics, paints and coatings. /16/

Chlorinated paraffins are lipophilic (fat soluble) and persistent in the environment. Their very low vapor pressure indicates that the compounds will not volatilize easily. Chlorinated paraffins have low water solubility and a high log Kow (n-octanol-water partition coefficient, which describers the relationship between lipophilicity and hydrophilicity, water solubility of the substance). Therefore, if released to water, they will not volatilize from water or remain in solution but will adsorb to sediment or suspended solid material. If released to soil, chlorinated paraffins are bound to the soil particles and are not expected to volatilize or to leach into groundwater. /16/

SCCPs, short-chain chlorinated paraffins with a carbon chain length of C10-C13, are classified as toxic to aquatic organisms, and carcinogenic to rats and mice. In 2017 they were categorised as possibly carcinogenic to humans. Since December 2018 the use of SCCPs have been banned globally under the Stockholm Convention on Persistent Organic Pollutants (UNEP/POPS/SC-8/11). The ban on SCCPs has led to their replacement by MCCPs, medium chain chlorinated paraffins with a carbon chain length of C14-C17. /17/

However, also MCCPs are toxic to the aquatic environment and persistent. In July 2021 MCCPs were added to the Candidate List of Substances of Very High Concern (SVHC) under the REACH Regulation (Registration, Evaluation, Authorisation and Restriction of Chemicals). /18/ MCCPs are also on the candidate list of substances to be added to the Stockholm Convention list of Persistent Organic Pollutants (POPs)/19/.

In addition, LCCPs, long chain chlorinated paraffins, with a carbon chain length of >C18 are used in products on the market. Only the SCCPs and MCCPs were analysed in Helsinki material samples and stormwater.

Isothiazolinones

Isothiazolinones are a group of biocides. They are organic compounds which exhibit antimicrobial properties, and they are antifouling agents. They are used to control bacteria, fungi, and algae e.g. in cooling water systems, fuel storage tanks, pulp and paper mill water systems, oil extraction systems, wood preservation. They are also frequently used in cosmetics, shampoos and other hair care

products. /23/ In construction materials isothiazolinones are used in lacquers, paints and varnishes /23/.

Together with their wanted function, controlling or killing microorganisms, isothiazolinones also have undesirable effects – they have a high aquatic toxicity. /22/ Even though they have a high aquatic toxicity they are soluble to water and in general, they present high volatility and are sensitive to thermal and pH conditions leading to transformation/degradation of them, which decreases their environmental effects. For human health isothiazolinones are strong sensitizers, producing skin irritations and allergies. /24/

In the EU, the use of some of isothiazolinone compounds in consumer products has been banned, and even stricter criteria for labeling and warning in chemical products have been approved. /24/

Metals

Metals can end up into the environment from various metallic construction materials and products. Other major sources of metals in environment are traffic, mining and heavy industry. Metals also occur in environment naturally in soil and bedrock. Aluminum, chromium, copper, lead and zinc were the metals detected both in material samples and in stormwater in Helsinki.

Aluminum is widely used in construction, and it is suitable for both interior and exterior construction. It is used for example in doors, windows, facades, skylights, railings, fences, scaffolding, ladders, stairs. /6/ Aluminum is also the third most common element in soil, right after oxygen (O) and silicon (Si) /7/. In the Earth's crust, aluminum is the most abundant metallic element with 8,23% by mass /26/. No information about natural background concentrations of aluminum in soil in Helsinki area was available. Based on the study made by Geological Survey of Finland in Pirkanmaa and Satakunta areas the average natural background concentration of aluminum in topsoil was 8920-18300 mg/kg and in subsoil 8520-17900 mg/kg /27/.

Chromium is used in metal alloys to give them hardness and in the manufacture of stainless steel. For example, tools often contain 3-5 weight percentage chromium. Chromium is also used to coat steel and plastics to create a shiny surface. /9/. Chromium used to be a common additive in paints to increase durability and provide protection against corrosion and reflective properties. Today chromium is still used e.g. in automotive paints. /10/ Chromium compounds are found in the environment from the erosion of chromium-containing rocks. Typical background concentration of chromium in soil is <500 mg. /9/ Based on the study made by City of Helsinki in 2009 the average natural background concentration of chromium in soil in Helsinki area parks and yards of apartment houses is around 15-65 mg/kg /8/.

Copper has played a role in architecture for thousands of years starting from the ancient Egypt. Copper has been used e.g. in doors, claddings, roof coverings and shingles as its own or in alloys (brass and bronze). Today, architectural copper is used in roofing systems, flashings and copings, rain gutters and downspouts, building expansion joints, wall cladding, domes, spires, vaults, and various other design elements. /11/

Copper is biostatic, meaning bacteria and many other forms of life will not grow on it. Due to its biostatical nature, copper is used in handrails, bedrails, bathroom fixtures, counter tops especially in

public facilities (hospitals, nursing homes, mass transit facilities) as well as in residential buildings. /11/

In nature, copper occurs in a variety of minerals, including e.g. native copper, copper sulfides, copper carbonates. Typical background concentrations of copper do not exceed 150 mg/kg in soil. /11/. Based on the study made by City of Helsinki in 2009 the average natural background concentration of copper in soil in Helsinki area parks and yards of apartment houses is around 10-30 mg/kg /8/.

Despite the fact lead is poisonous for human health and environment, it has many uses in the construction industry even today. Lead is used e.g. as roofing material, cladding, flashing, gutters and gutter joints, and roof parapets. Lead rarely occurs in its native, metallic form. It is generally combined with sulfur. Typical background concentrations of lead in soil do not exceed 100 mg/kg. /12/ Based on the study made by City of Helsinki in 2009 the average natural background concentration of lead in soil in Helsinki area parks and yards of apartment houses is around 10-70 mg/kg /8/.

Like lead, also zinc has been used for thousands of years for different purposes first as a zinc-copper alloy brass and later as a separate element. Today zinc is most commonly used as an anti-corrosion agent, and galvanization i.e. coating of iron or steel. /13/ In construction zinc is used e.g. in architectural applications for rainwater systems, cladding and roofing /14/. Typical background concentrations of zinc do not exceed 100 mg/kg in soil /13/. Based on the study made by City of Helsinki in 2009 the average natural background concentration of zinc in soil in Helsinki area parks and yards of apartment houses is around 20-90 mg/kg /8/.

Organophosphate flame retardants

Organophosphate flame retardants, OPFRs, have been used to replace harmful brominated flame retardants. They are widely used as flame retardants in various consumer products such as textiles, electronics, industrial materials and furniture to prevent the risk of fire by delaying its start and propagation by interrupting or hindering the combustion process. They are also utilized as plasticizers, antifoaming or anti-wear agents in lacquers, hydraulic fluids and floor polishing agents. /20/ In building materials OPFRs are used e.g. in sealing and insulating foams, plastic and rubber products, sealants and adhesives /21/.

OPFRs have been associated with e.g. neurotoxicity, developmental toxicity, damage to the reproductive function, endocrine disruption and carcinogenicity. OPFRs are less persistent than the brominated flame retardants they have been used to replace, but they are often found in the environment in higher concentrations than the brominated compounds /4/

PFAS (per- and polyfluoroalkyl substances)

PFAS, per- and polyfluoroalkyl substances are a large group of substances used in various types of products mainly for their grease, water and dirt repellent properties. In building materials PFAS (including fluoropolymers) are used e.g. in roofing materials, waterproof membranes, gutters, coatings of windows, different wood-based products like plywood and fibre boards and in solar panels. In addition, PFAS are found in some paints, metal coatings, wood varnishes, plastic coatings, sealants, crystals, adhesives, tapes and electrical wires and cables used in construction. /4/

PFAS are very persistent in the environment, and they either do not degrade, or they degrade into persistent PFAS. Some PFAS are also bioaccumulative. The adverse effects of many PFAS are poorly studied, but certain PFAS are known to e.g. be reprotoxic, carcinogenic and immunosuppressive. /4/

Phthalates

Phthalates are a group of chemicals mainly used to make plastics more durable, last longer and easier to maintain. Due to that they are often called plasticizers. In construction phthalates can be found especially in various PVC (polyvinyl chloride) products and materials. Examples of exterior products and materials including phthalates are roof membranes, waterproofing membranes, sealants, plastic skylights on terraces and various types of pipes, such as sewer pipes and rainwater wells. /5/

Phthalates degrade easily in the environment by bio- and photodegradation and anaerobic degradation. Due to that they usually do not accumulate in soil or organisms or in the food chain, and they are not stored in the human body. However, due to their widespread use, we are exposed to phthalates on a daily basis. Many phthalates are endocrine disruptors, and some are toxic to aquatic organisms. /5/

Methodology

Material sampling

Material sampling in Helsinki was implemented by actual field sampling and by analyzing construction materials purchased from the material manufactures or hardware stores. Materials for laboratory analysis were selected based on the original material lists used in two residential construction sites (Postipuisto area and Kuninkaantammi area) built by City of Helsinki Housing Production.

Material manufactures were contacted and asked their willingness to participate in the NonHazCity3 project. All the selected manufacturers accepted the invitation. Sampling materials were delivered free of charge or purchased. Some of the material manufactures wanted to participate anonymously. Due to this sample description includes only sample ID and material type.

Chemicals to be analyzed were selected based on the existing knowledge and information of chemicals used in construction materials. Due to the limited budget the list of chemicals had to be kept moderate. The following chemicals were analyzed: biocides and transformation products of biocides, phthalates, metals (aluminum, cadmium, chromium, copper, lead, nickel, zinc and tin), isothiazolinones, PFAS (perfluoro and polyfluoroalkyl substances), short-chain and medium-chain chlorinated paraffins and organophosphate flame retardants.

Postipuisto area

Postipuisto area is a newly built residential area located around 5 km north of the Helsinki city center. Based on the original material lists of Postipuisto buildings together eight material samples were selected for the laboratory analysis. Construction phase of the Postipuisto site was finished by the time the field sampling was implemented (June 20, 2023). Yet two field samples were able to be collected.

Material samples from Postipuisto site included facade brick and mortar (field samples), fiber cement board, facade brick, paints for wood and concrete surfaces, protective agent for stone and concrete surfaces and flame retardant for wood (purchased materials). The field samples were taken into gas resistant plastic backs and sealed tightly. Before delivering to the laboratory the samples were stored in a cool and dry storage room. The laboratory analyses were performed by Eurofins and SGS laboratories.

Picture 1. Apartment houses in Helsinki Postipuisto area.

Picture 2. Apartment houses in Helsinki Postipuisto area.

Kuninkaantammi area

Kuninkaantammi is a newly built residential area located around 10 km north of the Helsinki city center. City of Helsinki Housing Production construction site consisted of five 3-4 floor wooden apartment houses. Based on the original material lists of Kuninkaantammi buildings together ten material samples were selected for the laboratory analysis. Construction phase of the Kuninkaantammi site was ongoing by the time the field sampling was implemented (June 29, 2023). Material samples from Kuninkaantammi site included bitumen membrane used for roofing, wooden terrace

and facade boarding and concrete (field samples) and coating cement, paints for wood and concrete surfaces, protective agent for concrete surfaces and flame retardant for wood (purchased materials). The field samples and dry material samples were taken into gas resistant plastic backs and sealed tightly. Before delivering to the laboratory the samples were stored in a cool and dry storage room. The laboratory analyses were performed by Eurofins and SGS laboratories.

Picture 3. Wooden apartment houses in Helsinki Kuninkaantammi area.

Picture 4. Stormwater pond located south of the Kuninkaantammi site.

Table 1. Summary of material samples.

Sample ID	**Material and sampling site**	**Analysis***
MAT_01	Facade brick, Postipuisto	E, OFR, PFAS
MAT_02	Facade mortar, Postipuisto	E, OFR, PFAS
MAT_03	Concrete slab, Kuninkaantammi	E
MAT_04	Bitumen membrane (roofing), Kuninkaantammi	B, E, OFR, PFAS, PHT
MAT_05	Wooden terrace boarding, Kuninkaantammi	B, E, I, OFR, PFAS

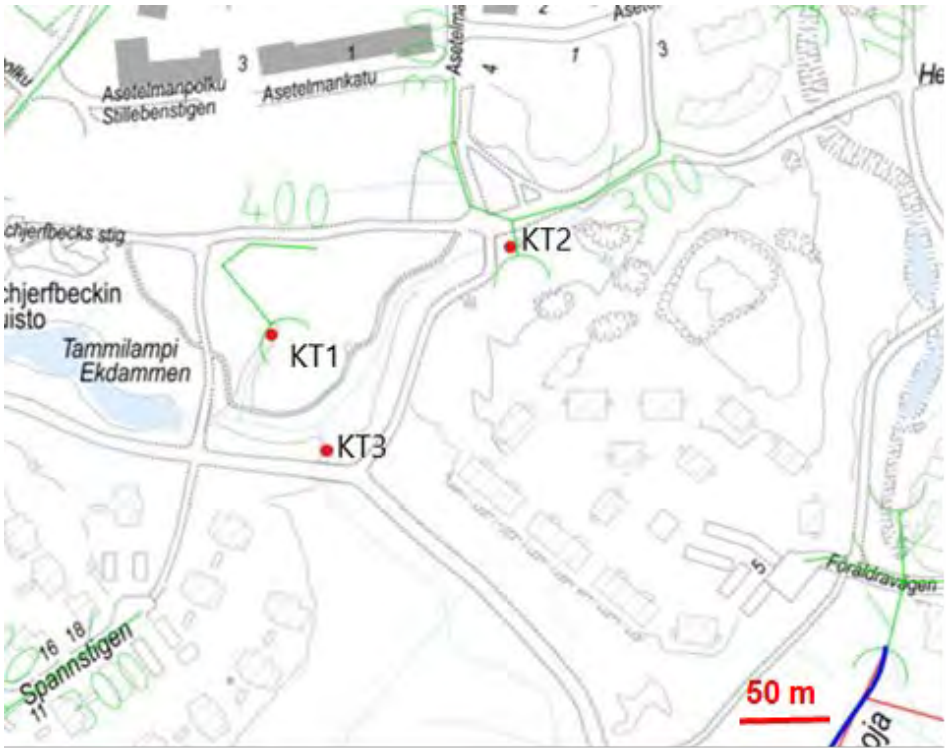
MAT_06	Wooden facade boarding, fire protected, Kuninkaantammi	B, CF, E, I, OFR, PFAS
MAT_07	Wooden facade boarding, grey, Kuninkaantammi	B, CF, E, I, OFR, PFAS
MAT_10	Fiber cement board, Postipuisto	E, I, OFR, PFAS
MAT_12	Facade brick, multicolored, Postipuisto	E, OFR, PFAS
MAT_14	Coating cement, Kuninkaantammi	E, PFAS
MAT_15	Paint 1, for wooden outside surfaces, Kuninkaantammi	B, CF, E, I, OFR, PFAS, PHT
MAT_16	Paint 2, for wooden outside surfaces, Postipuisto	B, E, I, PFAS, PHT
MAT_17	Paint for outside concrete surfaces, Postipuisto	B, E, I, OFR, PFAS, PHT
MAT_18	Surface treatment agent for concrete, Kuninkaantammi	B, E, I, OFR, PFAS, PHT
MAT_19	Surface treatment agent for stone and concrete, Postipuisto	B, E, I, OFR, PFAS, PHT
MAT_20	Flame retardant 1, Postipuisto	B, CF, E, I, OFR, PFAS, PHT
MAT_21	Paint 3, for wooden outside surfaces, Kuninkaantammi	B, CF, E, I, OFR, PFAS, PHT
MAT_22	Flame retardant 2, Kuninkaantammi	B, CF, E, I, OFR, PFAS, PHT

***Analysis**
B, biocides and transformation products of biocides
CF, chlorinated paraffins
E, elements / metals
I, isothiazolinones
OFR, organophosphate flame retardants
PFAS, per- and polyfluoroalkyl substances
PHT, phthalates

Stormwater sampling

As a stormwater sampling area was selected only Kuninkaantammi area. Within Postipuisto stormwater catchment area are located several buildings, which are built by other builders than City of Helsinki Housing Production and no information of materials used in them was available. Also, stormwater catchment area is large and not so easy to handle.

Stormwater sampling in Helsinki Kuninkaantammi area was carried out on December 19, 2023. Weather conditions during the sampling were as follows: temperature 3-4 °C, cloudy, wind NE 7-9 m/s. Previous days before the sampling were rainy. Sampling was performed by a certified environmental sampler working for environmental monitoring and supervision team of City of Helsinki urban environment sector. The samples were collected from three sampling locations shown in pictures 5 and 6.



Picture 5. Map of Helsinki Kuninkaantammi area and stormwater sampling locations.

Picture 6. Aerial photo of Kuninkaantammi area with stormwater catchment area and sampling locations.

Two parallel samples were to be taken from each sampling location (separated with identifiers A/B) every 45 minutes. At the sampling location KT1 the water flow decreased too much before taking the parallel sample, and no representative parallel sample was received from the location. In connection

with sampling water sample temperature was measured. Waterflow of the observation points was estimated using a strainer and a measuring stick.

The laboratory analysis included the same chemicals than analyzed from material samples: biocides and transformation products of biocides, phthalates, metals, isothiazolinones, PFAS, short-chain and medium-chain chlorinated paraffins and organophosphate flame retardants.

The water samples were taken into glass and plastic containers. The samples were stored in cooler bags and delivered to the laboratories by the sampler or by a courier within 24 hours of the sampling. No blank samples were analyzed. The laboratory analyses were performed by Eurofins and SGS laboratories.

Table 2. Summary of stormwater sampling.

Sample ID	**Temperature (°C)**	**Flow volume (l/min)**	**Analysis***	**Notes**
KT1A	1,2	<10	B, CF, E, I, OFR, PFAS, PHT	Minor flow
KT2A	3,6	15	B, CF, E, I, OFR, PFAS, PHT	
KT2B	3,8	10	B, CF, E, I, OFR, PFAS, PHT	
KT3A	0,6	1200	B, CF, E, I, OFR, PFAS, PHT	
KT3B	0,6	1200	B, CF, E, I, OFR, PFAS, PHT	

***Analysis**
B, biocides and transformation products of biocides
CF, chlorinated paraffins
E, elements / metals
I, isothiazolinones
OFR, organophosphate flame retardants
PFAS, per- and polyfluoroalkyl substances
PHT, phthalates

Results

Material samples

Biocides and transformation products of biocides

Biocides and transformation products of biocides were analysed in 12 material samples by Eurofins and SGS laboratories.

Biocides and transformation products of biocides analysed by SGS laboratories included 12 known chemicals used among others as preservatives, rodenticides, insecticides and repellents, and wood preservatives.

As test methods were used DIN 38407-35, DIN 38407-36 and DIN EN ISO 10695. Reporting limit of the analyzed chemicals was 0,05 mg/kg and 0,5 mg/kg. Together four material

samples were analyzed. In sample MAT_05, wooden terrace boarding used in Kuninkaantammi area was detected propiconazole and tebuconazole, concentrations respectively 8,3 mg/kg and 8,7 mg/kg. Also, in sample MAT_07, wooden facade boarding used in Kuninkaantammi area was detected both propiconazole and tebuconazole with concentrations just above the laboratory's reporting limit, concentrations respectively 0,07 mg/kg and 0,05 mg/kg. Concentrations of the rest of the analysed biocides and transformation products of the biocides were below laboratory's reporting limits.

Table 3. Results of biocide analysis of material samples implemented by SGS laboratories. KT means Kuninkaantammi area.

mg/kg	MAT_04 KT	MAT_05 KT	MAT_06 KT	MAT_07 KT
Tebuconazole	<0,05	**8,7**	<0,05	**0,05**
Propioconazole	<0,05	**8,3**	<0,05	**0,07**

Biocides and transformation products of biocides analysed by Eurofins laboratories included 10 chemicals of which all were the same as analysed by SGS laboratories. Reporting limit of the analysed chemicals was 1 mg/kg. The test methods used were LA-Peztizide-003.075/31/2023 (A) or internal method including extraction, clean up and LC-MS/MS or GC-MS after extraction_(B). No biocides or transformation products of biocides were detected in concentrations above the laboratory's detection limit.

Chlorinated paraffins

Material analysis of chlorinated paraffins included short (C10-C13) and middle chained (C14-C17) chlorinated paraffins. The analyses were implemented by Eurofins laboratories. Concentrations of short and middle chained chlorinated paraffins were calculated using as a basis the total concentration of the chlorinated paraffins (C10-C20). As a test method was used LA-GC-006.01_7/14/2022 (A). GC-MS was done after extraction of the samples. Reporting limit of the chlorinated paraffins was 50 mg/kg or 100 mg/kg. Together six material samples were analyzed. All the detected concentrations were below the laboratory's reporting limit.

Isothiazolinones

Isothiazolinones were analysed in 12 material samples by Eurofins and SGS laboratories.

The group of isothiazolinones analysed by SGS laboratories included the four most known isothiazolinone compounds: methylisothiazolinone (MIT), benzylisothiazolinone (BIT), octylisothiazolinone (OIT), dichloroisothiazolinone (DCOIT).

As a test method was used LC-MS/MS after extraction_(B)SOP M 2544. Reporting limit of the analysed chemicals was 1 µg/kg. Together four material samples were analysed by SGS laboratories. Isothiazolinone compounds were detected in all samples. The highest concentrations of isothiazolinones were detected in MAT_05, wooden terrace boarding used

in Kuninkaantammi area. The lowest concentrations of isothiazolinones were detected in MAT_10, painted fiber cement board used in Postipuisto area. In general, isothiazolinone compounds were detected in all treated boardings.

Table 4. Results of isothiazolinone analysis of material samples implemented by SGS laboratories. PP means Postipuisto area and KT Kuninkaantammi area.

µg/kg	MAT_05 KT	MAT_06 KT	MAT_07 KT	MAT_10 PP
Methylisothiazolinone MIT	**2644**	**113**	**291**	**11**
Benzylisothiazolinone BIT	**29**	**424**	**199**	**304**
Octylisothiazolinone OIT	**15116**	**7,7**	**21**	<1
Dichloroisothiazolinones DCOIT	<1	**58**	**183**	n.d.

The group of isothiazolinones analysed by Eurofins laboratories included the same chemicals as analysed by SGS laboratories plus methylchloroisothiazolinone (CIT), butylbenzisothiazolinon (BBIT) and methylbenzoisothiazolinon (MBIT).

As a test method was used LC-MS/MS after extraction_(B). Reporting limit of the analysed chemicals was 100 µg/kg. Together eight material samples were analysed by Eurofins laboratories. Isothiazolinone compounds were detected in all but one sample. The highest concentrations of isothiazolinones were detected in material samples MAT_15, paint 1 for wooden outside surfaces used in Kuninkaantammi area and MAT_21, paint 3 for wooden outside surfaces used in Kuninkaantammi area. High concentration of isothiazolinones was detected also in sample MAT_18, surface treatment agent for concrete used in Kuninkaantammi area. The concentrations of isothiazolinones were below the laboratory's reporting limit only in sample MAT_19, surface treatment agent for stone and concrete used in Postipuisto area.

Table 5. Results of isothiazolinone analysis of material samples implemented by Eurofins laboratories. PP means Postipuisto area and KT Kuninkaantammi area.

µg/kg	MAT_15 KT	MAT_16 PP	MAT_17 PP	MAT_18 KT	MAT_19 PP	MAT_20 PP	MAT_21 KT	MAT_22 KT
Methyliso-thiazolinone MIT	**3600**	**45000**	**6800**	**1100**	<100	**3600**	**37000**	**2800**
Benzyliso-thiazolinone BIT	**220000**	**13000**	**84000**	**180000**	<100	**7400**	**220000**	**67000**
Octylisothiazolinone OIT	<100	<100	<100	**38000**	<100	<100	<100	<100
Dichloroiso-thiazolinones DCOIT	**16000**	**100000**	**1400**	<100	<100	<100	**1000**	<100
Methylchloroiso-thiazolinone CIT	**170**	<100	<100	<100	<100	**7000**	<100	<100
Butylbenzoiso-thiazolinone BBIT	<100	<100	<100	<100	<100	<100	<100	<100

Methylbenzoiso-thiazolinone MBIT	<100	<100	**8600**	<100	<100	<100	<100	**31000**

Metals

Elements i.e. metals analysed from material samples included aluminum (Al), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), zinc (Zn), and tin (Sn). Metals were analysed in all 18 material samples by SGS and Eurofins laboratories.

Together ten material samples were analysed by SGS laboratories. As a test method was used ICP-AES extraction and SGSF528 analysis. The most common metal in analysed materials was aluminum. Aluminum was detected in all but one material sample. Copper and zinc were detected in six samples, chromium in five samples and nickel in four samples. The reporting limits of analyzed metals were 1 mg/kg, 10 mg/kg, or 20 mg/kg.

Concentration of aluminum varied between 121 mg/kg and 20 660 mg/kg. The lowest concentration of aluminum was detected in material sample MAT_05, wooden facade boarding used in Kuninkaantammi area and the highest in material sample MAT_10, painted fiber cement board used in Postipuisto area. Concentrations of other detected metals were relatively low; chromium 17-113 mg/kg, copper 16-228 mg/kg, nickel 18-33 mg/kg and zinc 13-155 mg/kg. No cadmium, lead or tin were detected in concentrations above the laboratory's reporting limit.

The largest variety of metals was detected in concrete, bitumen roofing membrane, painted fiber cement board and in coating cement. They all included aluminum, chromium, copper, nickel, and zinc. The results of metal analysis implemented by SGS laboratories are presented in table 3.

Table 6. Results on metal analysis of material samples implemented by SGS laboratories. PP means Postipuisto area and KT Kuninkaantammi area.

mg/kg	MAT_01 PP	MAT_02 PP	MAT_03 KT	MAT_04 KT	MAT_05 KT	MAT_06 KT	MAT_07 KT	MAT_10 PP	MAT_12 PP	MAT_14 KT
Al	**3235**	**5033**	**7822**	**5092**	<20	**126**	**121**	**20660**	**15310**	**9480**
Cd	<1,0	<1,0	<1,0	<1,0	<1,0	<1,0	<1,0	<1,0	<1,0	<1,0
Cr	**10**	<10	**28**	**18**	<10	<10	<10	**37**	**113**	**17**
Cu	<10	**18**	**57**	**16**	**228**	<10	<10	**66**	<10	**33**
Pb	10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Ni	<10	<10	**33**	**19**	<10	<10	<10	**19**	<10	**18**
Zn	<10	**38**	**36**	**20**	<10	<10	**13**	**155**	<10	**76**
Sn	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10

Metals in eight material samples were analysed by Eurofins laboratories. As a test method DIN EN ISO 17294-2 ICP-MS_2017-01 (E) was used. The most common metal in analysed materials was aluminum. Aluminum was detected in all but one material sample. Copper was detected in four samples, chromium and zinc in three samples, and nickel and lead in

two samples. The reporting limits of analyzed metals were 0,1 mg/kg, 0,2 mg/kg, 0,5 mg/kg, 1 mg/kg, or 5 mg/kg.

The concentration of aluminum varied between <5 mg/kg and 3 500 mg/kg. The lowest concentration of aluminum was detected in flame retardant 1 (MAT_20) used in Postipuisto area and the highest in paint 3 for wooden outside surfaces (MAT_21) used in Kuninkaantammi area. Concentrations of other detected metals were relatively low; chromium 1-823 mg/kg, copper 2-9 mg/kg, lead 0,5-0,6 mg/kg, nickel 11-13 mg/kg and zinc 6-290 mg/kg. No cadmium or tin were detected in concentrations above the laboratory's reporting limit.

The largest variety of metals was detected in paint 1 for wooden outside surfaces (MAT_15) used in Kuninkaantammi area, in paint for outside concrete surfaces (MAT_17) used in Postipuisto area and in surface treatment agent for concrete (MAT_18) used in Kuninkaantammi area. No metals above the laboratory's detection limit were detected in flame retardant 1 (MAT_20) used in Kuninkaantammi area and only aluminum in surface treatment agent for stone and concrete (MAT_19) used in Postipuisto area and in flame retardant 2 (MAT_22) used in Kuninkaantammi area. The results of metal analysis implemented by Eurofins laboratories are presented in table 4.

Table 7. Results on metal analysis of material samples implemented by Eurofins laboratories. PP means Postipuisto area and KT Kuninkaantammi area.

mg/kg	MAT_15 KT	MAT_16 PP	MAT_17 PP	MAT_18 KT	MAT_19 PP	MAT_20 PP	MAT_21 KT	MAT_22 KT
Al	**220**	**125**	**2500**	**2300**	**12**	<5	**3500**	**250**
Cd	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,1
Cr	**27**	**1**	<1	**82**	<1	<1	<1	<1
Cu	**8**	**9**	**2**	<1	<1	<1	**2**	<1
Pb	<0,5	<0,5	**0,5**	**0,6**	<0,5	<0,5	<0,5	<0,5
Ni	**13**	<1	<1	**11**	<1	<1	<1	<1
Zn	<5	<5	**6**	**290**	<5	<5	**8**	<2
Sn	<5	<5	<5	<5	<5	<5	<5	<1

Organophosphate flame retardants

Material analysis of organophosphate flame retardants included together 15 different phosphate-based chemicals used as additives in flame retardants. The analyses were implemented by Eurofins laboratories. As a test method was used LA-GC-002.01_9/25/2023 (A). GC-MS was done after extraction and derivatization of the samples. Reporting limit of the chemicals was 2 mg/kg or 5 mg/kg. Together 15 material samples were analyzed. All the detected concentrations were below the laboratory's reporting limit.

PFAS (per- and polyfluoroalkyl substances)

PFAS compounds (per- and polyfluoroalkyl substances or chemicals) were analysed in 17 material samples by SGS and Eurofins laboratories.

The material samples MAT_01 - MAT_14 (total nine samples) were analysed by SGS laboratories. The analysis included 49 different PFAS compounds. As a test method was used DIN 38414-14 mod. The PFAS concentrations in all material samples were below laboratory's reporting limit 2,5 µg/kg.

The material samples MAT_15 - MAT_22 (total eight samples) were analysed by Eurofins laboratories. The analysis included 62 different PFAS compounds of which 45 were the same as analyzed by SGS laboratories. As a test method was used laboratory's internal method. The PFAS concentrations were below laboratory's reporting limits 1,0 µg/kg and 10 µg/kg in all samples except in sample MAT_19, surface treatment agent for stone and concrete used in Postipuisto area.

In sample MAT_19 was detected total PFAS concentration more than 20 000 µg/kg. The detected PFAS compounds and concentrations were as follows: PFBA 12 µg/kg, PFPeA 4,7 µg/kg, PFHxA 54 µg/kg, 5:3 FTCA 6,6, µg/kg and 6:2 FTOH 20 000 µg/kg.

Phthalates

Phthalates were analysed in 17 material samples by SGS and Eurofins laboratories.

Material analysis of phthalates implemented by SGS laboratories included together nine phthalate-based chemicals. As a test method was used non-accredited method VDI 4301 Bl. 5 mod. Only one material sample, MAT_04, bitumen roofing membrane used in Kuninkaantammi area was analysed. Reporting limit of the analyzed chemicals was 5,0 mg/kg. The concentrations of analyzed phthalates were below the laboratory's reporting limit.

Together eight material samples were analysed by Eurofins laboratories. Analysis included bis(2-ethylhexyl)adipate (DEHA) and 11 phthalate-based chemicals of which nine were the same as analysed by SGS laboratories. As a test method was used LA-GC-002.01_9/25/2023 CAS. GC-MS was done after extraction and derivatization. Reporting limits varied between 5 mg/kg and 100 mg/kg. Only in one sample, MAT_17, paint for outside concrete surfaces used in Postipuisto area was detected a bentsylbutylphthalate (BBP) concentration 26 mg/kg, which was above the laboratory's detection limit.

Stormwater analysis

Biocides and transformation products of biocides

Stormwater analysis of biocides and transformation products of biocides was implemented by SGS laboratories.

The test methods used were DIN 38407-35 2010-10, DIN 38407-36 2014-09, and DIN EN ISO 6468 1997-02. Reporting limit of the analysed chemicals was 0,01 µg/l, 0,02 µg/l or 0,05 µg/l.

In sample KT1A all the analysed chemicals were below the laboratory's reporting limit.

In sample KT2A was detected propiconazole and tebuconazole, concentrations respectively 0,88 µg/l and 0,43 µg/l. Also, the parallel sample KT2B included both propiconazole and tebuconazole, concentrations respectively 0,81 µg/l and 0,36 µg/l.

In sample KT3A was detected mecoprop concentration 0,37 µg/l. In the parallel sample KT3B mecoprop concentration was 0,38 µg/l. In a parallel sample KT3B was detected also propiconazole concentration just above the laboratory's reporting limit, 0,06 µg/l.

Table 8. Results of biocides and transformation products of biocides analysis of stormwater samples implemented by SGS laboratories.

µg/l	KT1A	KT2A	KT2B	KT3A	KT3B
Cybutryne	<0,05	<0,05	<0,05	<0,05	<0,05
Cypermethrin	<0,01	<0,01	<0,01	<0,01	<0,01
Desmethyldiuron	<0,05	<0,05	<0,05	<0,05	<0,05
Diuron	<0,05	<0,05	<0,05	<0,05	<0,05
Irgarol Metab. M1	<0,02	<0,02	<0,02	<0,02	<0,02
Isoproturon	<0,05	<0,05	<0,05	<0,05	<0,05
Mecoprop	<0,05	<0,05	<0,05	**0,37**	**0,38**
Permethrin	<0,05	<0,05	<0,05	<0,05	<0,05
Propiconazole	<0,05	**0,88**	**0,81**	<0,05	**0,06**
Tebuconazole	<0,05	**0,43**	**0,36**	<0,05	<0,05
Terbuthylazine	<0,02	<0,02	<0,02	<0,02	<0,02
Terbutryn	<0,05	<0,05	<0,05	<0,05	<0,05

Chlorinated paraffins

Stormwater analysis of organophosphate flame retardants was implemented by Eurofins laboratories. Stormwater analysis of chlorinated paraffins included short (C10-C13) and middle chained (C14-C17) chlorinated paraffins and the total concentration of chlorinated paraffins (C10-C20). As a test method LA-GC_212.02_7/15/2016 (B) was used. Reporting

limit of the chlorinated paraffins was 1 µg/l. All the detected concentrations were below the laboratory's reporting limit.

Isothiazolinones

Stormwater analysis of isothiazolinones was implemented by SGS laboratories.

As a test method for stormwater samples to analyze isothiazolinones SOP M 2544 was used. Reporting limit of the analyzed chemicals was 0,01 µg/l, 0,02 µg/l or 0,05 µg/l. No concentrations of isothiazolinones above the laboratory's reporting limit was detected.

Metals

Stormwater analysis of metals was implemented by SGS laboratories. Analysis included iodine (I), aluminum (Al), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), zinc (Zn) and tin Sn). In addition to metals, boron (B)was also analysed, as boron based biocidal products are commonly used e.g. in roofings. As a test method for total iodine was used ICP-MS method based on EN 15111 standard. The total concentration of metals except tin and boron was analyzed by ICP-MS method based on EN ISO 17294-2 standard. The total concentration of tin and boron was analyzed by ICP-AES method based on ISO 11885 standard. Reporting limits of the metals varied between 0,1 and 200 µg/l. Detected concentrations of cadmium, nickel, tin, and boron were below laboratory's reporting limit. The highest detected metal concentrations were aluminum (400-1800 µg/l), copper (4,8-17 µg/l) and zinc (6,7-34 µg/l).

Table 9. Results of metal analysis of stormwater samples implemented by SGS laboratories.

µg/l	KT1A	KT2A	KT2B	KT3A	KT3B
I	**14**	**3,2**	**3,1**	**3,6**	**3,1**
Al	**400**	**590**	**670**	**1800**	**1700**
Cr	<1,0	**2,3**	**2,2**	**4,2**	**4,0**
Cu	**4,8**	**17**	**15**	**11**	**11**
Pb	**0,5**	<0,5	**0,5**	**1,4**	**1,3**
Zn	<5,0	**8,4**	**6,7**	**34**	**31**

Organophosphate flame retardants

Stormwater analysis of organophosphate flame retardants were implemented by Eurofins laboratories. The analysis included 15 different phosphate-based chemicals used as flame retardants. As a test method was used LA-GC-050.021_9/18/2023 (A) based on DIN ISO 18856. GC-MS was done after extraction of the samples. Reporting limit of the chemicals was 0,1 µg/l or 0,5 µg/l. Only TCCP (C), tris(2-chloro-1-methylethyl) phosphate also knows as tris(chloropropyl)phosphate was found in sample KT2A and the parallel sample KT2B. Concentrations were respectively 0,18 µg/l and 0,12 µg/l.

Table 10. Results of organophosphate flame-retardant analysis of stormwater samples implemented by Eurofins laboratories.

µg/l	KT1A	KT2A	KT2B	KT3A	KT3B
TCPP (C)	<0,1	0,18	0,12	<0,1	<0,1

PFAS (per- and polyfluoroalkyl substances)

Stormwater analysis of PFAS (per- and polyfluoroalkyl substances) was implemented by SGS laboratories. The analysis included 49 different PFAS compounds. As a test method was used ISO 21675:2019. The reporting limits were 0,3 ng/l, 0,6 ng/l, 1 ng/l or 2 ng/l.

The largest variety of PFAS compounds, 25 different substances, was found in sample KT1A. The total concentration of the PFAS compounds in sample KT1A was 340,08 ng/l. In stormwater samples KT2A and KT2B 10 different PFAS compounds were detected. Total concentration of the PFAS in sample KT2A was 22,7 ng/l and in sample KT2B 24,6 ng/l. In stormwater sample KT3A 15 different and in sample KT3B 16 different PFAS substances were detected. The total concentrations respectively were 49,2 ng/l and 37,51 ng/l.

Table 11. Results of PFAS analysis of stormwater samples implemented by SGS laboratories.

ng/l	KT1A	KT2A	KT2B	KT3A	KT3B
PFPrS	**1,8**	**1,2**	**1,4**	**1,3**	**0,81**
PFBS	**3,0**	**2,3**	**1,7**	**0,98**	**0,6**
PFPeS	**0,81**	<0,6	<0,6	<0,6	**1,5**
PFHxS	**13**	<0,3	<0,3	**6,1**	**3,7**
PFHpS	<0,6	<0,6	<0,6	<0,6	<0,3
PFOS, branched	**15**	<0,2	<0,2	**1,6**	**1,4**
PFOD, linear	**49**	**0,56**	**0,57**	**4,6**	**4,4**
PFOS, total	**64**	**0,56**	**0,57**	**6,2**	**4,8**
PFECHS	**1,1**	<0,3	<0,3	<0,3	<0,3
PFBA	**4**	**2,2**	**2,5**	**2,0**	**1,3**
PFPeA	**19**	**5,9**	**8,2**	**12**	**4,3**
PFHxA	**11**	**6,4**	**6,6**	**4,7**	**3,9**
PFPpA	**4,8**	**1,7**	**1,1**	**1,1**	**1,1**
PFOA, branched	**0,71**	<0,3	<0,3	<0,3	<0,3
PFOA, linear	**7,5**	**0,94**	**1,0**	**1,1**	**1,1**
PFOA, total	**8,2**	**0,94**	**1,0**	**1,1**	**1,1**
PFNA	**28**	<0,3	<0,3	**2,3**	**1,9**
PFDA	**0,89**	<0,6	<0,6	<0,6	<0,3
PFUnDA	**78**	<1	<1	**3,4**	**4,3**
PFTrDA	**2,1**	<1	<1	<1	<1
6:2 FTS	**7,9**	<0,3	<0,3	**0,67**	<0,6
8:2 FTS	**14**	<0,6	<0,6	<0,6	**1,3**

PFBSA	**0,81**	<0,6	<0,6	<0,6	<0,3
PFHxSA	**2,2**	<0,6	<0,6	<0,6	<0,3
PFOSA	**0,86**	<0,3	<0,3	<0,3	<0,3
N-EtFOSAA	**2,4**	<1	<1	<1	<1
sum 4 PFAS LB	**110**	**1,5**	**1,6**	**16**	**13**
Sum total	340,08	22,7	24,6	49,2	37,51

Phthalates

Stormwater analysis of phthalates was implemented by SGS laboratories. Stormwater analysis of phthalates included 15 different phthalate-based chemicals. As a test method was used EN ISO 18856:2005. Middle chained chlorinated paraffins (MCCP) were analyzed using non-accredited in-house GC-MS method and bronopol by using in-house LC-MS-MS method. Reporting limit of the phthalates was 0,1 µ/l, 0,4 µ/l, 0,5µg/, 1 µg/l or 5 µg/l. Diisononylphthalate (DINP) and diisodecylphthalate (DIDP) were detected in stormwater samples KT2A, KT2B, KT3A and KT3B. The detected concentrations varied between 1,0 and 1,7 µg/l.

Table 12. Results of phthalate analysis of stormwater samples implemented by SGS laboratories.

µg/l	KT1A	KT2A	KT2B	KT3A	KT3B
Diisononylphthalate DINP	<1	1,0	1,7	1,2	1,3
Diisodecylphthalate DIPD	<1	<1	1,3	1,2	1,1

Interpretation and discussion of results

The scope of the construction material and stormwater sampling was to compare the analysis results of the most commonly used hazardous chemicals in pure construction materials, in material samples taken from the construction sites and in stormwater. Based on the analysis results was estimated which construction materials and hazardous chemicals are potential pollutants of stormwater and environment.

Biocides and transformation products of biocides

Biocides were detected in two Kuninkaantammi area material samples MAT_05, wooden terrace boarding and MAT_07, wooden facade boarding and in two stormwater locations, KT2 and KT3. According to the material safety data sheets biocides have not been added into paints, treatment agents for stone and concrete surfaces and flame retardants.

In material samples was found propiconazole and tebuconazole, when in stormwater was detected also mecoprop. This indicates that the origin of the biocides in stormwater is partly the surrounding area, partly the construction site.

It is noticed that biocides were found in material sample MAT_07, wooden facade boarding, but not in paint or flame retardant used for facade boarding treatment. Without further investigations it is not possible to determine the exact source of biocides in facade boarding.

Based on this study biocides in construction materials are not considered to pollute surrounding environment and surface waters.

Chlorinated paraffins

The detected chlorinated paraffin concentrations both in Postipuisto and Kuninkaantammi area material samples and in Kuninkaantammi area stormwater samples were below the laboratory's reporting limit. According to the available material safety data sheets chlorinated paraffins have not been used in materials in concern. Chlorinated paraffins are not considered as potential pollutants in Postipuisto and Kuninkaantammi areas.

Isothiazolinones

Isothiazolinones were detected in all but one Postipuisto and Kuninkaantammi are material samples, but not in Kuninkaantammi area stormwater. Based on the available material safety data sheets isothiazolinones have been used in materials in concern. The weight percentage of isothiazolinones in materials varies between <0,001 % and <5 %, concentrations respectively <0,01 mg/kg and <50 mg/kg. Isothiazolinones are soluble to water and in general, they present high volatility and are sensitive to thermal and pH conditions. Based on the literature isothiazolinones in aqueous systems are influenced by nucleophiles, such as metals, amines, thiols, and sulfides, which easily leads to transformation/degradation of them /24/. It is possible that isothiazoline used in Kuninkaantammi area facade boarding paints have either vaporized before ending up into stormwater or transformed/degraded in stormwater.

When comparing isothiazolinones concentrations in paints and flame retardants and wooden facades treated with the same agents, it is noticed that concentrations in pure agents are remarkably higher than in facades. The method of analysis affects this. Not only the paint, but also the surface layer of the wooden pieces was removed, which dilutes the concentrations. Isothiazolinones are soluble to water, and they present high volatility. They are also sensitive to thermal and pH conditions leading to transformation/degradation of them, which contributes to the analysis results.

Though high concentrations of isothiazolinones were detected in pure paints, flame retardants and surface treatment agents for stone and concrete, the concentrations in material samples and in stormwater do not show isothiazolinones to be a risk to pollute environment and surface water.

Metals

Aluminum, chromium, copper, lead and zinc were the elements / metals detected in Postipuisto and Kuninkaantammi area material samples and in Kuninkaantammi area stormwater.

Aluminum was detected in all but one of both Postipuisto and Kuninkaantammi area material samples and in all Kuninkaantammi area stormwater locations. Aluminum is widely used in construction. It is also the third most common element in soil, right after oxygen and silicon /7/.

Based on the study made by City of Helsinki in 2014 concentrations of aluminum in stormwater in residential areas varied between 370 and 3400 µg/l /28/. Compared to the study the aluminum concentrations detected in Kuninkaantammi area stormwater (400-1800 µg/l) are on a normal level. The source of aluminum in stormwater is probably both manmade and natural.

Chromium was found in four Postipuisto are and in five Kuninkaantammi area material samples and in two Kuninkaantammi stormwater locations, KT2 and KT3. No metallic parts or tools used in Kuninkaantammi site were analysed, but chromium was detected in paint for wooden outside surfaces and surface treatment agent for concrete. Typical background concentrations of chromium are less than 500 mg/kg in soil /9/. Based on the study made by City of Helsinki in 2009 the average natural background concentration of chromium in soil in Helsinki area parks and yards of apartment houses is around 15-65 mg/kg /8/ Based on the stormwater study concentrations of chromium in stormwater in residential areas varied between 1,4 and 65 µg/l /28/. Compared to the study the chromium concentrations detected in Kuninkaantammi area stormwater (<1,0-4,2 µg/l) are on a normal level. Part of chromium in stormwater may be natural of origin from surrounding soil and bedrock and part of it manmade from construction site.

Copper was found in six out of 10 Kuninkaantammi site material samples and in all stormwater locations. The highest concentration of copper 228 mg/kg was detected in material sample MAT_05, wooden terrace boarding. Copper is biostatic, meaning bacteria and many other forms of life will not grow on it /11/. It is possible that copper has been added into terrace boarding treatment agent to increase its resistance against bacteria and fungi. No information about terrace boarding manufacture was available to ensure this. In nature, copper occurs in a variety of minerals, including e.g. native copper, copper sulfides, copper carbonates. Typical background concentrations of copper do not exceed 150 mg/kg in soil /11/. Based on the study made by City of Helsinki in 2009 the average natural background concentration of copper in soil in Helsinki area parks and yards of apartment houses is around 10-30 mg/kg /8/. Based on the stormwater study concentrations of copper in stormwater in residential areas varied between 5 and 125 µg/l /28/. Compared to the study the copper concentrations detected in Kuninkaantammi area stormwater (4,8- 17 µg/l) are on a normal level. Part of copper in stormwater may be natural of origin from surrounding soil and part of it manmade from construction materials and parts.

Lead was found only in one Postipuisto area and one Kuninkaantammi area material sample. In sample MAT_18, surface treatment agent for concrete, the lead concentration was just above the laboratory's reporting limit. Also, in stormwater the detected lead concentrations were low. Lead has had numerous ways of usage since prehistoric times. Despite the fact lead is poisonous for human health and environment, it has many uses in the construction industry even today. Lead is used e.g. as roofing material, cladding, flashing, gutters and gutter joints, and roof parapets. Lead rarely occurs in its native, metallic form. It is generally combined with sulfur. Typical background concentrations of lead in soil do not exceed 100 mg/kg /12/. Based on the study made by City of Helsinki in 2009 the average natural background concentration of lead in soil in Helsinki area parks and yards of apartment houses is around 10-70 mg/kg /8/. Based on the stormwater study concentrations of lead in stormwater in residential areas varied between 0 and 15 µg/l /28/. Compared to the study the lead concentrations detected in Kuninkaantammi area stormwater (<0,5-1,4 µg/l) are on a normal level. The source of lead in stormwater seems to be other than construction materials, e.g. traffic or nature.

Zinc was found both in Postipuisto and Kuninkaantammi area material samples and in two Kuninkaantammi area stormwater locations, KT2 and KT3. Like lead, also zinc has been used for thousands of years for different purposes first as a zinc-copper alloy brass and later as a separate element. Zinc is most commonly used as an anti-corrosion agent, and galvanization i. e. coating of iron or steel, is the most familiar form /13/. In construction zinc is used e.g. in architectural applications for rainwater systems, cladding and roofing /14/. Typical background concentrations of zinc do not exceed 100 mg/kg in soil /13/. Based on the study made by City of Helsinki in 2009 the average natural background concentration of zinc in soil in Helsinki area parks and yards of apartment houses is around 20-90 mg/kg /8/. Based on the stormwater study concentrations of zinc in stormwater in residential areas varied between 14 and 170 µg/l /28/. Compared to the study the zinc concentrations detected in Kuninkaantammi area stormwater (<5-34 µg/l) are on a normal level. The source of zinc in Kuninkaantammi area stormwater is probably both manmade and natural.

When comparing metal concentrations in paints and flame retardants and wooden facades treated with the same agents, it is noticed that concentrations in pure agents are remarkably higher than in facades. The method of analysis affects this. Not only the paint, but also the surface layer of the wooden pieces was removed, which dilutes the concentrations.

Based on this study metals in construction materials are not considered to pollute surrounding environment and surface waters.

Organophosphate flame retardants

Organophosphate flame retardants were not found in Postipuisto or Kuninkaantammi area material samples, but in Kuninkaantammi area stormwater. Based on the material safety data sheets organophosphate flame retardants have not been used in materials in concern.

Tris(2-chloro-1-methylethyl)phosphate, TCPP, which was found in low concentrations in stormwater, is mainly used in the EU as a flame-retardant additive for polyurethane and in flexible foams for furniture /25/. Material sampling and analysis did not include polyurethane, but it has been used as a construction material in Kuninkaantammi area. Without further investigations the source of TCPP in stormwater cannot be verified.

PFAS (per- and polyfluoroalkyl substances)

PFAS compounds were found only in one material sample MAT_19, surface treatment agent for stone and concrete, which has been used in Postipuisto area. No PFAS compounds were detected in Kuninkaantammi area material samples, but they were found in all Kuninkaantammi area stormwater samples. According to the material safety data sheets PFAS compounds have not been used in materials in concern.

Based on the material analysis results the source of PFAS in Kuninkaantammi stormwater seems not to be the construction materials used on the site. Material of stormwater pipes and wells is hard plastic, but without further investigations it is not possible to determine the exact source of PFAS compounds in stormwater.

It needs to be noticed that the highest PFAS concentrations in Kuninkaantammi area stormwater were detected in sampling point KT1A, which is located closest to the construction site. Reporting limit of PFAS compounds in material samples was 1,0 - 10 µg/kg and in stormwater 0,3 - 1 ng/l. This means PFAS concentrations in stormwater were able to be analysed in a scale that is thousand times more accurate than the scale in material samples. The difference between the scales may have influenced the results.

Phthalates

Phthalates were found only in one material sample, MAT_17, paint for outside concrete surfaces, which has been used in Postipuisto area. No phthalates were detected in Kuninkaantammi area material samples, but they were found in two stormwater locations, KT2 and KT3 with low concentrations. According to the material safety data sheets phthalates have not been used in materials in concern.

Phthalates are used to make plastics more durable and due to that they are often called plasticizers. Material of Kuninkaantammi area stormwater pipes and wells is hard plastic, and it is possible that some plasticizers have been used in manufacturing process. Without further investigations it is not possible to determine the exact source of phthalates in Kuninkaantammi area stormwater.

As a whole, based on this study the potential exterior construction materials to pollute the environment and surface waters are paints, flame retardants and surface treatment agents for stone and concrete. Respectively potential polluting chemicals are isothiazolinones and PFAS compounds.

PFAS compounds were detected only in one material sample, MAT_19, surface treatment agent for stone and concrete, but because they were widely found in stormwater, they need to be named as potential pollutants. The source of PFAS compounds is most likely plastic stormwater piping and well materials. To ensure this, further investigations are recommended.

Conclusions

Due to the limited number of material and stormwater samples and laboratory analysis it is not possible to draw broad conclusions of the study.

Based on the limited study biocides, chlorinated paraffins, metals, phosphorus flame retardants and phthalates are not used in construction materials in such a scale that they pose a significant risk to the environment and surface waters.

The potential pollutants based on the concentrations found in pure construction materials are isothiazolinones used as biocides in exterior paints, flame retardants and surface treatment agents for stone and concrete. Though high concentrations of isothiazolinones were detected in pure agents, the concentrations in material samples and in stormwater were considerably lower. In fact, in stormwater the concentrations were below laboratory's reporting limit. Isothiazolinones are soluble to water, and they present high volatility. They are also sensitive to thermal and pH conditions leading to transformation/degradation of them. On what scale these characteristics have effect on the zero result in stormwater is an open question and an object of interest.

Potential pollutants of the environment and surface waters are also PFAS compounds. They were detected only in one material sample, but widely in stormwater, which proves the fact – PFAS is everywhere.

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Occurrence of substances of concern in construction materials in Tallinn

Construction material

BEF Estonia and city of Tallinn

Appendix 3

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NHC3 GoA2.1. Deliverable D.2.1

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Interreg Baltic Sea Region

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SUSTAINABLE WATERS NonHazCity 3

NonHazCity

Contents

Abstract

Organophosphorus flame retardants, per- and polyfluoroalkylated substances (PFAS), phthalates and other plasticizers, chlorinated paraffins, metals, styrene, HBCD, acrylonitrile and isothiazolinones were tested in selected 15 different construction materials. The purpose was to check the safety of these materials in order to use them in the construction of a new kindergarten as part of the NHC3 project. The laboratory analyses were performed by GALAB Laboratories Hamburg and SGS Institute Fresenius.

We didn't find PFAS in gypsum wallboards (external and internal) and in moisture-resistant fibreboard panel. We also didn't find flame retardants HBCD in polystyrene insulation plate and SCCP, MCCP in PVC floor coverings. We found new emerging chemicals organophosphorus flame retardants and plasticizers (other than phthalates): 3,7% of TCPP in polyurethane insulation plate and TBEP, TMCP in PVC floor covering materials; plasticizers DINCH (very large quantities, 13-20% in material), DEHT, DEHA in PVC floor coverings. We can say, that organophosphorus flame retardants have started to be used in certain materials and phthalates as plasticizers in the PVC flooring materials replaced by newer generation plasticizers (DINCH, DEHT, DEHA etc.).

Abbreviations

MIT	2-Methyl-4-isothiazolin-3-one
CIT	5-Chloro-2-methyl-4-isothiazolin-3-one
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	Perfluorobutanesulfonic acid
PFPeA	perfluoropentanoic acid
PFDeA	Perfluorodecanoic acid
PFDoA	Perfluorododecanoic acid
PFDoS	Perfluorododecanesulfonate
PFDS	Perfluorodecanesulfonate
PFOcDA	Perfluorooctadecanoic acid
PFOS	Perfluorooctansulfonate
PFOSA	Perfluorooctanesulfonamide
PFPeA	Perfluoropentanoic acid
PFPeS	Perfluoropentanesulfonate
PFTA	Perfluorotetradecanoic acid
PFTrA	Perfluorotridecanoic acid
PFUnA	Perfluoroundecanoic acid
PF-3,7-DMOA	Perfluoro-3,7-dimethyl octanoic acid
H4PFHxS	4:2 Fluortelomersulfonate
6:2 FTS	6:2 Fluortelomersulfonate
FTS	8:2 Fluortelomersulfonate
PFHxA	perfluorohexanoic acid
PFHpA	perfluoroheptanoic acid
PFOA	perfluorooctanoic acid
PFNA	perfluorononanoic acid
PFHxS	perfluorohexanesulfonic acid
PFCA	perfluorocarboxylic acid

PFSA	perfluorosulfonic acid
DMP	dimethyl phthalate
DEHP	diethylhexyl phthalate
DiBP	diisobutyl phthalate
TBAC	Tributyl-O-acetyl-Citrat
DEHT	Bis-(2ethylhexyl)-terephthalat
DEHA	Bis-(2ethylhexyl)—Adipat
DiDP	Di-iso-decyl-phthalat
TBEP	Tris-(2-butoxyethyl-phosphat
DINCH	1,2-Cyclohexanedicarboxylic acid, diisononyl ester
DPHP	Bis-(2-propylheptyl)-phthalate
DBP	dibutyl phthalate
TCPP	tris(2-chloro-1-methylethyl) phosphate
TCEP	Tris(2-chloroethyl) phosphate
TDCPP	Tris(1,3-dichloro-2-propyl) phosphate
TOCP	Tri-o-cresyl phosphate
TEP	Triethylphosphate
TBEP	Tris (2-butoxyethyl) phosphate
TPP	Triphenylphosphate
TEHP	Tris (2-ethylhexyl)-phosphate
TMCP	Tris-m-cresyl phosphate
TPCP	Tris-p-cresyl phosphate
SCCP	Short chain chlorinated paraffins
MCCP	Medium chain chlorinated paraffins
HBCD	Hexabromocyclododecane

Introduction

City of Tallinn and BEF EE compiled a wish-list of construction materials for chemical analyses together. The aim was to better check the safety of materials already used for one kindergarten (built in Tallinn, Estonia) and there was a wish to use them also in NHC3 project for the construction of a new kindergarten. We also wanted to check out some new materials.

Substance screening

Chemicals to be analysed were selected based on the existing knowledge and information of chemicals used in construction materials.

The following substances or substance groups were analysed: organophosphorus flame retardants, per- and polyfluoroalkylated substances (PFAS), phthalates and other plasticizers, chlorinated paraffins, metals, styrene, HBCD, acrylonitrile, isothiazolinones.

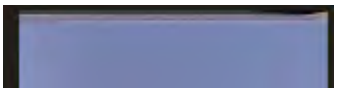
Methodology

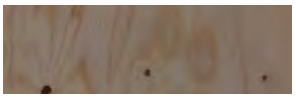
Sampling:

Material sampling in Tallinn was implemented by purchasing construction materials and mixtures from building materials stores or asking for samples from building materials producers' representatives in Estonia. In total there were 15 construction materials on the list.

More detailed information on which substances were specifically analysed from which building materials can be found in Table 1.

Table 1. List of construction materials and the chemical substances that were tested from these materials

Materials	Analysed substances
Polyurethane Insulation plate (external) 	Organophosphorus flame retardants
Polystyrene Insulation plate (external) 	Organophosphorus flame retardants, Styrene, HBCD, Acrylonitrile
Moisture-resistant fiberboard panel (Module suspended ceiling) 	Organophosphorus flame retardants, Per- and polyfluoroalkylated substances (PFAS)

Plywood Board 	Organophosphorus flame retardants
Cross laminated timber board (CLT) 	Organophosphorus flame retardants
MDF wall panel 	Organophosphorus flame retardants
Gypsum Wallboard (internal) 	Per- and polyfluoroalkylated substances (PFAS)
Gypsum Wallboard (external) 	Per- and polyfluoroalkylated substances (PFAS)
Acoustic glass wool board (acoustic ceiling) 	Metals
Acoustic glass wool board (frame wall) 	Metals
PVC Floor covering (1) 	Organophosphorus flame retardants, Chlorinated paraffins, Metals, Phthalates and other plasticizers

PVC Floor covering (2) 	Organophosphorus flame retardants, Chlorinated paraffins, Metals, Phthalates and other plasticizers
Tile Grout (universal grout for tiles and clinker)	Metals
Decorative Plaster (internal & external) 	Isothiazolinones
Wood Stain (external)	Isothiazolinones

Methods:

The laboratory analyses were performed by GALAB Laboratories Hamburg and SGS Institute Fresenius. Test methods were the following:

- Organophosphorus flame retardants: DIN EN 71-11 2006-01 (EN 71-9 for additional test scope); GC-MS/MS;

- Per- and polyfluoroalkylated substances (PFAS): SOP-487: 2023-06, LC-MS-MS;

- Phthalates and other plasticizers: SOP M 889 2015-01, GC-MS after extraction with toluene;

- Metals: SOP No 79:2021-11 (microwave-assisted digestion), DIN EN ISO 17294-2:2017-01, ICP-MS;

- Chlorinated paraffins (MCCP, SCCP): DIN EN ISO 18219 2015-09, GC-MS;

- Isothiazolinones: SOP No 625, 2022-06

- Styrene: Headspace-GC-MS, after addition of dimethylacetamide and internal standard D8-Toluene

- HBCD: GC-MS, SOP M 3441:2019-06

- Acrylonitrile: Headspace-GC-MS, after addition of dimethylacetamide and internal standard D8-Toluene

Results

Organophosphorus flame retardants

Material analysis of organophosphorus flame retardants included together 12 different chemicals used as flame retardants. Reporting limit was 5 mg/kg. Together 8 material samples were analysed. TCPP (37000) and TEP (23) were detected in polyurethane insulation plate (external); TBEP (35) in one PVC Floor covering and TMCP (17) in another PVC Floor covering. All other detected concentrations were below the laboratory's reporting limit.

Per- and polyfluoroalkylated substances (PFAS)

Material analysis of PFAS included together 27 different chemicals. Reporting limit was 1 µg/kg. Together 3 material samples were analysed. All the detected concentrations were below the laboratory's reporting limit.

Phthalates and other plasticizers

Material analysis of phthalates and other plasticizers included together 46 different chemicals. Reporting limit was 100 mg/kg. Two different PVC floor coverings were analysed. DiDP (410), DEHA (4100) and DEHT (5300) were detected in one sample. Very high DINCH concentrations were found in both samples – 130000 and 200000 respectively. Despite the manufacturer's declaration that its product does not contain phthalates, DiDP was detected in one PVC floor covering.

Metals

Material analysis of metals included lead, cadmium, chromium and mercury. Reporting limit was 0,1 mg/kg. Together 5 material samples were analysed. Detected concentrations were relatively low. Pb (18) and Cr (105) was detected in acoustic glass wool board (acoustic ceiling); Pb (21) and Cr (192) in acoustic glass wool board (frame wall). PVC floor coverings contained metals in the range Pb (0,6-1,6), Cr (2-3,8) and Cd (0,2). Tile Grout (universal grout for tiles and clinker) contained Pb (0,9) and Cr (23). Other detected metals were below the laboratory's reporting limit.

Chlorinated paraffins

Material analysis of chlorinated paraffins included short (C10-C13) and middle chained (C14-C17) chlorinated paraffins. Reporting limit was 50 mg/kg. Together 2 samples of PVC floor coverings were analysed. All the detected concentrations were below the laboratory's reporting limit.

Isothiazolinones

Isothiazolinones were analysed in 2 material samples. Reporting limit was 0,05 mg/kg. Detected concentrations were relatively low. MIT (0,32) and CIT (6,4) were detected in decorative plaster (internal & external) and MIT (0,44) and CIT (0,38) in wood stain (external).

Styrene, HBCD, Acrylonitrile

Styrene, HBCD and acrylonitrile were analysed in polystyrene insulation plate (external). Styrene 410 mg/kg was detected. Other detected concentrations were below the laboratory's reporting limit.

The results of testing are summarized in Tables 2(a) and (b).

Table 2 (a). Results of analyses of construction materials (n.d. = not detected)

Materials	Organophosphorus flame retardants (mg/kg)	Per- and polyfluoroalkylated substances (PFAS) (µg/kg)	Phthalates and other plasticizers (mg/kg)	Metals (mg/kg)	Chlorinated paraffins (mg/kg)
Polyurethane Insulation plate (external)	TCPP (37000) TEP (23)				
Polystyrene Insulation plate (external)	n.d.				
Moisture-resistant fiberboard panel	n.d.	n.d.			
Plywood Board	n.d.				
Cross laminated timber board (CLT)	n.d.				
MDF wall panel	n.d.				
Gypsum Wallboard (internal)		n.d.			
Gypsum Wallboard (external)		n.d.			
Acoustic glass wool board (acoustic ceiling)				Pb (18) Cr (105)	
Acoustic glass wool board (frame wall)				Pb (21) Cr (192)	
PVC Floor covering (1)	TBEP (35)		DiDP (410) DEHA (4100) DEHT (5300) DINCH (130000)	Pb (1,6) Cr (3,8)	n.d.
PVC Floor covering (2)	TMCP (17)		DINCH (200000)	Pb (0,6) Cr (2) Cd (0,2)	n.d.
Tile Grout (universal grout for tiles and clinker)				Pb (0,9) Cr (23)	

Table 2 (b). Results of analyses of construction materials (n.d. = not detected)

Materials	Isothiazolinones (mg/kg)	Styrene (mg/kg)	HBCD (mg/kg)	Acrylonitrile (mg/kg)
Polystyrene Insulation plate (external)		410	n.d.	n.d.
Decorative Plaster (internal & external)	MIT (0,32) CIT (6,4)			
Wood Stain (external)	MIT (0,44) CIT (0,38)			

Interpretation and discussion of results

As a result of chemical testing of selected by us construction materials, we did not find hazardous chemicals we were looking for in very large quantities. When preparing for the testing, we assumed that their amounts in the construction materials could be higher than our results showed.

We didn't detect such "classical" substances like PFAS in gypsum wallboards (external and internal) and in moisture-resistant fibreboard panel. We also didn't detect "old" flame retardants HBCD in polystyrene insulation plate and SCCP, MCCP in PVC floor coverings.

But we found new emerging chemicals like organophosphorus flame retardants or plasticizers (other than phthalates). We detected 3,7% of TCPP in polyurethane insulation plate; TBEP and TMCP in PVC floor covering materials. We found plasticizers DINCH, DEHT, DEHA in PVC floor covering materials, whereas DINCH was contained in very large quantities, 13-20% in this material.

Conclusions

We cannot draw broad conclusions because there were too few building materials and substances analysed. But, based on the results of this study, we can say, that certain panels or boards used in construction usually do not contain PFAS any more. Also, HBCD and MCCP, SCCP are not used as flame retardants any more.

Organophosphorus flame retardants have started to be used in certain materials instead of them. This result can be considered as expected since the "old" flame retardants will be replaced with "new" ones.

The old plasticizers (such as phthalates) in the flooring materials (PVC) have also started to be replaced by newer generation plasticizers like DINCH, DEHT, DEHA etc.

Annex

All results of chemical analyses of construction materials

Organophosphorus flame retardants

		Moisture-resistant fiberboard panel	**Polyurethane Insulation plate** (external)	**Polystyrene Insulation plate** (external)	**Plywood Board**	**Cross laminated timber board (CLT)**	**MDF wall panel**	**PVC Floor covering (1)**	**PVC Floor covering (2)**
	Reporting limit (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)
Tris(2-chloroethyl) phosphate (TCEP)	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Tris(1-chloro-2-propyl) phosphate (TCPP)	5	n.d.	37000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Tris(1,3-dichloro-2-propyl) phosphate (TDCPP)	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Tri-o-cresyl phosphate (TOCP)	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Trimethylphosphate	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Triethylphosphate (TEP)	5	n.d.	23	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Tributylphosphate	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Tris (2-butoxyethyl) phosphate (TBEP)	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	35	23

Triphenylphosphate (TPP)	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Tris (2-ethylhexyl)-phosphate (TEHP)	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Tris-m-kresylphosphate (TMCP)	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	17	n.d.
Tris-p-kresylphosphate (TPCP)	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

Chlorinated paraffins

		PVC Floor covering (1)	**PVC Floor covering (2)**
	Reporting limit (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)
Short chain chlorinated paraffins (SCCP)	50	n.d.	n.d.
Medium chain chlorinated paraffins (MCCP)	50	n.d.	n.d.

Per- and polyfluoroalkylated substances (PFAS)

		Moisture-resistant fiberboard panel (Module suspended ceiling)	**Gypsum Wallboard (internal)**	**Gypsum Wallboard (external)**
	Reporting limit (µg/kg)	Detected amount (µg/kg)	Detected amount (µg/kg)	Detected amount (µg/kg)
7H-Dodecanefluoroheptanoic acid (HPFHpA)	1	<1	<1	<1
Perfluorobutanoic acid (PFBA)	1	<1	<1	<1
Perfluorobutanesulfonate (PFBS)	1	<1	<1	<1
Perfluorodecanoic acid (PFDeA)	1	<1	<1	<1
Perfluorododecanoic acid (PFDoA)	1	<1	<1	<1
Perfluorododecanesulfonate (PFDoS)	1	<1	<1	<1
Perfluorodecanesulfonate (PFDS)	1	<1	<1	<1
Perfluoroheptanoic acid (PFHpA)	1	<1	<1	<1
Perfluoroheptanesulfonate (PFHpS)	1	<1	<1	<1
Perfluorohexanoic acid (PFHxA)	1	<1	<1	<1
Perfluorohexadecanoic acid (PFHxDA)	1	<1	<1	<1
Perfluorohexanesulfonate (PFHxS)	1	<1	<1	<1
Perfluorononanoic acid (PFNA)	1	<1	<1	<1
Perfluorononanesulfonate (PFNS)	1	<1	<1	<1
Perfluorooctanoic acid (PFOA)	1	<1	<1	<1
Perfluorooctadecanoic acid (PFOcDA)	1	<1	<1	<1

Perfluorooctansulfonate (PFOS)	1	<1	<1	<1
Perfluorooctanesulfonamide (PFOSA)	1	<1	<1	<1
Perfluoropentanoic acid (PFPeA)	1	<1	<1	<1
Perfluoropentanesulfonate (PFPeS)	1	<1	<1	<1
Perfluorotetradecanoic acid (PFTA)	1	<1	<1	<1
Perfluorotridecanoic acid (PFTrA)	1	<1	<1	<1
Perfluoroundecanoic acid (PFUnA)	1	<1	<1	<1
Perfluoro-3,7-dimethyl octanoic acid (PF-3,7-DMOA)	1	<1	<1	<1
4:2 Fluortelomersulfonate (H4PFHxS)	1	<1	<1	<1
6:2 Fluortelomersulfonate (6:2 FTS)	1	<1	<1	<1
8:2 Fluortelomersulfonate (FTS)	1	<1	<1	<1

Metals

		Acoustic glass wool board (acoustic ceiling)		**Acoustic glass wool board** (frame wall)		**PVC Floor covering (1)**	**PVC Floor covering (2)**	**Tile Grout** (universal grout for tiles and clinker)
	Reporting limit (mg/kg)	Detected amount (mg/kg)	Reporting limit (mg/kg)	Detected amount (mg/kg)	Reporting limit (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)
Lead (Pb)	0,1	18	0,4	21	0,1	1,6	0,6	0,9
Cadmium (Cd)	0,1	<0,1	0,4	<0,4	0,1	<0,1	0,2	<0,1
Chromium (Cr)	0,1	105	0,4	192	0,1	3,8	2	23
Mercury (Hg)	0,1	<0,1	18	<0,4	0,1	<0,1	<0,1	<0,1
Sum Cd/Cr/Hg/Pb	0,4	123	1,6	214	0,4	5,4	2,8	24

Phthalates and other plasticizers

		PVC Floor covering (1)	**PVC Floor covering (2)**
	Reporting limit (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)
Di-iso-butyl-phthalate (DIBP)	100	n.d.	n.d.
Di-n-butyl-phthalate (DBP)	100	n.d.	n.d.
n-Pentyl-iso-pentyl-phthalate (3 isomere)	100	n.d.	n.d.
Di-hexyl-phthalate (linear&branched) (DHexP)	100	n.d.	n.d.
Bis(2-ethylhexyl) phthalate (DEHP)	100	n.d.	n.d.
Benzyl-butyl-phthalate (BBP)	100	n.d.	n.d.
Di-n-octylphthalate (DnOP)	100	n.d.	n.d.
Di-iso-decyl-phthalate (DiDP)	100	410	n.d.
Di-undecyl-phthalate (DUP)	100	n.d.	n.d.
4-Nonylphenol	100	n.d.	n.d.
4-n-Octylphenol	100	n.d.	n.d.
4-n-Nonylphenol	100	n.d.	n.d.
Di-iso-pentyl-phthalate (iPeP)	100	n.d.	n.d.
n-Penthyl-iso-Penthyl-phthalate (nPeiPeP)	100	n.d.	n.d.
Di-n-penthyl-phthalate (nPeP)	100	n.d.	n.d.
Bis-(2-methoxyethyl)-phthalate (DMEP)	100	n.d.	n.d.
Di-n-hexyl-phthalate (DnHexP)	100	n.d.	n.d.
Di-iso-heptyl-phthalate (DiHeP)	100	n.d.	n.d.
Di-iso-nonyl-phthalate (DiNP)	100	n.d.	n.d.
Di-ethyl-phthalate (DEP)	100	n.d.	n.d.
Tri-ethyl-citrate (TEC)	100	n.d.	n.d.
Di-allyl-phthalate (DallP)	100	n.d.	n.d.
Di-butyl-sebacat (DBS)	100	n.d.	n.d.
Tri-butyl-citrate	100	n.d.	n.d.
Tri-butyl-0-acetyl-citrate (TBAC)	100	120	n.d.
Bis(2-ethylhexyl) adipate (DEHA)	100	4100	n.d.
Di-n-heptyl- phthalate (DnHepP)	100	n.d.	n.d.
Bis(2-ethylhexyl) terephthalate (DEHT)	100	5300	n.d.
Di-cyclo-hexyl phthalate (DCHP)	100	n.d.	n.d.
Di-iso-nonylcyclohexan-1-2-dicarboxylate (DINCH)	100	130000	200000
Bis-(2-propylheptyl)-phthalate (DPHP)	100	n.d.	n.d.

n-octyl-n-decyl phthalate (DnDP)	100	n.d.	n.d.
Di-propyl-phthalate (DPrP)	100	n.d.	n.d.
Di-iso-nonyl-adipate (DINA)	100	n.d.	n.d.
Di-iso-octyl-phthalate (DIOP)	100	n.d.	n.d.
Di-C6-C10-alkyl-phthalate	100	n.d.	n.d.
Di-mixed-decyl-hexyl-octyl-phthalate	100	n.d.	n.d.
Di-n-nonyl-phthalate (DNP)	100	n.d.	n.d.
Di-iso-hexyl-phthalate	100	n.d.	n.d.
Di-(C7-C11 alkyl) phthalate (linear & branched)	100	n.d.	n.d.
Dimethylterephthalate	100	n.d.	n.d.
2,2,4-trimethyl-1,3-pentandiol-diisobutyrate	100	n.d.	n.d.
4-tert-butylphenol	100	n.d.	n.d.
4-tert-pentylphenol	100	n.d.	n.d.
4-tert-octylphenol	100	n.d.	n.d.
4-n-heptylphenol	100	n.d.	n.d.

Isothiazolinones

		Decorative Plaster (internal & external)	**Wood Stain** (external)
	Reporting limit (mg/kg)	Detected amount (mg/kg)	Detected amount (mg/kg)
2-Methyl-4-isothiazolin-3-one (MIT)	0,05	0,32	0,44
5-Chloro-2-methyl-4-isothiazolin-3-one (CIT)	0,05	6,4	0,38

Styrene

	Polystyrene Insulation plate (external)	
	Reporting limit (mg/kg)	Detected amount (mg/kg)
	0,4	410

HBCD

	Polystyrene Insulation plate (external)
Reporting limit (mg/kg)	Detected amount (mg/kg)
50	n.d.

Acrylonitrile

	Polystyrene Insulation plate (external)
Reporting limit (mg/kg)	Detected amount (mg/kg)
1	n.d.

Occurrence of substances of concern in Baltic Sea Region buildings, construction materials and sites

Preschool air and dust
Storm water & Construction material
City of Västerås
Appendix 4

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NHC3 GoA2.1. D.2.1

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Contents

Abstract

Building materials may contain and emit substances that are hazardous to health and the environment. These substances can be found in indoor air and accumulate to dust particles indoors. Also, substances used on the exteriors of buildings may leach via rainwater to stormwater and other water bodies. This study was initiated to learn more about how these substances are spread indoors and in storm water.

Dust, floor materials, and indoor air were sampled in four preschools in Västerås, and storm water was sampled from four storm water ponds or ditches in Västerås. Screening of the samples included plasticisers, organophosphates, bisphenols, PFAS, biocides, chlorinated paraffins, brominated flame retardants, and more.

The results show that substances that today are regulated were found in higher concentrations in the older preschools, and alternative substances, such as alternative plasticisers, were found in higher concentrations in the newer preschools.

Electronic equipment, such as monitors and lighting, can emit flame retardants to the indoor environment.

Newer preschools had higher concentrations of VOCs, which can be expected as products emit more VOCs when they are new.

The concentrations of substances in storm water were in general rather low. Small catchment areas, dilution from nature water and vegetation could be some of the reasons. Presence of PFAS in stormwater is a concern.

The results should be viewed as snapshots and more screening is needed to get more knowledge of the presence of hazardous substances in the Västerås area.

Abbreviations

Definitions of all abbreviations that are used or mentioned in the report, for example different chemical substances.

6:2 FTS	6:2 fluorotelomer sulfonate
6:2/8:2 diPAP	6:2/8:2 diisopropylaminodiphenylamine
6:2diPAP	6:2 diisopropylaminodiphenylamine
6:2PAP	6:2 propoxylated phenol amine
6:6 PFPi	6:6 perfluoropolyethylene telomer isomer
6:8 PDPi	6:8 perfluorodecylpolyethylene telomer isomer
8:2 diPAP	8:2 diisopropylaminodiphenylamine
8:2FTS	8:2 fluorotelomer sulfonate
8:2PAP	8:2 propoxylated phenol amine
8:8 PFPi	8:8 perfluoropolyethylene telomer isomer
ATBC	Acetyltributylcitrate
BIT	Benzisothiazolinone
BVB	Byggvarubedömningen
BPA	Bisphenol A
BPAF	Bisphenol AF
BPF	Bisphenol F
BPS	Bisphenol S
BzBP	Benzylbutylphthalate
CIT	5-chloro-2-methyl-4-isothiazolin-3-one
CMIT	5-chloro-2-methyl-4-isothiazolin-3-one
DBP	Dibutyl phthalate
DCOIT	4,5-dichloro-2-n-octyl-4-isothiazolin-3-one
DecaBDE	Decabromodiphenyl ether
DEHA	Diethylhexyl adipate
DEHP	Diethylhexyl phthalate
DEHT	Diethylhexyl terephthalate
DEP	Diethyl phthalate
DiBP	Diisobutyl phthalate
DiDP	Diisodecyl phthalate
DINCH	Diisononylcyclohexane-1,2-dicarboxylate
DiNP	Diisononyl phthalate
diSamPAP	di-Sam-diisopropylaminodiphenylamine
DMP	Dimethyl phthalate
DnBP	Dibutyl phthalate
DPHP	Di(2-propylhexyl) phthalate
EHDPP	Ethylhexyldiphenyl phosphate
Et-FOSAA	Ethyl phosphate
FOOSA	Phosphonamide
FPePA	Fluorotelomerpropoxylated ethanolamine
HpBDE	Heptabromodiphenyl ether
HxBDE	Hexabromodiphenyl ether
LCCP	Long Chain Chlorinated Paraffins (C18-C21)

MCCP	Medium Chain Chlorinated Paraffins (C14-C17)
MIT	2-methyl-4-isothiazolin-3-one
MTBE	Methyl tert-butyl ether
NH4-N	Ammonium nitrogen
NO23-N	Nitrite and nitrate nitrogen
OIT	2-Octyl-2H-Isothiazol-3-One
p,p-DDT	Dichlorodiphenyltrichloroethane
PAH	Polycyclic aromatic hydrocarbons
PAH16	16 polycyclic aromatic hydrocarbons
PBDE 100	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyls
PCB7	7 polychlorinated biphenyls
PFAS	Per- and polyfluoroalkyl substances
PFBA	Perfluorobutanesulfonate
PFBS	Perfluorobutan-1-sulfonate
PFCA	Perfluorinated carboxylic acid
PFDA	Perfluorodecanoic acid
PFDoDA	Perfluorododecanoic acid
PFDS	Perfluorodecane-1-sulfonate
PFHpA	Perfluorohexanoic acid
PFHxA	Perfluorohexanesulfonate
PFHxS	Perfluorohexanesulfonate
PFNA	Perfluorononanoic acid
PFNS	Perfluorononanesulfonate
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonate
PFPeA	Perfluoropentanoic acid
PFPrA	Perfluoropropanoic acid
PFSA	Perfluorosulfonic acid
PFUnDA	Perfluoroundecanoic acid
PO4-P	Phosphorus
SCCP	Short Chain Chlorinated Paraffins (C10-C13)
TBBPA	Tetrabromobisphenol A
TBEP	Tris(2-butoxyethyl) phosphate
TBP	Tri-n-butyl phosphate
TBT	Tributyltin
TCEP	Tris(chloroethyl) phosphate
TCPP	Tris(2-chloro-1-methylethyl) phosphate
TCrP-mix	Trikresyl phosphate mixture
TDCPP	Tris[2-chloro-1-(chloromethyl)ethyl] phosphate (TDCPP)
TDCP	Tricresyl phosphate
TeBDE	Tetrabromodiphenyl ether
TEHP	Tris(2-ethylhexyl) phosphate
TiBP	Triisobutyl phosphate
TnBP	Trinonyl phosphate

ToCrP	Trioctyl phosphate
Total N	Total nitrogen
Total P	Total phosphorus
TOTM	Trioctyl trimellitate
TPhP	Triphenyl phosphate
TrBDE	Tribromodiphenyl ether
TVOC	Total volatile organic compounds
α-HBCDD	Alpha-hexabromocyclododecane
α-HCH	Alpha-hexachlorocyclohexane
β-HCH	Beta-hexachlorocyclohexane
γ-HBCDD	Gamma-hexabromocyclododecane
γ-HCH	Gamma-hexachlorocyclohexane

Introduction / Theoretical background

Building materials may contain and emit hazardous substances. These substances can be found in indoor air and accumulate to dust particles indoors. Substances used on the exteriors of the buildings may leach via rainwater to stormwater and water bodies. This study is made within the EU Interreg funded project NonHAzCity3, Work package 2.1 “Screening and monitoring of hazardous substance occurrence in building materials and sites”.

Children are extra sensitive to hazardous substances and City of Västerås has decided to build toxin free preschools. Materials in the preschools are logged in the Byggvarubedömningen (BVB) logbook, and the buildings are certified according to Miljöbyggnad Silver. Suppliers are instructed to choose building materials that are assessed as “Recommended” or “Accepted” by BVB.

In this study two new Miljöbyggnad Silver certified preschools were compared with two older preschools. The dust screening results would also be compared with dust screening performed by project partner City of Stockholm.

Stormwater was sampled and analysed to see the prevalence of hazardous substances from buildings in storm water. City of Västerås samples storm water regularly but has never analysed this wide spectrum of substances before.

The storm water results would also be compared with the results from project partners City of Helsinki, Turku University of Applied Sciences, and City of Stockholm.

Sampling and analysing are costly. The focus in this study was to learn which possible substances that can be found in preschools and stormwater. Analysing many different substances were prioritised before repetitive sampling. The results should be viewed as snapshots and more sampling is needed to get more predictable figures.

Substance screening

Hazardous chemicals were analysed in air, dust, materials, and stormwater.

Dust was sampled in two new preschools and two older preschools, with the aim to compare the substances found in newer and older preschools. Floor material samples were analysed for plasticisers and PFAS to see if substances in the floor also could be found in the dust.

VOC in air was sampled in the same four preschools.

Storm water was sampled from three ponds and ditches connected to newly developed areas, and from one pond receiving stormwater from an older areal. Table 1 describes the sampling matrix, number of samples and substances analysed.

Table 1, Sampling matrix

Matrix	Group of Substances
Dust, 4 preschools, 8 locations, 8 samples	Plasticisers (including phthalates and alternatives), organophosphates, bisphenols, PFAS, isothiazolinones, chlorinated paraffins, brominated flame retardants, organochlorine pesticides
Material, 2 preschools, 4 locations, 4 samples	Plasticisers, PFAS
Air, 4 preschools, 4 locations, 4 samples	VOCs
Storm water, 4 locations, 7 samples	Plasticisers (including phthalates and alternatives), organophosphates, PFAS, chlorinated paraffins, brominated flame retardants, biocides (including isothiazolinones), metals, nutrients, TBT, PCB, MTBE, PAH
Additional Storm water, 2 locations, 4 samples	PFAS

The dust substance group screening included plasticisers, organophosphates, bisphenols, PFAS, isothiazolinones, chlorinated paraffins, brominated flame retardants and organochlorine pesticides. Previous studies have shown the presence of these substances in indoor dust, and they can all be hazardous to health and environment. Their presence and health effects are well described in the NonHazCity3, Building material catalogue for tox-free construction (1).

Plasticisers are common in PVC floor material, and linoleum floors are sometimes treated with polish containing PFAS: Floor material samples were taken to study any correlations with plasticisers and PFAS in floor materials and dust.

Storm water screening included plasticisers, organophosphates, PFAS, isothiazolinones, chlorinated paraffins, brominated flame retardants, biocides, metals, nutrients, TBT, PCB, MTBE and PAH. Biocides are common in paints and wood treatment. Metals can leach from metal building materials but also from traffic. Nutrients and metals made it possible to compare the water status with reference water bodies, river Svartån and lake Mälaren.

TBT has been measured in lake Mälaren for many years. The main source of TBT in Mälaren is boat paint and the municipality runs a project convincing boat owners to remove TBT contaminated paint from their boats. TBT was analysed to check if there are other sources of TBT into Mälaren. PCBs are prohibited today but were chosen to ensure that these substances no longer pose problem in the selected catchment areas. MTBE, an additive in petrol, was included to indicate if the storm water was influenced by traffic. Some of the buildings in the catchment areas have tar paper roofs that could be sources of polyaromatic hydrocarbons, PAHs to the storm water.

Methodology

Sampling of dust, materials, and air in preschools

Sampling sites – preschools

Four preschools were chosen for the study. Two represent older preschools and two represent the newer concept preschools, certified by Miljöbyggnad Silver. Two dust samples and one VOC sample were taken at each preschool. Material samples were taken at the older preschools, in total two samples in two schools.

Bäckby Norra, Vas1 and Vas2

Bäckby Norra preschool was built in 1973 and is located in Bäckby neighbourhood five kilometres from the city centre. The façade is made of wood, and the interior floor materials are made of PVC and linoleum. The preschool allows children from 1 to 5 years old, with different groups made of up to 13 children. Dust samples were taken in the rooms “Ugglan” (Vas1) and “Torget” (Vas2). Ugglan is a smaller classroom with linoleum floor, where only one group of children can do activities, and Torget is a considerably bigger, multi-purpose common room, joint with a corridor and other classrooms. This room had a projector, a light table, and some other pedagogic lighting equipment. The school’s staff was instructed to not clean the room three to four weeks prior, in order to leave enough dust particles to carry out the samplings.

Torget and some common areas of the preschool were renovated somewhere between 1990 and 2000. The exterior wood panels were painted in 2018. Some classrooms, including Ugglan, were painted in 2018.

Önsta, Vas3 and Vas4

Önsta preschool is in the Önsta-Gryta neighbourhood, located five kilometres from the city centre. The school was completed in June 2018 and is built according to Västerås preschool concept model and Miljöbyggnad Silver certified. Wood covers the façade and the establishment develops on two levels, with two sections per floor. The dust samples were taken in two different rooms – one for each floor. The rooms were called “Kastanjen” (Vas3), upper floor, and “Björken” (Vas4), ground floor, and are comparable with Vas1 in terms of size and use. Both rooms have PVC floors (with alternative plasticisers) and wall mounted monitors. The school’s staff was instructed to not clean the room three to four weeks prior, in order to leave enough dust particles to carry out the samplings. Dust was collected behind the monitor in both rooms.

Blåsbo, Vas5 and Vas6

Blåsbo preschool is located rather central, just a few hundred meters from the main streets of Västerås. It is also a concept preschool and was completed in November 2018. It is very similar, almost identical to Önsta preschool with 8 child groups. The exterior brick façade is however different from Önsta. Blåsbo preschool is adjacent to a primary school. The samples were taken in two different rooms on the upper floor. The rooms were called: “Hamnen” (Vas5) and “Skeppet” (Vas6). The room Skeppet is like the rooms Kastanjen and Björken in Önsta preschool and have a wall mounted monitor. Hamnen, Vas5, is a larger multi-purpose common room, joint with other classrooms. Both rooms have PVC floors with alternative plasticisers. The school’s staff was instructed to not clean the room three to four weeks prior, to leave enough dust particles to carry out the samplings. Dust was not collected behind the monitor in Vas6. Vas5 has no monitor.

Vetterslund, Vas7 and Vas8

Vetterslund preschool, built in the middle of the 1960’, got renovated in 2005. This establishment contains five different aisles. The samplings were taken in two different rooms in the school: “Kaprifolen” (Vas7) and “The Green Room” (Vas8). Kaprifolen is adjacent to the main room where

the children eat, play, and do other activities. An electric cabinet is next to the Kaprifolen room. The rooms were equipped with PVC and/or linoleum flooring. The green room has a green textile carpet covering the floor. The school's staff was instructed to not clean the room three to four weeks prior, in order to leave enough dust particles to carry out the samplings.

The exterior of the preschool was painted about 2-3 years ago. The green room, Vas8, was also repainted during this time.

Dust sampling

Dust was collected with a vacuum cleaner with a specially designed nozzle with attached filter. New filters and nozzles were used for each sampling. Shelves, windowsills, and other surfaces approximately 0,5 meters above the floor were vacuumed.

Material sampling

Two material samples were taken at each of the older preschools, locations Vas1-2 and Vas7-8, to analyse plasticisers and PFAS, Table 2. No floor samples were taken at the newer preschools, Vas3-4 and Vas5-6, as floor material information is logged in Byggvarubedömningen, and information about the floor material and plasticisers were obtained from the projects' logbook.

Table 2, Material samples, locations and probable materials

Sample	Sample location	Probable material
Vas1	A room in connection to Vas1 room	PVC
Vas2	Vas2 room	PVC or linoleum
Vas7	A corridor in connection to Vas7	PVC
Vas8	Vas8 room	PVC or linoleum

Air sampling of VOCs

One passive air sampler was installed in each preschool, in the locations Vas1, Vas4, Vas6 and Vas8.

The samplers were installed approximately 2 meters above floor level, depending on where they could be out of reach from the children. After one week the samplers were closed, taken down and sent via mail to the consultant laboratory for analysis.

Storm water sampling

11 stormwater sample sets and one blank sample set were collected at 4 different locations: 2 at GO (Gotö), 2 at ST (Stomnät) (including 1 blank test), 6 at KA (Kartograf) (including 4 additional PFAS samples), and 1 at EL (Eriksborg/Erikslund). The locations are described in section Sampling sites – stormwater.

Samples were taken between October and December 2023. The two additional PFAS samples were taken at the KA location between the end of March and the beginning of April 2024. These extra samples aimed to assess how the stormwater in the catchment area was influenced by the buildings in the catchment area. Specifically, the two additional samples at KA were collected at the opposite ends of the catchment area, one at the inlet and one at the outlet. While the outlet sample, KAout, corresponded to the KA sampling site, the inlet sample, KAin, constituted a new location, and although still in the same catchment area, it technically increased the number of sampling sites to 5.

The sampling process involved two phases: Phase 1 involved preparing the bottles for sampling, and Phase 2 involved collecting the stormwater sample. Bottle preparation entailed thoroughly rinsing the bottles three times with pond water. Subsequently, the bottles were filled to the brim with pond water using an adjustable shaft for easy access. After promptly sealing the bottles with their

corresponding lids, marking the bottles with sampling point, water temperature and sampling time, they were placed inside a cooler bag along with four ice packs each to maintain the samples' temperature cool during transportation to the laboratory. The samples were transported to the laboratory for screening on the same day they were collected. This method was used for all samples except the samples for plasticisers. These sample bottles were stored in the freezer before being sent together to the laboratory for analysis. This analysis was made by another laboratory. All sample bottles were sent together to the laboratory in an insulated box via mail. Table 3 show the type of bottles used for each substance group.

A blank test was sampled at the ST sampling site. Bottles were filled with MilliQ water and sent to the laboratory for analysis, together with the other samples.

Table 3, Storm water sampling containers.

Substance	Analysed from	Bottle volume	Bottle material
Nutrients	All samples	500 ml	Plastic
Tributyltin	All samples	1000 ml	Glass
PAH	All samples	2 x 200 ml	Glass
PCB	All samples	2 x 200 ml	Glass
Brominated flame retardants	All samples	2 x 500 ml	Glass
MTBE	All samples	100 ml	Glass
PFAS	All samples	2 x 250 ml	Plastic
Metals	All samples	150 ml	Plastic
Isothiazolinones	Only KA2, ST2, GO2	100 ml	Glass
Biocides	Only KA2, ST2, GO2	2 x 1000 ml + 1 x 500 ml + 1 x 100 ml + 1 x 100 ml	Glass
Organophosphates	All samples	2 x 1000 ml	Glass
Chlorinates paraffins	Only EL, KA1, ST1, GO1	2 x 500 ml	Glass
Phthalates and alternative plasticisers	All samples	2 x 1000 ml	Nalgene PTFE

Sampling sites – stormwater

It was decided to sample stormwater from open ponds or ditches and five sampling sites were suggested in the beginning. One representing about 20 years old villas, one with recently built apartment blocks, and three younger sites where two of them were still under construction. During the time for sampling there was unfortunately not enough water in the storm water ditch from the apartment area, and this location had to be excluded from sampling. The chosen sampling sites are described below.

Eriksborg/Erikslund, EL

In the catchment area of the Eriksborg, previously called Erikslund, sampling site, (EL), there are separate resident villas, mainly built between 1997-2003, in the area of Eriksborg-Hagaberg. The facades of the houses are mainly wood panels, and the roofs are mainly made of concrete tiles, though other exterior materials are also present. The roads in the area are asphalted, and the yards of the houses are mainly traditional gardens with grass and bushes. The catchment area is approximately 40 hectares. This area is approximately five kilometres from Västerås city centre.

Sampling was conducted from a stormwater pond with continuous but slow water flow. Concrete pipes connect the ditches under a small road. Vegetation with trees and plants are established along the inflowing ditch and around the pond. Maps and drawings of the catchment are shown in Figure 1 and Figure 2.

Figure 1, Aereal photo of EL catchment area with sampling location. The catchment area is inside the red line and the red dot marks the sampling location.

Figure 2, Map of Eriksborg/Erikslund area. Red dot marks the sampling location..

Gotö, GO

The Gotö sampling site, (GO), is located in Barkarö area, about nine kilometres from Västerås city centre. The area is not yet fully established, with some completed houses, some not yet finished houses, a completed house with garden for persons with special needs and a preschool under

construction. The villas are mainly wooden villas with concrete tile roofs. The first building was built in 2020, but the majority of the houses were built in 2023. Some of the villas have a complete garden, some are under development. The roads are paved. The stormwater ditch has inflow from an agricultural field on one side and the new residential area on the other side. Sampling was taken at a small pond connected to the storm water ditch with a wooden construction that leads heavy water flows to a runoff field. The ditch is continuously filled with slow running water. The catchment area is approximately 5,5 hectares. Maps and drawings of the catchment are shown in Figure 3 and Figure 4.

Figure 3, Aereal photo of GO catchment area with sampling location. The catchment area is inside the red line and the red dot marks the sampling location.

Figure 4, Map of Gotö area. Red dot marks the sampling location..

Kartograf, KA

The catchment area of the Kartograf, KA, sampling site, has an area of approximately 4,1 hectares in Skälby area. It is mostly comprised of brand-new housing units, of which some are still under construction. Close to the sampling site, within the catchment area, there is also a small playground with synthetic grass cover. The major Kartograf sampling site, (KAout), consists of a stormwater swale with a dry buffer zone located southeast of the catchment area. Northwest of the catchment area is another storm water swale with dry buffer zone, (KAin). KAin receives water from forest and agricultural land north of the Kartograf catchment area. After entering the swale, the water runs under the catchment area to the outlet swale KAout. KA1 and KA2 were taken at the KAout location.

Additional PFAS samples were collected twice at KAin and KAout, to see if the buildings contribute with additional PFAS to storm water. The catchment area is located in Skälby neighbourhood, see Figure 5 and Figure 6.

Figure 5, Aereal photo of KA catchment area with sampling location. The catchment area is inside the red line and the red dot marks the sampling location. KAin is located northwest just outside the catchment area. The red dot indicates the sampling location for KA1, KA2 and KAout.

Figure 6, Map of Skälby and the KA catchment area.. Red dot marks the sampling location.

Stomnät, ST

The Stomnät sampling site, (ST), in Skälby area, is south of the KA sampling location. The storm water runs along an open ditch next to a small road in the catchment area. It continues underneath a pedestrian path and out into a small pond and further along the ditch. The outlet is closed off with a metal grate, to prevent trash and other materials to obstruct the water flow. The sampling took place in the pond, where water was accessible, see Figure 7 and Figure 8. The catchment area is approximately 9,7 hectares. The houses are mainly wooden houses with concrete roofs, built between 2012 and today.

Figure 7, Aereal photo of ST catchment area with sampling location. The catchment area is inside the red line and the red dot marks the sampling location.

Figure 8, Map of Skälby and ST area. Red dot marks the sampling location.

All map figures were prepared by Terese Renström, Mälarenergi.

Sampling conditions

The first set of samples was made in the end of October and beginning of November when the temperature was still above freezing point. Snow was covering the ground during the second sampling sets, and it was needed to remove the ice from the ST and GO locations before sampling. Table 4 describes weather conditions during sampling.

The EL1 organophosphate glass bottles broke during transport and new samples were taken for organophosphates, marked as EL1.1.

Table 4, Temperature and rainfall condition during sampling and previous 24 hours.

Sample	Date	Av temp. prev. 24h (°C)	Max. temp prev. 24h (°C)	Min. temp. prev. 24h (°C)	Water temp during sampl. (C)	Rain previous 24h (mm)	Rain during sampl. (mm)	Comment
KA1	2023-10-27	2,7	4,1	1,6	9	0	0	No snow or ice
ST1	2023-10-27	2,7	4,1	1,6	8	0	0	No snow or ice
Blank	2023-10-27	2,7	4,1	1,6	8	0	0	No snow or ice
GO1	2023-10-30	1,3	2,7	0,2	4	0,2	0	No snow or ice
EL1	2023-11-09	4,3	5,7	2,1	8	3	0	No snow or ice
EL1.1	2023-11-24	2,4	6,0	0,7	-	0	0	Only relevant for organo-phosphate sampling
ST2	2023-12-12	-0,3	0,5	-1,2	1	2	0	Snow and icy cover/ axe used to remove ice
GO2	2023-12-12	-0,3	0,5	-1,2	0,5	2	0	Snow and icy cover/ ice drill and axe used to reach water
KA2	2023-12-13	-2,3	-0,5	-3,0	2	0,8	0	Snow but no icy cover
KA3in	2024-03-28	5,1	10,5	1,3	5,9	0	0	No snow or ice/low water level
KA3out	2024-03-28	5,1	10,5	1,3	5,5	0	0	No snow or ice/low water level
KA4in	2024-04-08	8,9	14,5	2,4		0	0	No snow or ice
KA4out	2024-04-08	8,9	14,5	2,4		0	0	No snow or ice

Results

Results from dust screening in preschools

Following substances were found in the sampled dust. Two samples each were taken on four preschools. Locations are described in the section “Sampling sites – prescools”.

Plasticisers in dust

Phthalates and alternative plasticizer were found in all locations in the dust samples, see Table 5.

The older preschools, Vas1-2 and Vas7-8 had higher concentrations of DEHP, especially Vas1-2 with 235,59 and 784,39 µg/g respectively. The alternative plasticiser DEHT was the main plasticiser found in the newer preschools, Vas3-6. The older preschool Vas7-8 had lowest total concentrations of plasticisers, about 2-4 times lower than in the samples from the other preschools.

Table 5, Phthalates and alternative plasticizers in preschool dust (µg/g). Locations are described in Sampling Preschools – dust, material, and air.

(µg/g)	Vas1	Vas2	Vas3	Vas4	Vas5	Vas6	Vas7	Vas8
Phthalate esters								
DMP	0,014	0,009	0,018	0,005	0,102	0,029	<LoQ	<LoQ
DEP	0,87	0,28	0,14	0,18	0,08	<LoQ	0,13	0,13
DiBP	2,53	6,03	1,23	0,32	0,85	0,26	0,90	0,93
DnBP	15,65	25,24	1,54	0,76	1,68	0,34	4,83	6,75
BzBP	2,48	2,91	0,98	1,48	0,55	0,70	14,63	9,06
DEHP	235,59	784,39	28,60	37,11	14,70	19,42	107,15	69,01
DiNP	17,02	35,07	18,23	26,84	10,72	38,46	66,98	170,39
DiDP	11,82	17,41	23,28	22,30	21,73	28,57	19,89	44,28
DPHP	1,25	0,65	0,60	0,45	0,47	1,92	0,90	1,54
Alternative plasticisers								
ATBC	101	1,48	12,46	20,58	5,03	4,76	1,16	7,87
DEHA	21,78	2,04	4,02	3,53	1,47	2,46	3,49	6,49
DEHT	252,35	149,99	1015,35	823,06	871,30	938,59	22,55	71,11
DINCH	58,64	10,27	67,26	21,40	8,08	89,28	5,63	13,34
TOTM	4,18	0,29	0,65	0,37	2,48	3,50	0,55	19,79
Sum phthalates and alternative plasticizers	**725**	**1036**	**1179**	**958**	**939**	**1128**	**248**	**420**

PFAS in dust

PFAS was found in all locations, see Table 6.

A number of PFAS analysed were not detected in any of the dust samples: PFTrDA, PFTeDA, PFHxDA, PFODA, PFPrS, PFPeS, PFHpS, PFUnDS, PFDoDS, PFTrDS, FPrPA, FHpPA,, FHpPA, Gen-X, ADONA, 6:2 FTUA, 8:2 FTUA, 10:2 FTUA, PFOSA, FOSAA, Me-FOSAA. Vas1 and Vas2 showed much higher PFAS concentrations than the other locations, and Vas6 and Vas7 had the lowest concentrations. The substances 6:2PAP and 8:2PAP had the highest concentrations of all substances, 629,9 ng/g and

682,5 ng/g in the sample Vas2, however they were only found in six and four samples respectively. PFHxA, 6:2/8:2 diPAP and 8:2 diPAP were detectes in relatively high concentrations in several of the samples and were found in all samples.

Table 6, PFAS in dust in preschools (ng/g)

(ng/g)	Vas1	Vas2	Vas3	Vas4	Vas5	Vas6	Vas7	Vas8
PFPrA	2,458	7,543	0,201	2,056	10,192	1,572	3,362	1,710
PFBA	<LoQ	2,89	2,06	2,14	18,37	1,54	5,03	<LoQ
PFPeA	<LoQ	<LoQ	<LoQ	<LoQ	2,75	<LoQ	<LoQ	<LoQ
PFHxA	25,21	298,29	32,40	52,10	30,37	28,94	11,65	10,61
PFHpA	1,61	3,68	<LoQ	1,00	0,80	0,98	1,84	3,11
PFOA	3,32	7,87	0,54	0,78	1,03	<LoQ	4,65	2,83
PFNA	0,58	2,84	<LoQ	0,29	0,24	<LoQ	2,68	0,18
PFDA	1,98	4,66	0,62	1,51	2,37	<LoQ	3,29	2,13
PFUnDA	<LoQ	1,38	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ
PFDoDA	<LoQ	3,47	<LoQ	0,32	<LoQ	<LoQ	0,93	<LoQ
PFBS	<LoQ	<LoQ	3,22	3,54	0,78	<LoQ	<LoQ	<LoQ
PFHxS	0,80	0,82	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ
PFOS	2,74	6,38	<LoQ	<LoQ	<LoQ	<LoQ	1,27	1,67
PFNS	0,12	0,48	<LoQ	<LoQ	0,44	0,30	<LoQ	<LoQ
PFDS	<LoQ	4,90	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ
FPePA	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	0,09	<LoQ
6:2 FTS	0,37	1,23	0,17	0,57	0,35	0,16	0,23	0,89
8:2 FTS	1,83	8,68	0,16	0,45	0,88	0,21	0,50	2,24
Et-FOSAA	20,21	4,60	<LoQ	<LoQ	<LoQ	<LoQ	7,26	5,75
6:2PAP	555,84	629,90	33,99	<LoQ	18,95	<LoQ	4,48	22,89
8:2PAP	345,29	682,50	112,98	29,35	<LoQ	<LoQ	<LoQ	<LoQ
6:2diPAP	87,02	80,08	10,30	7,94	8,68	8,25	13,67	65,26
6:2/8:2 diPAP	132,51	105,45	2,15	2,58	2,08	1,55	6,40	4,12
8:2 diPAP	141,95	117,09	1,70	1,52	2,13	1,89	5,05	4,19
6:6 PFPi	0,39	21,89	<LoQ	<LoQ	0,95	0,57	<LoQ	<LoQ
6:8 PFPi	0,41	13,47	0,39	0,25	1,20	0,20	<LoQ	<LoQ
8:8 PFPi	0,15	1,18	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ
diSAmPAP	0,25	0,13	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ
Sum of PFAS	**1325**	**2011**	**201**	**106**	**103**	**46.1**	**72.4**	**128**

Organophosphates in dust

Organophosphate esters were found in all dust samples,see Table 7. TEP was analysed but under the detection limit. The samples Vas1-2 and Vas7-8 showed the highest results, between 56-201 µg/g, compared to Vas3-Vas6, where the concentrations only were between 3-6 µg/g. Highest concentrations were found for TCEP, TBEP and TEHP.

Table 8, organophosphate esters in preschool dust (µg/g)

(µg/g)	Vas1	Vas2	Vas3	Vas4	Vas5	Vas6	Vas7	Vas8
TiBP	0,0005	0,0016	<LoQ	<LoQ	0,0006	<LoQ	<LoQ	<LoQ
TnBP	0,0007	0,0020	0,0003	<LoQ	0,0017	0,0002	0,0082	0,0006
TCEP	5,53	141,45	0,29	0,34	0,13	0,11	51,42	75,55
TCPP	0,45	1,05	0,47	0,25	1,13	0,48	2,05	0,85
TDCP	0,28	4,40	1,13	0,40	0,23	0,32	0,55	1,87
TEHP	4,21	2,63	0,12	0,01	0,01	0,01	0,05	0,05
TBEP	82,70	51,08	2,48	0,41	0,30	0,28	1,02	1,13
TPhP	0,23	0,49	0,33	0,44	0,17	0,23	0,22	0,31
EHDPP	0,19	1,02	0,31	0,72	1,88	4,47	0,29	0,33
ToCrP	<LoQ	<LoQ	<LoQ	0,0005	0,0003	<LoQ	0,0004	0,0006
TCrP-mix	0,10	0,12	0,12	0,35	0,04	0,16	0,41	0,19
Sum organo-phosphates	**93**	**201**	**5**	**3**	**4**	**6**	**56**	**80**

Bisphenols in dust

Bisphenols were found in all samples, see Table 9. TBBPA showed highest concentration in all locations, between 60-98% of all detected bisphenols. Vas2 had the highest total concentration, 6300 ng/g, followed by Vas8 with 2400 ng/g. Vas4, Vas5, Vas6 and Vas7 had the lowest concentrations, 730 ng/g and below. BPAF was below the laboratory reporting limit in all samples.

Table 9, bisphenols in preschool dust (ng/g).

(ng/g)	Vas1	Vas2	Vas3	Vas4	Vas5	Vas6	Vas7	Vas8
BPF	<LoQ	9,30	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	3,77
BPA	142,24	162,21	23,70	29,28	15,39	40,01	85,81	123,83
BPS	<LoQ	17,30	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ
TBBPA	957	6057	1209	695	227	624	127	2298
Sum BPA and its analogues	**1100**	**6300**	**1200**	**730**	**250**	**660**	**220**	**2400**

Isothiazolinones in dust

Table 10 shows result for isothiazolinones in the dust samples. CMIT was analysed but not detected. Highest total concentrations were found in Vas4 with 4222 ng/g, followed by Vas5 and Vas 3, with 3541 ng/g and 2650 ng/g respectively. Lowest total concentration was found in Vas8 with 644 ng/g.

Table 10, isothiazolinones in preschool dust (ng/g)

(ng/g)	Vas1	Vas2	Vas3	Vas4	Vas5	Vas6	Vas7	Vas8
MIT	<LoQ	<LoQ	508	683	771	447	<LoQ	<LoQ
BIT	153	488	609	405	370	269	86,3	124
OIT	2064	1947	1533	3134	2400	1632	827	520
Sum Isothiazolinones	**2217**	**2435**	**2650**	**4222**	**3541**	**2348**	**914**	**644**

Chlorinated paraffins in dust

The results for chlorinated paraffins are shown in Table 11. Highest concentrations were found in Vas3 and Vas4, with concentrations of 154,3 and 185,9 µg/g respectively. Lowest concentrations were found in Vas5 and Vas6, with concentrations of 16,4 and 13,5 µg/g respectively.

Table 11, Chlorinated paraffins in preschool dust (µg/g).

(µg/g)	Vas1	Vas2	Vas3	Vas4	Vas5	Vas6	Vas7	Vas8
∑SCCPs (C10-C13)	41,4	38,2	47,8	45,4	1,73	1,45	28,2	23,1
∑MCCPs (C14-C17)	69,4	58,7	98,4	118	9,45	7,48	38,1	39,4
∑LCCPs (C18-C21)	23,1	21,4	8,11	23,4	5,23	4,52	8,53	9,11
Sum chlor.paraffins	133,9	118,3	154,3	186,9	16,4	13,5	74,8	71,6

Brominated flame retardants in dust

Brominated flame retardants in dust are presented in Table 12. β-HBCDD, PBDE 28, PBDE 47, PBDE 85, PBDE 99, PBDE 153, and PBDE 154 were analysed but were not detected. Highest concentrations were found in Vas7, 23,7 ng/g, followed by Vas2 with 2,00 ng/g. Lowest concentrations were detected in Vas3 and Vas4, with 0,61 and 0,75 ng/g respectively.

Table 12, Brominated flame retardants in dust(ng/g)

(ng/g)	Vas1	Vas2	Vas3	Vas4	Vas5	Vas6	Vas7	Vas8
α-HBCDD	1,74	1,52	0,52	0,64	1,00	0,85	4,27	0,86
γ-HBCDD	0,17	0,48	0,09	0,11	0,14	0,05	0,07	0,07
PBDE 100	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	19,4	<LoQ
Sum brom. flame ret.	**1,91**	**2,00**	**0,61**	**0,75**	**1,14**	**0,90**	**23,74**	**0,93**

Organochlorine pesticides in dust

Table 13 show organochlorine pesticides in dust. α-chlordane, β-chlordane, trans-Nonachlor and p,p-DDD were all under the detection limit. Highest concentrations were found in Vas7 and Vas8, with total concentrations of 127 and 217 ng/g respectively. No organochlorine pesticides were found in Vas2.

Table 13, Organochlorine pesticides in dust (ng/g).

(ng/g)	Vas1	Vas2	Vas3	Vas4	Vas5	Vas6	Vas7	Vas8
α-HCH	<LoQ	<LoQ	9,86	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ
β-HCH	5,90	<LoQ	25,0	<LoQ	<LoQ	<LoQ	<LoQ	143
γ-HCH	10,50	<LoQ	14,3	29,3	19,7	24,7	55,1	<LoQ
p,p-DDT	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	72,3	74,2
Sum org.chlor. pesticides	**16,4**	**0**	**49,2**	**29,3**	**19,7**	**24,7**	**127**	**217**

Results from floor material screening

Floor samples were taken at the locations Vas1, Vas2, Vas7 and Vas8, and were analysed for plasticisers and PFAS.

Plasticisers in materials

Plasticisers were found in all in floor materials and the results are shown in Table 13. Vas 8 and Vas 1 showed the highest concentrations of plasticisers in the material samples, 79349 and 71049 µg/g respectively, and Vas7 had the lowest concentration, 49 µg/g.

The locations Vas3, Vas4, Vas5 and Vas6 have identical floor products according to the projects' logbooks in Byggvarubedömningen (BVB). The floor product is the PVC-based floor Sarlon 15db. Material data for this floor was also retrieved from BVB. It contains 25 % Dioktyltereftalat (DEHT), which corresponds to 250000 µg/g, which was the highest concentration of plasticisers in floor materials, though this information was obtained with another method than the other samples. For the samples Vas 1-2 and Vas 7-8 DEHP, DiNP and DiDP were the plasticisers with the highest concentrations.

Table 14, Phthalates and alternative plasticizers in material (µg/g). Vas1-2 and Vas7-8 show result from collected dust analyses, and Vas3-6 shows information retrieved from the preschool building logbooks in Byggvarubedömningen. The same floor product is used in both preschools in the Vas3-4 and Vas5-6 locations.

(µg/g)	Vas1	Vas2	Vas7	Vas8		VAs3-6
Phthalates						
DMP	0,059	0,034	0,089	0,053		
DEP	4,1	2,5	0,92	2,1		
DiBP	21,8	55,7	5,8	142,9		
DnBP	370,2	150,5	24,7	111,5		
BBzP	829,4	81,3	1,6	2563,6		
DEHP	17753	14489	9,4	3229,1		
DiNP	39612	13421	3	70292		
DiDP	11091	1574,4	0,55	24,5		
DPHP	1155,4	237,5	0,051	28,3		
Alternative plasticizers						
ATBC	1,2	16,7	0,089	1,2		
DEHA	201,9	142,4	0,59	2951,3		
DEHT	3,5	72,6	0,026	1,6		250000
DINCH	5	162,2	2,4	0,94		
TOTM	0,56	1,1	<LoQ	0,068		
Sum phthalates and alternative plasticizers	**71049**	**30407**	**49**	**79349**		**250000**

PFAS in materials

PFAS were found in all floor samples, see Table 14. The following substances were analysed but below the limit of detection: PFPrA, PFPeA, PFUnDA, PFTrDA, PFTeDA, PFHxDA, PFODA, PFPrS, PFPeS, PFHpS, PFNS, PFUnDS, PFDoDS, PFTrDS, FPrPA, FPePA, FHpPA, Gen-X, ADONA, 6:2 FTUA, 8:2 FTUA, 10:2 FTUA, PFOSA, Me-FOSAA, 8:8 PFPi and diSAmPAP. Vas2 had the highest amount of PFAS in material and indoor air, 3182 ng/g, followed by Vas1 with 394 ng/g. Vas8 had the lowest concentration with 1,73 ng/g. 6:2PAP, 6:2/8:2 diPAP, 6:2diPAP, 8:2PAP, 8:2 diPAP and Et-FOSAA were the PFAS substances with highest concentrations. Of these, 6:2/8:2 diPAP were found in all material samples.

Table 15, PFAS in floor material (ng/g).

(ng/g)	Vas1	Vas2	Vas7	Vas8
PFBA	0,91	<LoQ	<LoQ	<LoQ
PFHxA	12,21	5,82	0,18	1,21
PFHpA	1,01	2,59	<LoQ	<LoQ
PFOA	1,68	5,8	<LoQ	<LoQ
PFNA	0,56	0,86	0,51	0,24
PFDA	<LoQ	2,31	<LoQ	<LoQ
PFDoDA	0,67	1,34	<LoQ	<LoQ
PFBS	0,2	<LoQ	<LoQ	<LoQ
PFHxS	0,54	0,53	<LoQ	<LoQ
PFOS	2,24	24,46	<LoQ	<LoQ
PFDS	1,62	11,1	<LoQ	<LoQ
6:2 FTS	0,11	<LoQ	<LoQ	<LoQ
8:2 FTS	<LoQ	0,63	<LoQ	<LoQ
FOSAA	<LoQ	3,47	<LoQ	<LoQ
Et-FOSAA	17,76	198	2,26	<LoQ
6:2PAP	146,01	802	<LoQ	<LoQ
8:2PAP	121,05	470	<LoQ	<LoQ
6:2diPAP	27,87	602	14,39	<LoQ
6:2/8:2 diPAP	27,85	682	13,66	0,28
8:2 diPAP	31,76	369	7,55	<LoQ
6:6 PFPi	<LoQ	0,45	<LoQ	<LoQ
6:8 PFPi	<LoQ	0,21	<LoQ	<LoQ
Sum of PFAS	**394**	**3182**	**38,5**	**1,73**

Results from Indoor air

VOCs in indoor air

Table 15 shows VOCs detected in the samples. Following VOCs were below the laboratory reporting limit in all samples: Benzene, m-xylene, 1,3,5-trimethylbenzene, 1- octen-3-ol, Naphthalene and Total-nonanol. Formaldehyde was not included in the analysis. Vas6 had the highest concentrations of VOCs, with 110 µg/m3 followed by Vas1 with 85 µg/m3. 2-ethylhexanol was the most prevalent substance and highest concentrations were found in Vas6 followed by Vas4.

Table 16, VOC in indoor air in toluene equivalents (µg/m3).

Toluene equivalents (µg/m3)	Vas1	Vas4	Vas6	Vas8
n-decane	<LoQ	<LoQ	<LoQ	0,7
α-Pinene	2,5	3,8	3,1	0,9
Toluene	0,9	1,3	1,1	2,5
n-hexanal	5,1	5,4	4,5	1,9
n-butanol	1,7	1,4	3,2	6,7
3-carene	1,6	2,4	1	<LoQ
Limonene	4,4	2	1,4	<LoQ
2-ethylhexanol	7,9	26	45	7,2
Benzyl alcohol	<LoQ	<LoQ	0,6	<LoQ
2,2,4-trimethyl-1,3-pentanediol diisobutyrate (TXIB)	<LoQ	2,4	<LoQ	2,2
TVOC* (Total VOC) Toluene equivalents:	**85**	**72**	**110**	**52**

Results from storm water sampling

Storm water samples were taken in 4 locations. One sample was taken at location EL, and two samples were taken at locations KA, ST and GO. More details about the sampling sites are described in the section Storm water sampling. Nutrients, metals, PFAS, and plasticisers were found in all samples. Pesticides and organophosphates were only found in a few samples. The blank sample tests showed concentrations of zinc and plasticisers, no other substances were detected in the blank sample.

Chlorinated paraffins, PCBs, TBT, MTBE PAHs and isothiazolinones were analysed but not detected in any sample.

Nutrients in storm water

Nutrients were found in all locations; the results are shown in Table 16. Total nitrogen was rather similar in all samples. No nutrients were found in the blank sample.

Table 17, Nutrients in storm water.

(mg/l)	EL	KA1	KA2	ST1	ST2	GO1	GO2
NH4-N	<LoQ	0,026	0,017	0,035	0,026	0,035	0,054
PO4-P	0,061	0,068	0,058	0,051	0,049	0,13	0,15
Total P	0,085	0,078	0,065	0,055	0,07	0,12	0,14
Total N	0,87	0,79	0,6	0,65	0,8	0,67	0,74
NO23-N	0,16	0,27	0,11	0,31	0,36	0,34	0,37

Metals in storm water

Metals were found in all samples, se Table 17. The EL sample had the highest total metal concentrations (19 µg/l). The other six samples were rather similar in concentrations and profiles, with some variations for cadmium and zinc. Barium was the metal with highest concentration in all sampling sites, followed by zinc and copper. The blank sample contained some zinc.

Table 18, Metals in storm water (µg/l). Note that the blank test contained some zinc.

(µg/l)	EL	KA1	KA2	ST1	ST2	GO1	GO2	Blank
Arsenik	1,2	0,65	0,49	0,63	0,47	0,62	0,65	<LoQ
Barium	27	27	20	24	21	26	23	<LoQ
Lead	2,7	0,31	0,73	0,37	0,62	0,36	0,35	<LoQ
Cadmium	0,044	0,051	0,039	<LoQ	<LoQ	0,05	0,048	<LoQ
Cobolt	0,77	0,18	0,45	0,22	0,32	0,26	0,25	<LoQ
Copper	7,8	3,9	3,4	2,9	3,1	2,7	4,1	<LoQ
Chrome	3,6	0,65	1,3	0,73	1,2	0,63	0,64	<LoQ
Nickel	4,4	2,6	2,6	2	2,2	1,8	1,8	<LoQ
Vanadin	5,3	1,2	1,5	1,4	1,7	1,4	1,5	<LoQ
Zink	19	11	10	5,2	7,3	<LoQ	3,9	3

Organophosphates in storm water

Only one organophosphate, tri(1.3-dikloro-isopropyl) Phosphate (TDCPP) was detected, in only one sample, ST2, see Table 18. TBP, TEHP, TBEP, TCEP and TCPP were analysed but under the detection limit.

No organophosphates were found in the blank sample.

Table 19, Organophosphate in storm water (µg/l).

(µg/l)	EL	KA1	KA2	ST1	ST2	GO1	GO2
TDCPP	<LoQ	<LoQ	<LoQ	<LoQ	0,026	<LoQ	<LoQ

Biocides in storm water

Three samples were taken for analysing of pesticides. 53 pesticides were analysed, but only seven were detected in the analyses. The following substances were analysed to be below the detection limit: 2,4-dichlorophenoxy acid, Atrazine, BAM (2,6-dichlorobenzamide), Bifenox, Bitertanol, Cyanazine, Desethylatrazine, Desisopropylatrazine, 2,4-dichloroprop, Dimethoate, Diuron, Etofumesate, Fenoxaprop, Fluroxipyr, HCH-gamma (Lindan), Hydroxyatrazine, Isoproturon, Chloridazone, Kvinmerak, MCPA, Mecoprop, Metamitrone, Metazachlor, Metribuzin, Metsulfuronmetyl, Simazin, Terbuthylazin, Thifensulfuronmetyl, Tribenuronmetyl, ETU (Etylentiourea), Desethyldesisopropylatrazine, Desethylterbutylazine, Desphenylchloridazone, Pirimicarb, Azoxystrobin, Metalaxyl, Imidacloprid, Boskalid, Amidosulfuron, DMST, Fluopicolide, Carbendazim, Propoxicarbazone-Na, Terbutryn, Thiamethoxam and Triallate. No blank sample was taken for pesticides.

Table 19 shows pesticides detected in one or more samples. No pesticides were detected in KA2. Six pesticides were detected in GO2 sample and two in the ST2. No blank sample was taken for pesticides.

Table 20, Pesticides in stormwater (µg/l).

(µg/l)	KA2	ST2	GO2
AMPA	<LoQ	0,016	0,048
Bentazone	<LoQ	<LoQ	0,011
Glyphosate	<LoQ	<LoQ	0,039
Clopyralid	<LoQ	<LoQ	0,036
Hydroxyterbutylazine	<LoQ	0,011	<LoQ
DMS (N,N-dimethylsulfamide)	<LoQ	<LoQ	0,015
Propiconazole	<LoQ	<LoQ	0,011
Sum Pesticides	**<LoQ**	**0,027**	**0,16**

PFAS in storm water

PFAS substances were detected in all samples and the results are shown in Table 20. Branched PFOA, PFDA, PFDA, PFUnDA, PFDoDA, PFTrDA, PFDS, PFOSA, PFPeS, PFHpS, PFNS, PFUnDS, PFDoDS and PFTrDS were analysed but below detection limit.

PFBA had the highest concentrations in nearly all samples, followed by linear PFOA. EL and KA1 had the highest total concentrations, 13 and 14 ng/l.

Table 21, PFAS in storm water (ng/l).

(ng/l)	EL	KA1	KA2	KA3 in	Ka3 out	KA4 in	KA4 out	ST1	ST2	GO1	GO2
PFBA	6,4	7,3	4,8	<LoQ	0,32	3,7	3,5	3,2	1,9	4,1	1,4
PFPeA	<LoQ	1,8	<LoQ	<LoQ	0,33	0,45	0,47	1,5	0,92	<LoQ	0,37
PFHxA	1,2	1,1	0,99	<LoQ	<LoQ	0,62	0,46	0,89	0,79	<LoQ	0,32
PFHpA	1	0,77	0,61	<LoQ	<LoQ	0,47	0,53	0,81	0,41	<LoQ	0,32
PFOA, linear	1,6	1,4	1,5	0,31	<LoQ	<LoQ	0,35	1,1	0,7	0,76	0,42
PFNA	0,5	<LoQ	<LoQ	1,4	0,66	1,1	1,7	<LoQ	<LoQ	<LoQ	<LoQ
PFBS	0,51	0,47	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ	0,5	0,35	<LoQ	0,36
PFHxS	0,41	0,32	<LoQ	<LoQ	<LoQ	0,74	1	<LoQ	<LoQ	0,97	0,63
PFOS, branched	0,61	0,48	0,48	<LoQ	<LoQ	0,45	0,38	0,37	0,48	<LoQ	0,23
PFOS, linear	0,79	0,27	<LoQ	0,43	0,42	0,37	0,49	<LoQ	0,83	<LoQ	0,33
6:2 FTS	<LoQ	<LoQ	1,1	<LoQ	<LoQ	0,37	<LoQ	<LoQ	<LoQ	<LoQ	<LoQ
PFOA, total	1,6	1,4	1,5	<LoQ	<LoQ	<LoQ	<LoQ	1,1	0,7	0,76	0,42
PFOS, total	1,4	0,75	0,48	1,7	0,66	1,1	2,1	0,37	1,3	<LoQ	0,56
Total 4 PFAS LB	**3,9**	**2,5**	**2**	**0,43**	**0,42**	**0,74**	**0,49**	**1,8**	**2**	**1,7**	**1,6**
Total 11 PFAS LB	**13**	**14**	**9,5**	**2,1**	**0,66**	**2,3**	**3**	**8,7**	**6,4**	**5,8**	**4,4**
Total 21 PFAS LB	**13**	**14**	**9,5**	**2,1**	**1,7**	**8,3**	**8,9**	**8,7**	**6,4**	**5,8**	**4,4**
Total 22 PFAS LB	**13**	**14**	**9,5**	**2,1**	**1,7**	**8,3**	**8,9**	**8,7**	**6,4**	**5,8**	**4,4**

Plasticisers in storm water

Plasticisers, phthalates and phthalate alternatives, were found in all samples, even in the blank sample, see Table 21. The phthalate DiDP and the alternative plasticiser DEHA were analysed but not detected. Highest total concentrations were found in samples for KA1, 169 ng/l and EL 138 ng/l. DEP, DiBP, DnBP, DPHP, ATBC and TOTM were found in the blank test sample. EL, KA1 and ST2 had higher total concentrations than the blank test.

Table 22, Plasticisers in storm water (ng/l).

(ng/l)	EL	KA1	KA2	ST1	ST2	GO1	GO2	Blank test
Phthalates								
DMP	6,68	1,46	0,988	1,34	2,74	3,94	2,91	<LoQ
DEP	19,4	6,27	<LoQ	5,22	4,7	7,05	7,25	5,4
DiBP	5,46	<LoQ	<LoQ	<LoQ	3,93	<LoQ	<LoQ	5,2
DnBP	<LoQ	<LoQ	<LoQ	<LoQ	16,7	<LoQ	<LoQ	27,8
BzBP	0,264	<LoQ	<LoQ	<LoQ	0,329	<LoQ	<LoQ	<LoQ
DEHP	<LoQ	46,6	<LoQ	<LoQ	13,8	<LoQ	<LoQ	<LoQ
DiNP	75,5	<LoQ	<LoQ	3,8	3,06	<LoQ	<LoQ	<LoQ
DPHP	<LoQ	107	17,5	13,2	8,59	8,11	2	3,53
Alternative plasticisers								
ATBC	23,3	7,47	5,65	1,81	6,54	7,45	24,6	8,08
DEHT	3,34	0,495	9,56	0,932	1,58	0,595	1,07	<LoQ
DINCH	3,83	<LoQ	<LoQ	2,79	1,64	1,63	12,8	<LoQ
TOTM	<LoQ	<LoQ	5,8	0,391	<LoQ	<LoQ	<LoQ	0,83
Sum phthalates and alternative plasticizers	**138**	**169**	**39,5**	**29,5**	**63,6**	**28,8**	**50,6**	**50,8**

Not detected substances in storm water

Brominated flame retardants, chlorinated paraffins, tributyl tin (TBT), PCBs, petroleum products, polyaromatic hydrocarbons and isothiazolinones were sampled in stormwater but were not detected in any sample.

Brominated flame retardants

All of the analysed flame retardants, DekaBDE, HxBDE, HxBDE, PnBDE, PnBDE, TeBDE, TrBDE and HpBDE were below detection limit in the seven samples.

Chlorinated paraffins

No Short chained (SCCP) nor medium chained (MCCP) chlorinated paraffins were detected in the storm water samples. Chlorinated paraffins were sampled in EL1, KA1, ST1 and GO1.

Tributyl tin (TBT)

TBT was not detected in the storm water samples.

PCBs

The seven samples were analysed for PCB-101 Pentachlorobifenyl, PCB-118 Pentachlorobifenyl, PCB-138 Hexachlorobifenyl, PCB-153 Hexachlorobifenyl, PCB-180 Heptachlorobifenyl, PCB-28 Trichlorobifenyl, PCB-52 Tetrachlorobifenyl, and all samples were below detection limit.

Petroleum Products/Oil (MTBE)

No MTBE was detected in the storm water samples.

Polyaromatic Compounds, PAH

The storm water samples were analysed for Acenaften, Acenaphthylene, Naphthalene, Anthracene, Phenanthrene, Fluoranthene, Fluorene, Pyrene, Benzo(a)anthracene, Benzo(a)pyrene, benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(ghi)perylene, Chrysene + Triphenylene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyren. All samples were below limit of detection.

Isothiazolinones

Isothiazolinones were included in the second sampling round, in the KA2, ST2 and GO2 samples. BIT, CIT, DCOIT, MIT and OIT were analysed but not detected in any sample.

Interpretation and discussion of results

The aim of this study was to learn more about possible substances emitting from buildings and especially from preschools in Västerås. The focus was to get a wide view to receive indications of occurring substances and the results should be seen as snapshots. Conclusions are based on the results from this study and comparisons with previous studies.

Interpretations of indoor dust, materials, and air screening

Initial expectations

The aim of the dust sampling was to compare substances in dust from older preschools and newer preschools. The newer preschools, Vas3-Vas6, are certified according to Miljöbyggnad Silver and the products are logged in the Byggvarubedömningen logbook. Therefore, it was expected to see lower substance concentrations in the newer than in the older preschools. It was also expected that substances found in materials from a preschool would be found in the dust of the same room. It was also expected that the substances and concentrations would be similar with the results from previous dust sampling in Stockholm (2) (3) (4).

Conclusions

Conclusions from dust and material screening

Compared with previous studies analysing dust in preschools, (3) (5) (6), the results in this study are within the same range (7). The results for each substance are discussed below.

Plasticisers in dust and materials

It was expected to find plasticisers from the floor material also in the sampled dust in the same preschool. The concentrations of regulated phthalates were expected to be lower in the newer preschools than in the older preschools.

Plasticisers in dust and material are presented in Figure 9 and Figure 10. When comparing these figures, it is visible that the substance concentrations in dust mirror the substance concentrations in the floor materials. The preschool represented by Vas7-8, an older preschool, had the lowest concentration of plasticisers in dust.

DEHP and DiNP in PVC floors are today replaced by alternative plasticisers such as DEHT. This is seen in the newer preschools, samples Vas3-4 and Vas5-6, where both material and dust have higher concentrations of DEHT than the older preschools.

The Vas1 and Vas7 floor material samples were taken from floors with a folded edge against the wall, which is a common installation for PVC floors, why it is surprising that Vas7 had the lowest concentrations of phthalates. The concentrations in Vas1, 71049 µg/g, equals to 7,1%, were also lower than expected. Previous studies (8), found phthalate concentrations between 14-70% for PVC floors installed between 1977-1980.

Besides the floor material, other possible sources of phthalates in buildings are lighting, cables, coatings and sealants (1). Products used in preschool activities can also contribute to plasticisers in the dust. For example, plastic toys and dolls are often made of PVC. Older resting mattresses can contain phthalates that are regulated today. However, between 2017 and 2021, all preschools within Västerås municipality replaced their older mattresses for PVC- and phthalate free alternatives.

It is a positive sign that the concentrations of regulated phthalates, such as DEHP, are much lower in the newer preschools. However, it is a concern that the concentrations of alternative plasticisers, such as DINCH and DEHT are higher in the newer preschools.

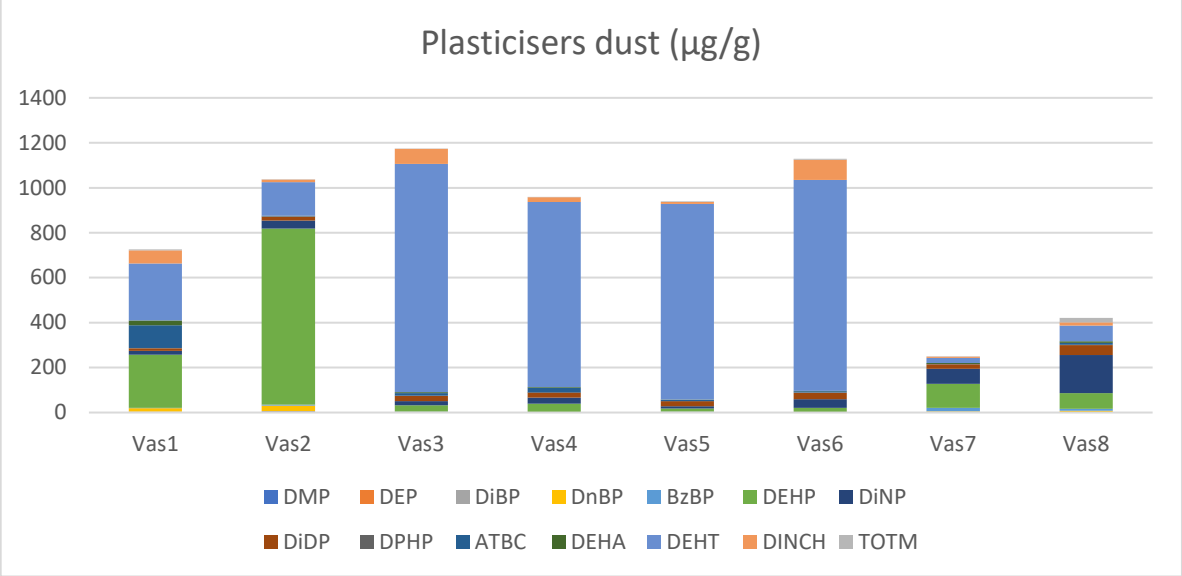

Figure 9, Plasticisers in dust samples.

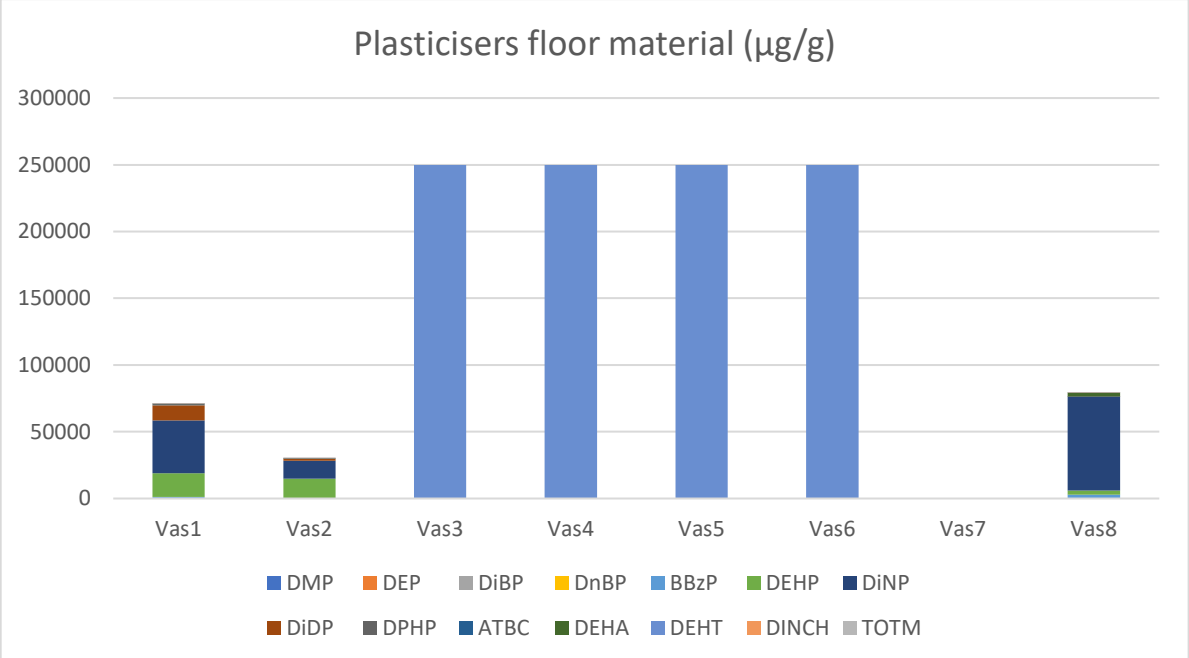

Figure 10, Plasticisers in materials according to material samples, Table 5, and data obtained from Byggvarubedömningen, see the section Material sampling.

PFAS in dust and materials

PFAS is present everywhere and it was expected to find PFAS in all samples. For example, de la Torre A. et al. (9) have described PFAS in dust in houses from three European cities. There was also a suspicion that especially linoleum floors could have the highest concentrations of PFAS, unintentionally added via floor care products.

It was surprising to see that the preschool represented by Vas1 and Vas2 had much higher concentrations of PFAS in dust than the other locations. The substance patterns in the sampled floor

materials for Vas1 and Vas2 are more or less similar to the dust substances patterns for Vas1 and Vas2, see Figure 11 and Figure 12. There is also a correlation between PFAS substances in the Vas7 floor and dust samples, though not as visible in the graphs. The five substances with the highest concentrations in the Vas7 dust sample were all included in the six PFAS-substances that were detected in the Vas7 material sample. 6:2diPAP had the highest concentrations in both material and dust.

It is therefore assumed that the PFAS detected in the dust can be sourced from the floor material. Preliminary results from another not yet published screening project have shown similar results with elevated concentrations of PFAS in some floor and dust samples. More studies on PFAS in floor materials are needed.

The PFAS in the floor material might have been added unintentionally during cleaning and floor care. In Vas1-2 and Vas7-8, old floor polish was removed between 2014 and 2017 and new base primer and wax was added on the floor surface. Floor care products may contain PFAS and is a very probable source of PFAS in the floors.

According to the NonHazCity3. Building material catalogue for tox-free construction (1)., other sources of PFAS in buildings are textiles, carpets and upholstery, wood boards, OSB and chipboards, wooden insulation, electrical and electronic equipment, linoleum, laminated floor covering, plastic piping, insulation materials and foams, paints, plaster, coatings, sealants, and architectural foil. Contaminants of PFAS can also be found in recycled materials (1).

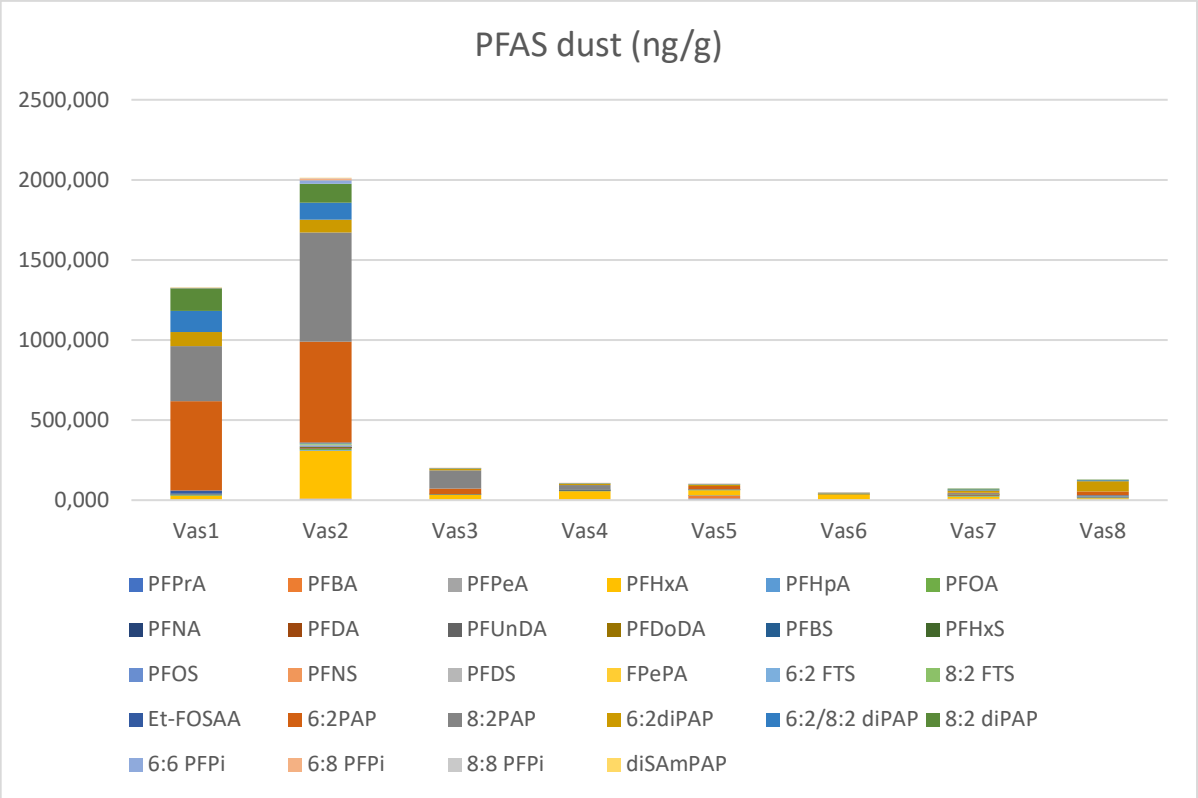

Figure 11, PFAS in dust, according to Table 6.

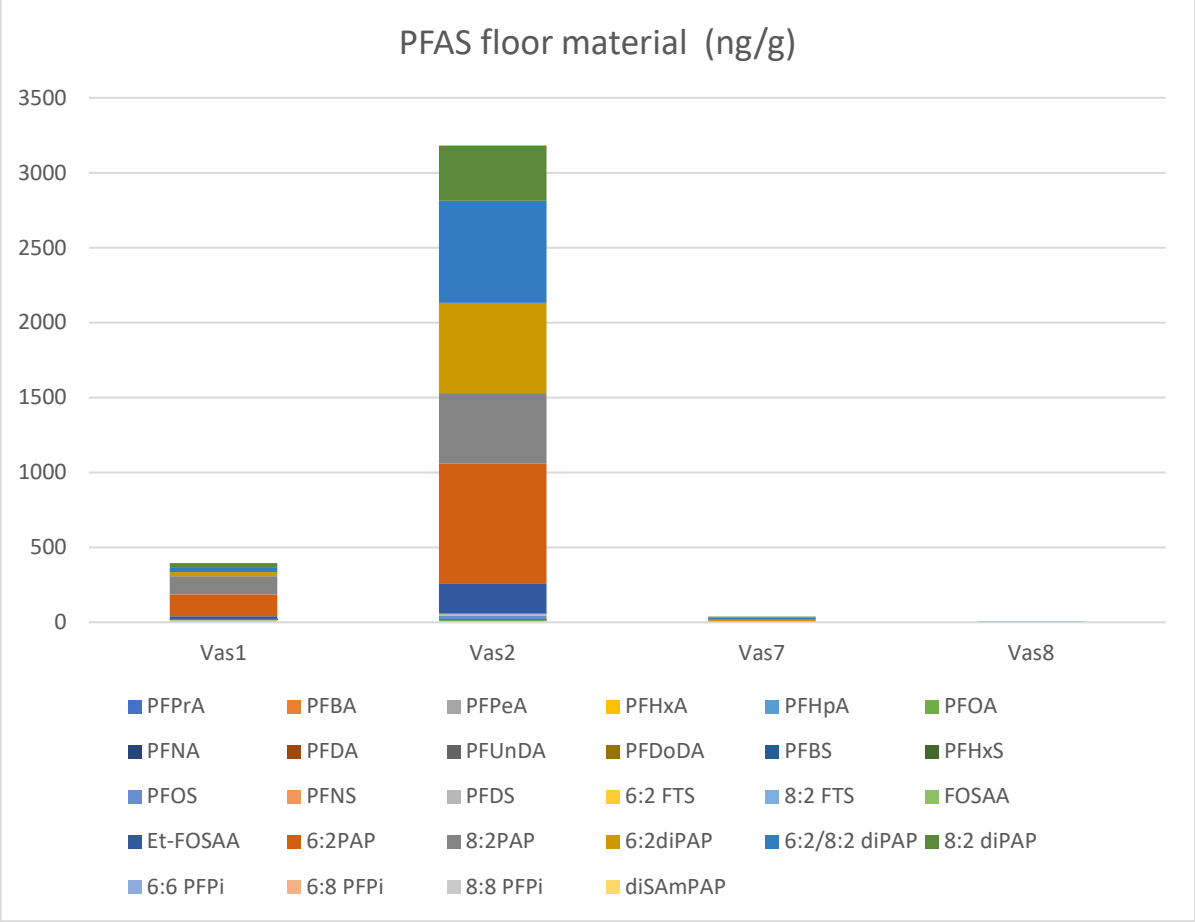

Figure 12, PFAS in floor materials, according to results presented in Table 14.

Organophosphate esters and brominated flame retardants

It was expected to find higher concentrations of organophosphates and brominated flame retardants in the older buildings, compared to the newer.

Figure 13 shows the results of organophosphate esters in dust. Organophosphates can be sourced from floor care products and flame retardants in products. Older resting mattresses used in preschools often contain organophosphate in the foam as flame retardants, but Västerås preschools have newer mattresses that should not be a source of organophosphates.

Figure 14 shows the results of brominated flame retardants in dust. These can be sourced from electronic and lighting equipment, insulation material, plastic materials, polymer foams, etc (1).

The older preschools, Vas1-2 and Vas7-8, showed the highest concentrations of organophosphates and brominated flame retardants. This was expected as these substances are less frequently used in newer buildings thanks to regulations. An electric cabinet next to Vas7 location may explain the elevated levels of PBDE in the Vas7 sampling.

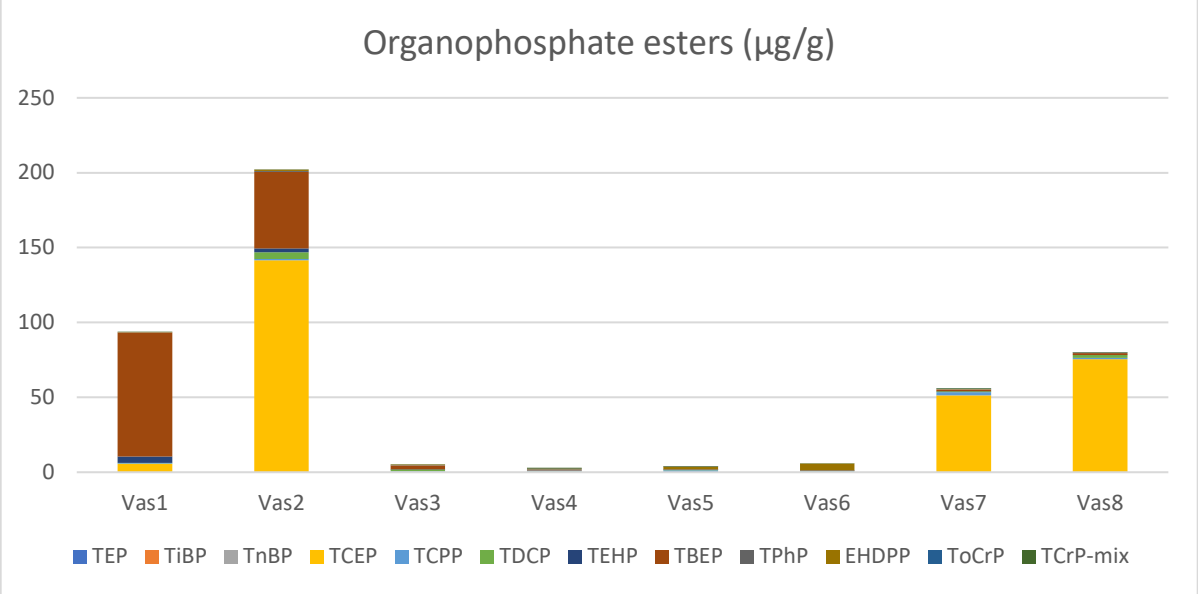

Figure 13, organophosphate esters in dust.

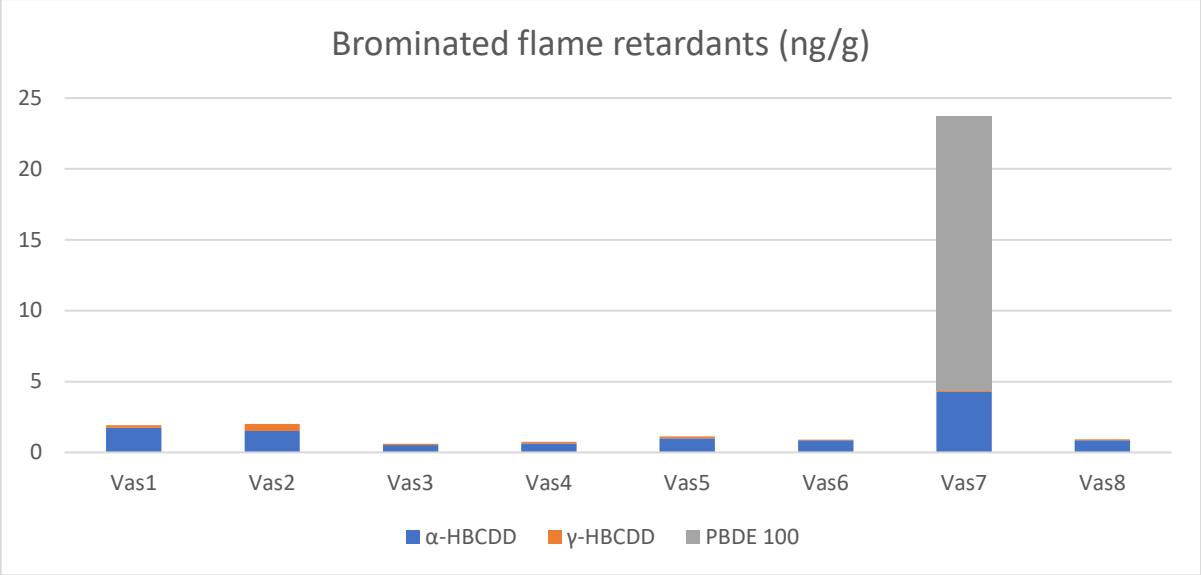

Figure 14, Brominated flame retardants in dust (ng/g). Note that TBBPA is reported together with the bisphenols in Figure 15.

Bisphenols

The concentrations of Bisphenol A, S, F, and AF were lower than expected, and the concentrations of TBBPA was higher than expected. Samples from preschools in a previous study in Stockholm (2), had much higher concentrations of these bisphenols than found in this study. However, some of the TBBPA concentrations were remarkably higher in the Västerås samples than in the Stockholm study, see Table 22. Vas2 and Vas8 peak in TBBPA, see Figure 15.

In the Vas2 location there was a projector turned on during the sampling, a light table and other pedagogic light equipment. These electrical appliances could be sources of TBBPA in the dust samples.

Dust was collected behind a monitor in Vas3 and Vas4, but not in Vas5 or Vas6, which may explain why Vas3-4 had higher concentrations of TBBPA than Vas5-6. Vas6 is identical to Vas3 and Vas4, and Vas5 is a larger room without monitor.

There can also be other sources of TBBPA in the buildings. TBBPA is a flame retardant often used in electronics, and in lighting and ventilation products (1).

Vas1, Vas2, Vas3 and Vas8 had the highest concentrations of bisphenols, indicating a slight trend towards lower concentrations in the newer preschools.

Table 23, Comparison of bisphenol concentrations in samples and previous sampling in Stockholm (2)

(ng/g)	Västerås lowest – highest	Stockholm lowest - highest
BPA	15,4 – 162	250 – 1650
BPS	<LoQ – 17,3	<LoQ – 950
BPF	3,77 – 9,30	<LoQ – 140
BPAF	Not detected	<LoQ – 20
TBBPA	227 – 6057	218 – 645

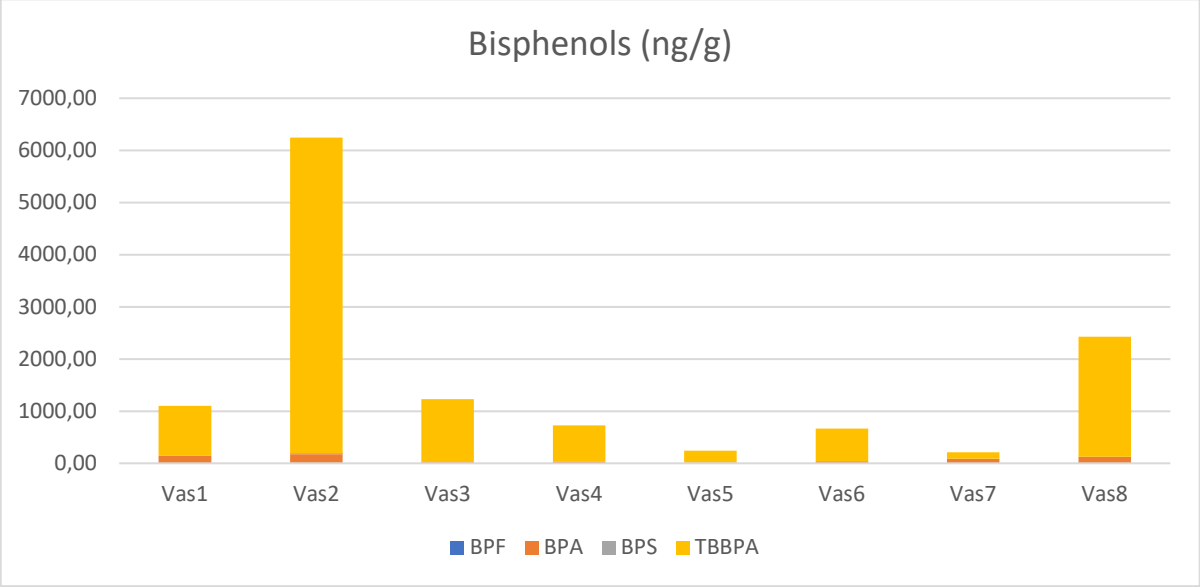

Figure 15, Bisphenols in dust.

Organochlorine pesticides

Organochlorine pesticides have been detected in buildings in previous studies. A Danish study by Bräuner et al (10) analysed dust in ten building and found high concentrations of DDT in two of them, both were private homes built in 1971 and 1973. Seven of the buildings had lower concentrations, between 9 to 76 ng/g. The authors mention carpeted floors as a possible source of DDT. The lower concentrations in the study are similar to the results in Vas7-8, which had 72 respectively 74 ng/g, see Figure 16.

Bräuner et al (10) found the HCH concentrations between <LoQ and 11 ng/g which is lower than all samples but Vas2.

It was not expected to find DDT or HCHs in the newer preschools, Vas3-4 and Vas5-6. It is a concern that these substances are found in new buildings, although concentrations are low.

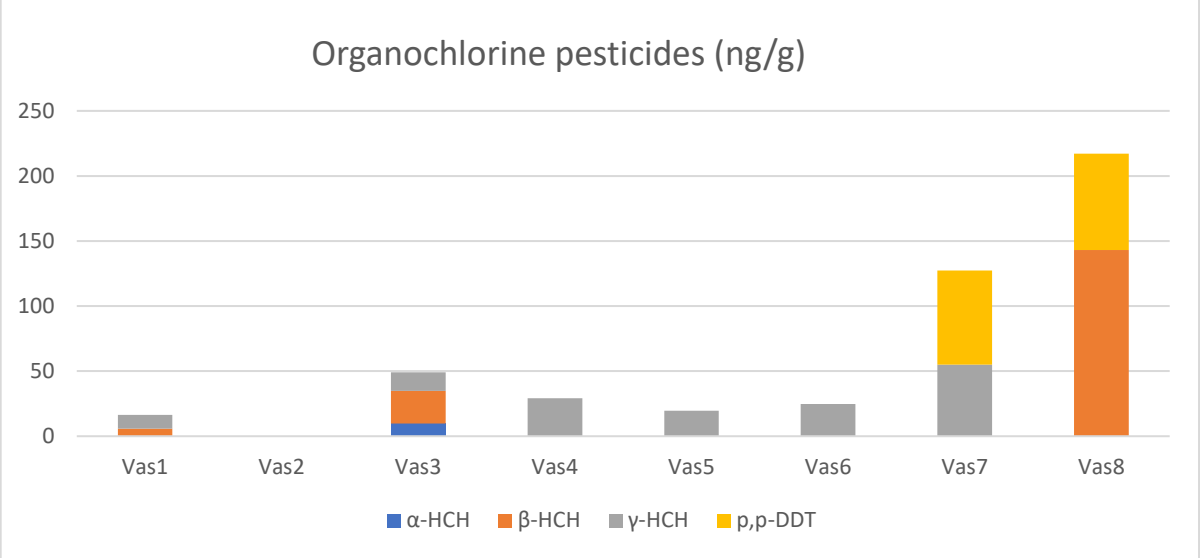

Figure 16, organochlorine pesticides in dust.

Isothiazolinones

Isothiazolinones are a group of preservatives commonly used in water-based paints, sealants, and adhesives (1). Figure 17 shows concentration of isothiazolinones in dust. These preservatives emit higher concentrations in the beginning of their life length. Vas3-4 and Vas5-6 had the highest concentration, which was expected as these samples represent the newest buildings.

The exterior of Vas1-2 was repainted in 2018. Parts of the inside was also repainted during the same time, including the Vas1 location. Vas7-8 was repainted outside and Vas8 was repainted inside somewhere between 2021-2022, why it was expected to find these concentrations of isothiazolinones.

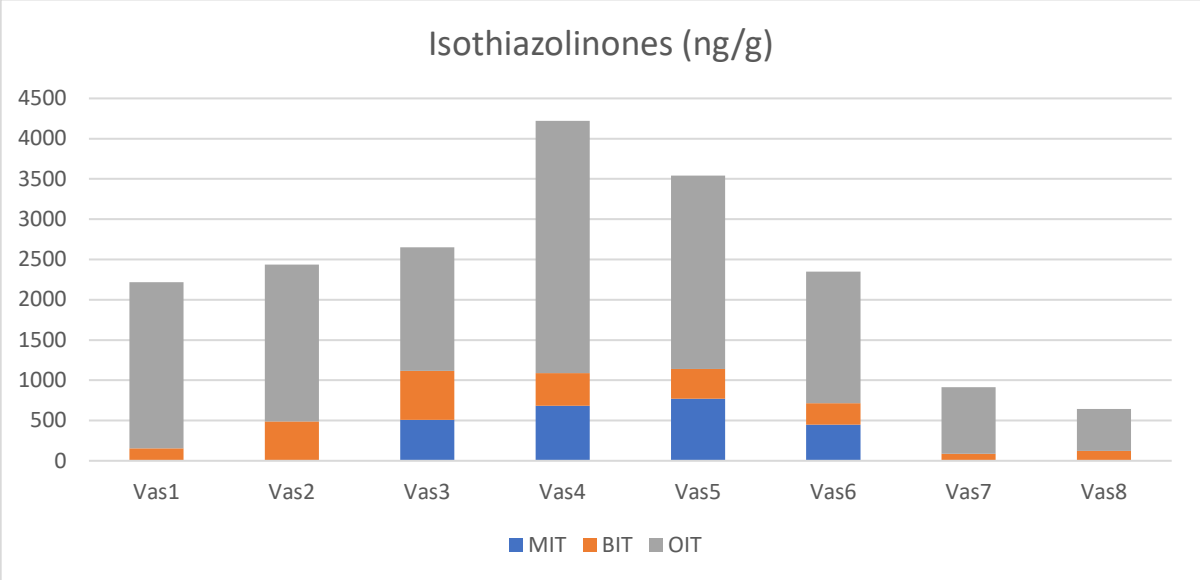

Figure 17, Isothiazolinones in dust.

Chlorinated paraffins

Chlorinated paraffins are used as plasticisers and flame retardants, and can be found in PVC and rubber products, paints, sealants, adhesives, polyurethane foams, chloroprene products, and more (1).

It is positive that the newest preschool represented by samples Vas5-6 have remarkably lower concentrations of chlorinated paraffins than the other preschools, see Figure 18. It is surprising that the other new preschool, samples Vas3-4, had such high concentrations. Both preschools are more or less identical in construction, but Vas3-4 was completed approximately six months before Vas5-6.

To learn more about chlorinated paraffins in buildings, it would be of great interest to further investigate product and material differences between the two concept preschools Vas3-4 and Vas5-6.

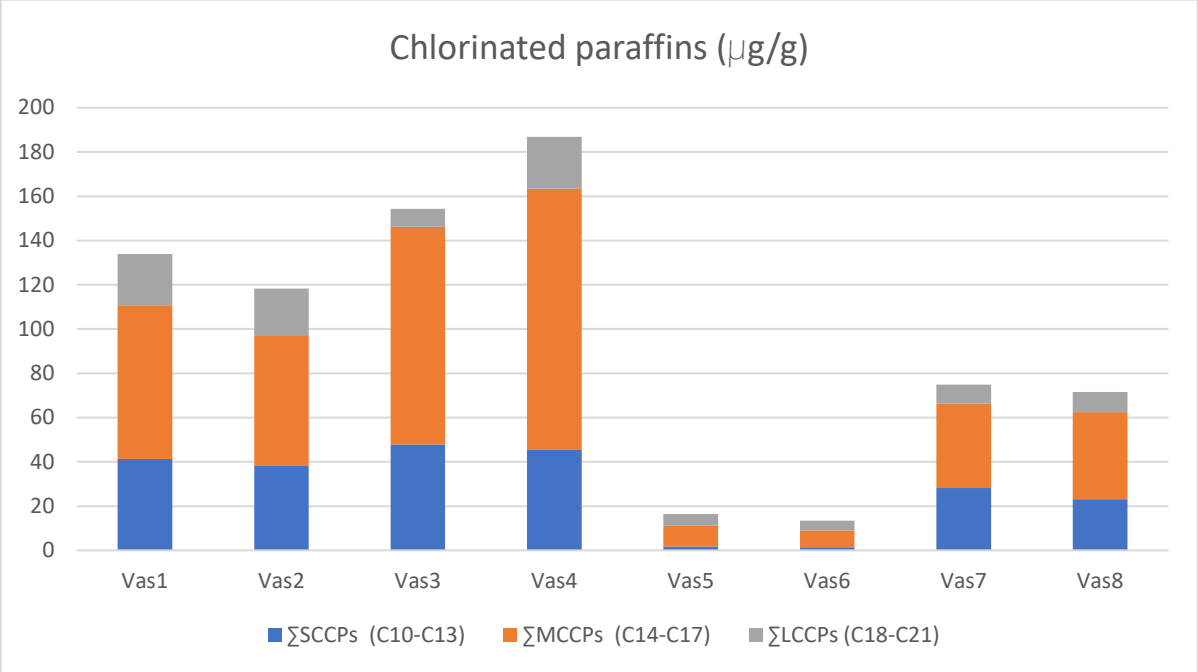

Figure 18, Chlorinated paraffins in dust.

VOC

All samples had total levels of VOC below the 300 µg/g limit which is used in practice, according to Giovanoulis G et al. (7), see Figure 20. The higher concentration of 2-ethylhexanol in Vas4 and especially Vas6 was surprising. The VOC sampling tube in Vas6 was installed in a decoration with hanging pencil-crayons, see Figure 19. It was suspected that these pens might release 2-ethylhexanol and could have influenced the sampling. As a control, one pencil from the decoration was sent to the laboratory for screening, and elevated levels of 2-ethylhexanol were found in the pen (11). It can therefore be assumed that the pens contributed to the elevated levels in Vas7.

Products emit higher concentrations of VOCs in the beginning of their life length, which can explain why Vas4 and Vas6 showed the highest concentrations of VOCs. The results are similar to previous screening in some Stockholm preschools (2).

Figure 19, VOC sampler installed next to pencil-crayons in Vas6 location.

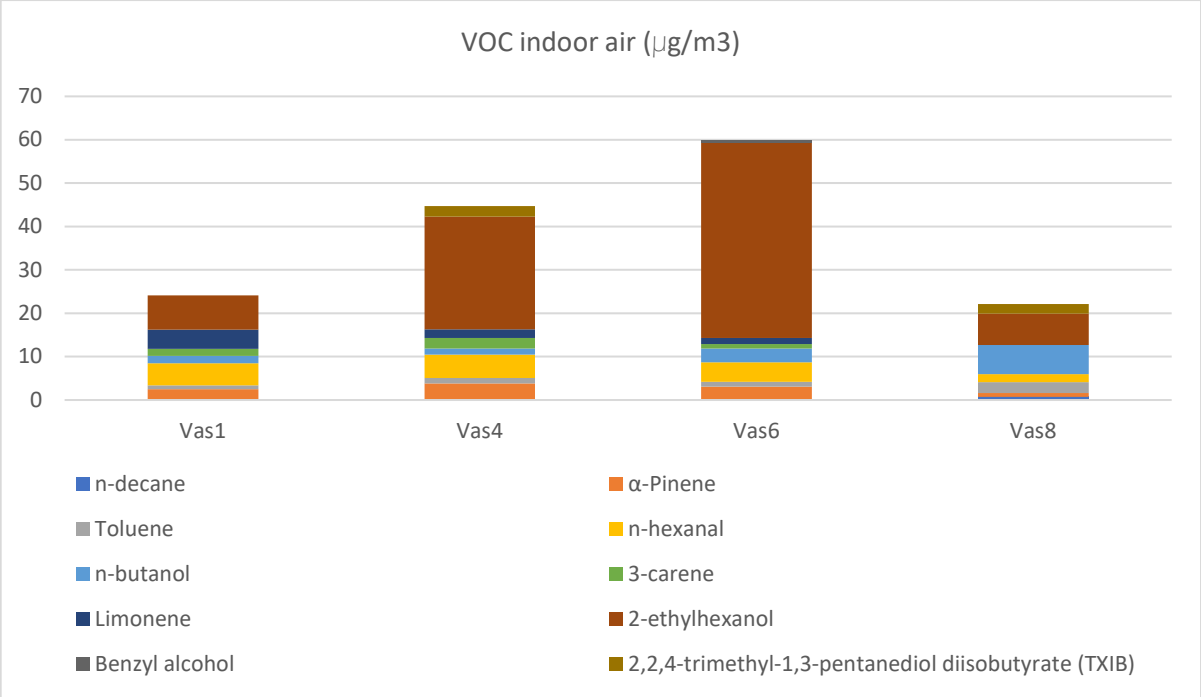

Figure 20, VOC in air in preschools.

Interpretations of storm water screening

Initial expectations

It was expected to find traces of all sampled substance groups in storm water, and that the results would be similar with the results from the other project partners.

Conclusions

It was positive to see that in general, the substance concentrations in storm water were low and sometimes below the detection limits. This can be explained by several reasons.

- KA, ST and GO locations have rather small catchment areas with mainly newly built villas with gardens or buildings under construction. Larger and more densely built areas would probably generate higher substance concentrations in storm water.

- The majority of the buildings in all four locations are villas with gardens. Rainwater from roofs and façades might be filtered through grass and soil that filters the storm water.
- The storm water runs mainly through open ditches with vegetation, allowing particles and pollutants to sediment and be filtered through underwater vegetation before the water reaches the sampling location. Plants can also absorb pollutants and remove them from the water. This has for example been tried for PFAS (12).
- The storm water ponds and ditches receive water from adjacent areas with trees and fields, diluting the storm water from the buildings.

Conclusions from storm water screening

Nutrients

Nutrients were found in all locations. Gotö location drains an agricultural field, which probably explains why Gotö had highest concentration of phosphor. Total phosphor in the other locations were more similar to total phosphor measured in river Svartån 2022 (13). Total nitrogen in all samples were below total nitrogen found in Svartån 2022.

Building materials are not considered a source of nitrogen and phosphor. In this study the nutrient analysis can indicate inflow from other sources than building materials. According to Västerås Storm water action plan (14), the sources of nitrogen and phosphor to storm water are sewage overflow and pipe misconnections, manure, industries, detergents, and atmospheric deposition.

Metals

Previous studies have shown that construction materials, such as metal roofs and rain gutter, leach metals to storm water, (15) (16). In Västerås, traffic has been assumed as the main source of lead, copper, cadmium, chrome, nickel, vanadium, and zinc in storm water (14) (17).

Figure 21 shows concentrations in sampled stormwater. The EL location has the largest catchment area with largest runoff from trafficked roads. This can explain why the EL sample showed higher concentrations of above-mentioned metals.

Barium concentrations are approximately the same for all samples, why it can be assumed that barium is not sourced from buildings nor traffic.

Figure 22 compares metal concentrations with the stream Svartån (13) and Mälarenergi storm water samples (18). Svartån is the stream that runs through Västerås city centre and into lake Mälaren. Mälarenergi is the municipal company for sewage, drinking water, and more. Barium, cobolt and vanadium were excluded from Figure 22 as these metals were not sampled in Svartån and Mälarenergi's sampling.

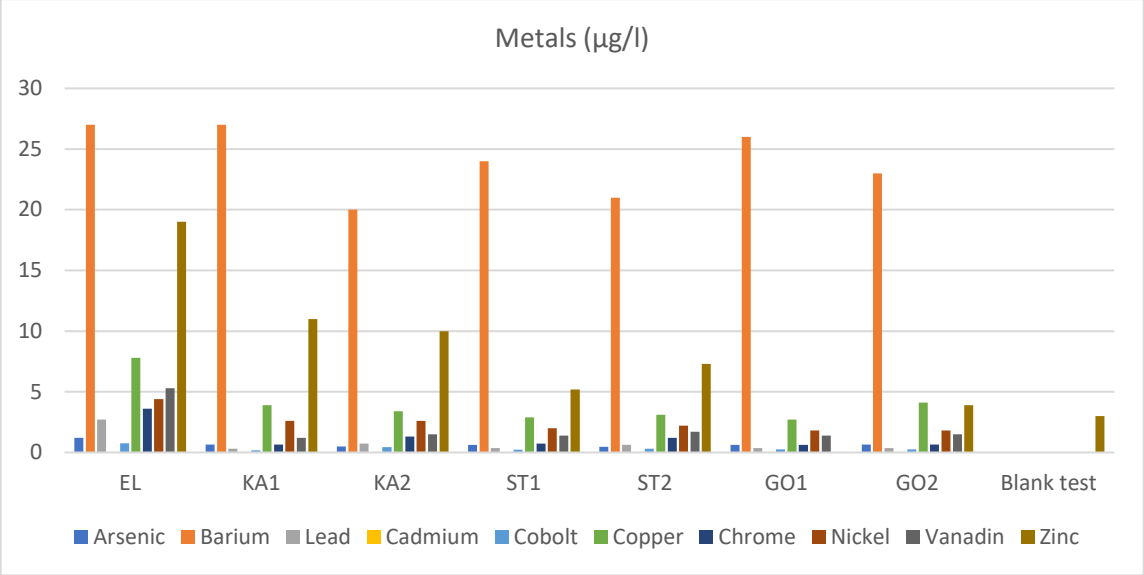

Figure 21, metals in sampled storm water.

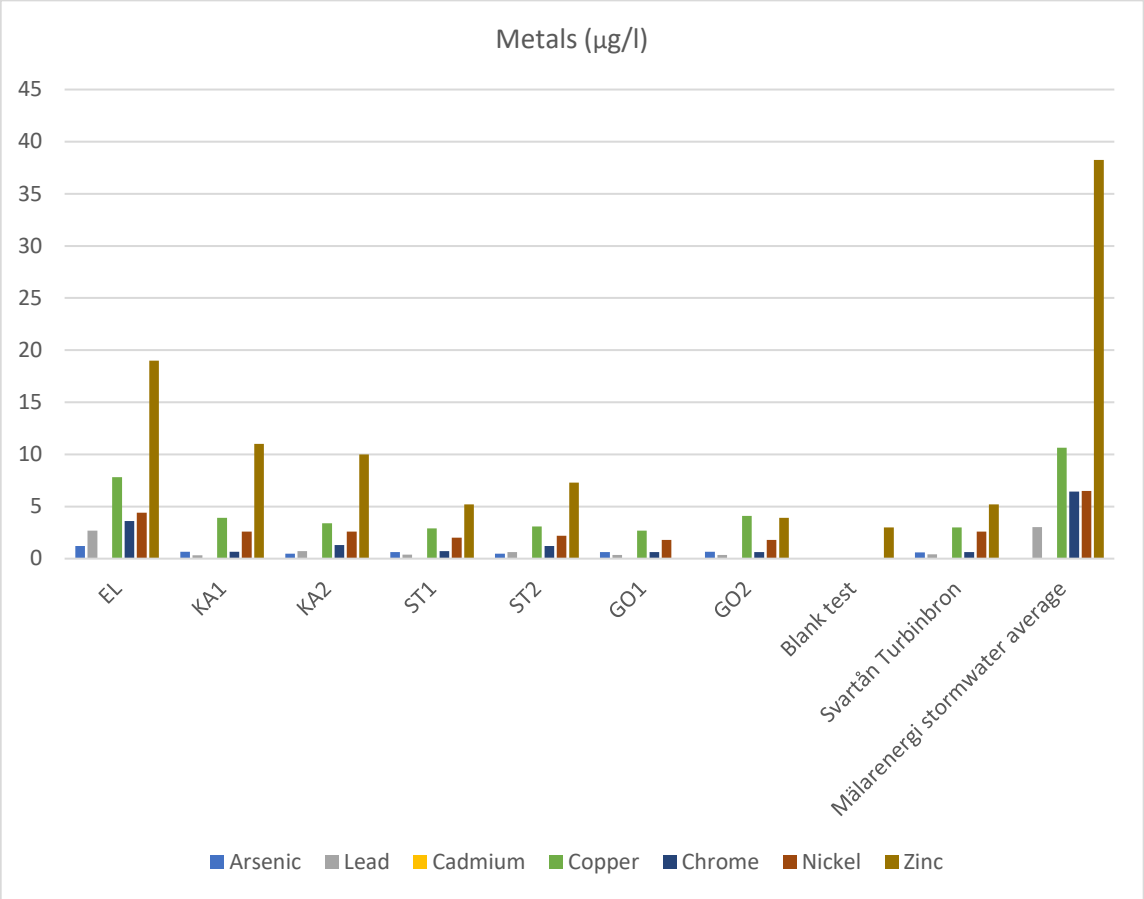

Figure 22, Metals in sampled storm water, in relation to river Svartån (Turbinbron) and Mälarenergi storm water samples. Data for barium, cobolt and vanadium are excluded as these metals are not analysed in Svartån Turbinbron and Mälarenergi samples (13) (18).

Organophosphates

TDCPP, in the ST2 sample, was the only organophosphate detected in the sampling. The ST2 location is a rather new residential area, developed since 2012. Figure 13 showed that the older preschools had higher concentrations of organophosphates in dust. Catchment areas with older buildings might have higher concentrations of organophosphates in storm water.

Pesticides

The storm water ditch running to the Gotö 2 sampling point drains agricultural fields on one side and villa gardens on the other side. Agricultural activities might explain why more pesticides were found in Gotö2 sampling point, see Figure 23. Glyphosate, AMPA (a metabolite of glyphosate), clopyralid and bentazone are plant protection herbicides that other studies also have detected in surface water (19) (20).

DMS, Hydroxyterbutylazine and Propiconazole can be sourced both from wood preservatives and plant protection. DMS is a metabolite of the fungiciedes tolylfluanide and cyazofamid (20), which have been used both in agriculture and in wood preservations. Tolylfluanide and cyazofamidcontain PFAS and have strict regulations today. Hydroxyterbutylazine and Propiconazole may derive from preservatives in wood (21). Propiconazole is approved by Echa for use as wood protection.

Hydroxyterbutylazine was only found in ST2. As this residential area is developed on previous agricultural land, it is impossible to determine if Hydroxyterbutylazine can be sources from agricultural activities or wood protection in buildings and other garden constructions.

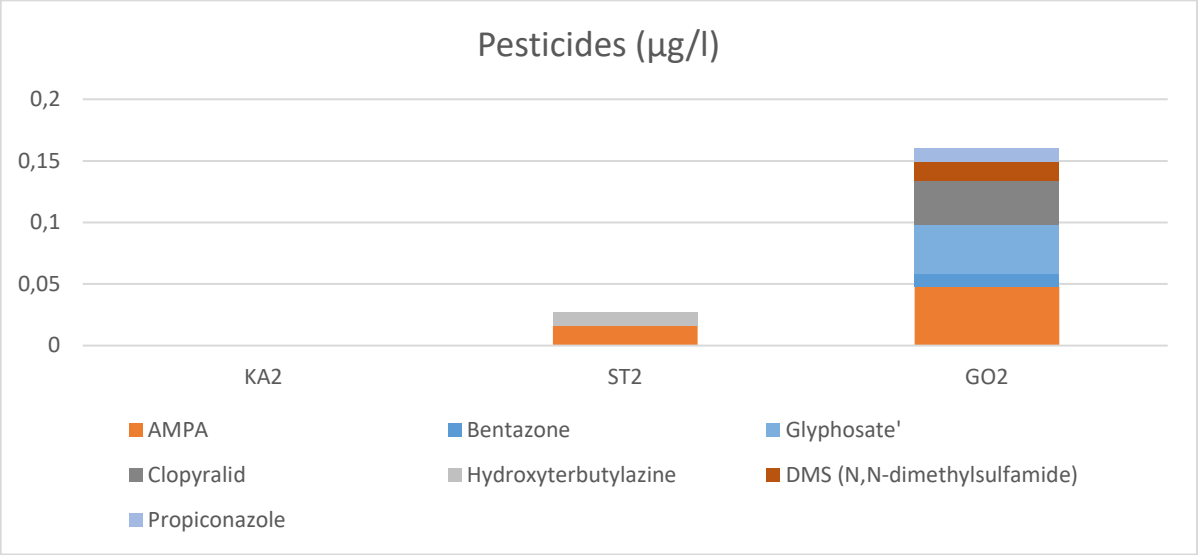

Figure 23, Pesticides in storm water

PFAS

The concentrations in the samples decreased between the first and second sampling in each location. For the later samples, KA3 and KA4, the concentration increased in the last samples. Comparing concentrations and outdoor temperature, Table 4, indicates that storm water contains more PFAS when the weather is warmer. However, more samples and analyses are needed to verify this hypothesis.

The differences between KAin and KAout are low, indicating that the buildings are not major sources of PFAS in the catchment area. More studies are needed.

All samples are below current Swedish drinking water limits, and also below the 2026 limits, with maximum 4 ng/l for PFAS4, and 100 ng/l for PFAS21. EL had the highest concentrations of total PFAS4 at 3,9 ng/l, which is near the limit of 4 ng/l. Figure 24 shows the single PFAS substances concentration in storm water and Figure 25 shows total PFAS concentration in storm water.

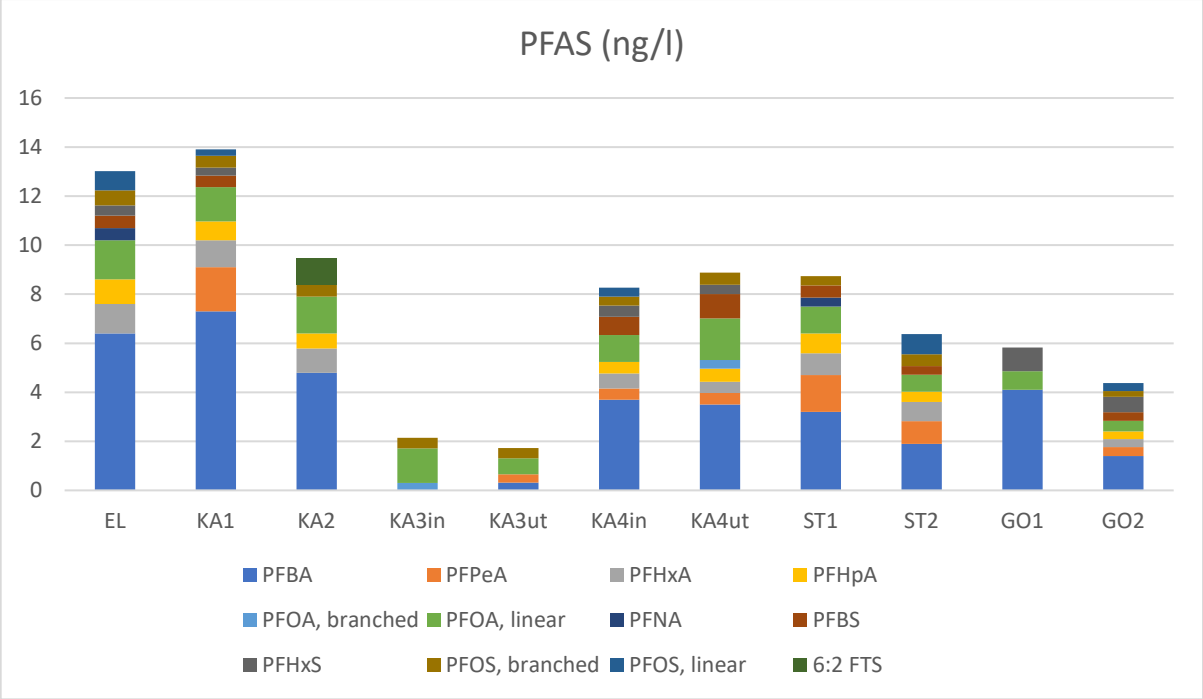

Figure 24, PFAS in storm water, ng/l.

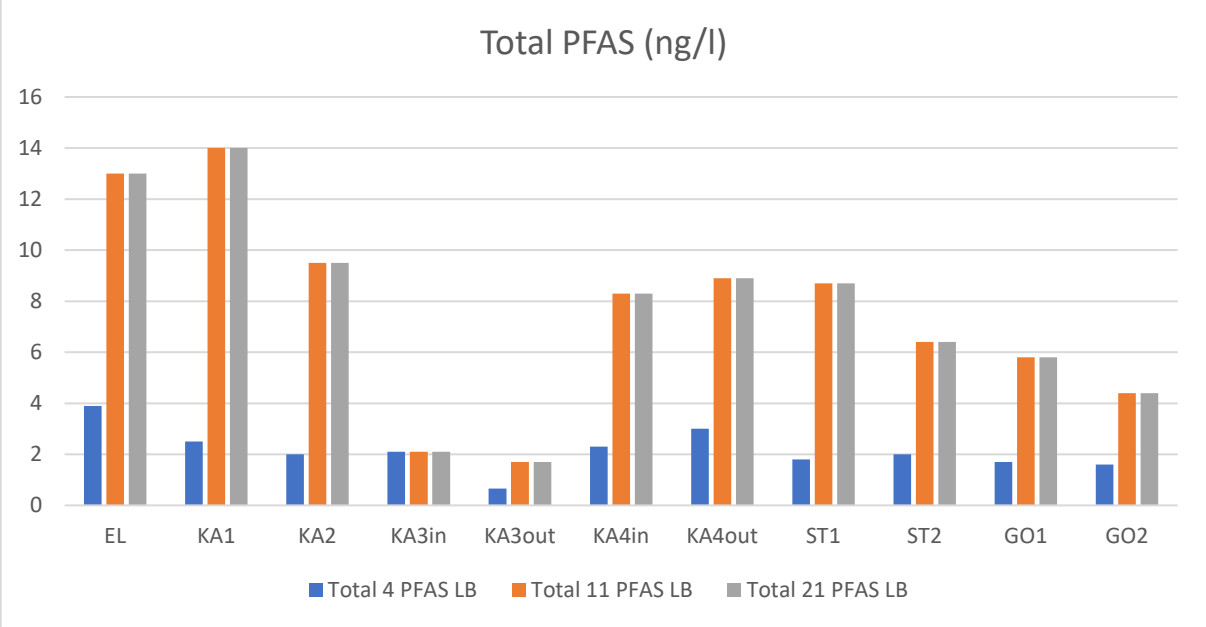

Figure 25, PFAS in storm water, ng/l.

Plasticisers

Previous studies show that phthalates can be released from building materials (22) (23).

Figure 26 show phthalates and phthalate alternatives in storm water. Highest total concentrations were found in EL, 107 ng/l and KA1, 161 ng/l. Some plasticisers were found in the blank test sample, even at higher total concentrations than KA2, ST, GO1 and GO2.

The results indicates that plasticisers are present in storm water, but more sampling and analyses are needed.

Previous sampling of sewage water indicate that phthalates are present in sewage water (24). A possible conclusion might be that household sewage water has higher concentrations of phthalates than storm water. Can dust be the main source of phthalates in sewage water?

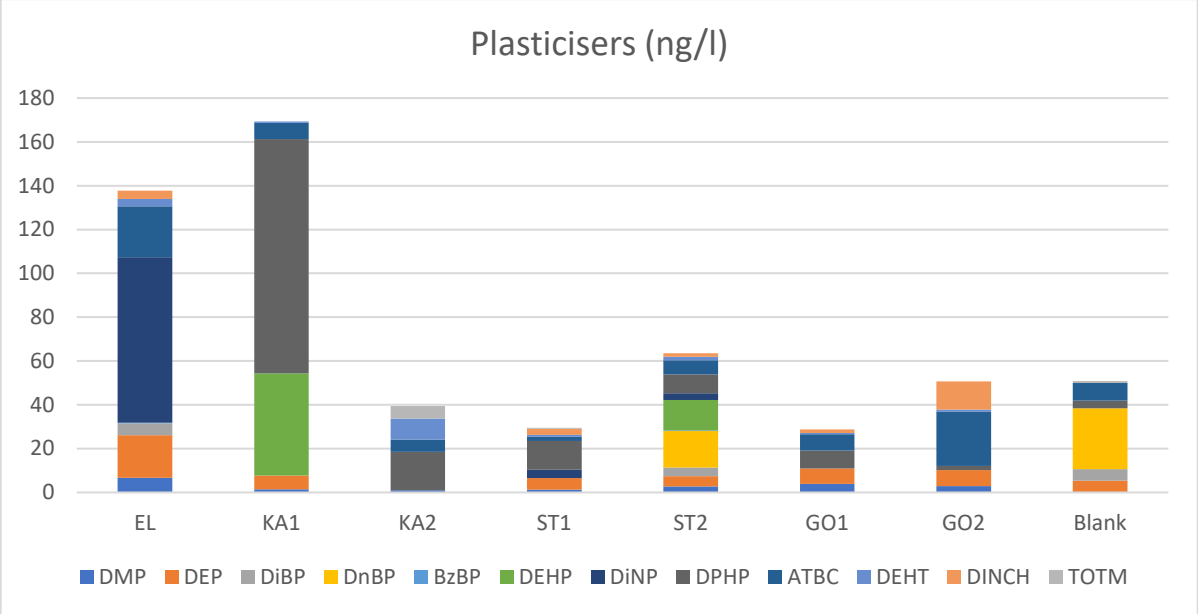

Figure 26, Plasticisers in storm water.

Not detected substances

It was very positive to see that many of the analysed substances could not be detected in the samples. Maybe more substances had been detected if the storm water hadn't been diluted by inflow from other storm water sources.

Brominated flame retardants were not found in the storm water samples. It would be interesting to continue this study with screening of storm water sludge.

The City of Västerås has made an effort to reduce TBT in lake Mälaren, especially by requiring private boat owners to remove TBT contaminated paint from their boats. It was positive not having found any TBT in storm water. The City of Västerås will continue the work with reducing TBT in lake Mälaren.

The use of PCB has been prohibited since many years. Not finding PCB in storm water indicates that the PCB regulations have been fruitful. The buildings in the sampled catchment areas were built after PCB was banned.

Finding no petroleum products (MTBE) indicates that the samples have not been heavily contaminated by traffic activities.

Polyaromatic Compounds, PAH, can be found in asphalt boards, tar paper, bitumen and asphalt-based roofing materials (1). Tar paper roofs are not unusual in Västerås, but not the most common roof material in the catchment areas, why PAHs could have been detected in the storm water samples.

The concentrations of isothiazolinones in dust were low, 4 µg/g in the most concentrated sample. Isothiazolinones reaching the storm water has probably been diluted to concentrations below detection limits.

Possible sources of error

Although the substances targeted in the screening were substances that are known to be used in building materials e.g. based on studies and databases, contribution from other sources, such as soil, air deposition and traffic, cannot be ruled out.

Improvements for further research

The storm water samples taken used in this study shows only the results for the time and day the samples were taken. To get a more precise picture, additional screening is needed.

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Appendix 5A.

Analysis of potentially hazardous substances in dust in preschools

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2024-05-31

Interreg Baltic Sea Region
Co-funded by the European Union
SUSTAINABLE WATERS
NonHazCity 3
goodpoint
Part of the Semcon Group

Summary

The work towards a non-toxic and sustainable society is extensive and ongoing. This work is particularly important when it comes to caring for the most vulnerable in society, especially children. It is therefore crucial to ensure that children are in safe environments. Part of this work therefore includes chemical safety. In the *City of Stockholm's Chemicals Plan 2020-2023*, children's everyday life is a prioritised area, and groups of substances with particular focus are described. In several follow-up studies, the City of Stockholm's Environment and Health Department has carried out controls on the indoor environment regarding exposure to potentially harmful substances.

This study is part of the Environment and Health Department's own mission to develop a systematic programme for monitoring health-related environmental toxicants. The aim of the programme is to identify new chemical trends and eventually enable a reduction of the chemical load in the city. The purpose of this study was to revisit selected preschools to monitor the development of the chemical load in the preschools' indoor environment. This was done through chemical analyses of dust and building materials that affect the preschools' indoor environment. Comparisons were made to previously conducted analytical studies of indoor environments and building materials, specifically focused on preschools. The study included 19 preschools in Stockholm that were selected for site visits and sampling. The selection of preschools included in the follow-up study was based on previously conducted studies.

In several follow-up studies, the City of Stockholm's Environment and Health Department has carried out controls on the indoor environment regarding the exposure to potentially harmful substances. Controls on interior materials and the chemical content of building and construction products have also been previously carried out.

One of the more well-studied groups of substances reported in dust is phthalates. In several studies, phthalates have been analysed in parallel with the substance group bisphenols. The concentrations of highly fluorinated organic substances (PFAS) in dust have been studied in various environments, including both Swedish and American preschools. Studies of concentrations of metals in dust and associated health risks for children have been conducted both internationally and in Sweden. Concentrations of chlorinated paraffins have been reported in studies of dust in Australia, Belgium, Canada, China, UK, Sweden, and South Africa.

In this study, one dust sample per preschool was analysed for the substance groups phthalates and alternative plasticisers, bisphenols, and PFAS. Nine of the dust samples were also analysed for chlorinated paraffins. Analyses of metals were also carried out on eight dust samples. Additionally, two material samples were collected and analysed for the substance groups phthalates and alternative plasticisers, bisphenols and PFAS.

The results of the analyses of phthalates and alternative plasticisers in dust established that the substances with the highest concentrations were 1,2-Cyclohexane dicarboxylic acid diisononyl ester (DINCH), diisononyl phthalate (DiNP) and di(2-ethylhexyl)terephthalate (DEHT). The substances present in the lowest concentrations were dimethyl phthalate (DMP), trioctyl trimellitate (TOTM) and diethyl phthalate (DEP). When comparing the mean values of the analysed concentrations of bisphenols in dust, bisphenol A (BPA) was present in the highest concentrations, followed by bisphenol S (BPS). The bisphenols present in the lowest concentrations were bisphenol AF (BPAF) and bisphenol F (BPF). Of the analysed PFAS substances, only six substances were detected in all dust samples. Seven of the PFAS substances could not be detected in any of the 19 dust samples. Based on the summarised mean values, it was noted that the PFAS substances present in the highest

concentrations were 6:2 diPAP and 6:2 PAP. Of the substances that could be detected in one or more of the samples, 6:2 FTS and perfluorobutanesulfonic acid (PFBS) were present in the lowest concentrations. As for the metals, zinc was the metal present in the highest concentration. This concentration was significantly higher than the other metals analysed. The metals present in the lowest concentrations were cadmium and cobalt.

When analysing phthalates and alternative plasticisers in material samples, DINCH was the substance detected in the highest concentration in all material samples based on mean values. The concentrations of DINCH were significantly higher than the other substances analysed. Of the phthalates and alternative plasticisers analysed, all but two (di(2-propylheptyl)phthalate (DPHP) and acetyltributylcitrate (ATBC)) were detected in all material samples. The substances detected in the lowest concentrations were DMP and diisodecyl phthalate (DiDP). Only two of the analysed bisphenols were detected in the two material samples. These were BPAF and BPA, with BPA occurring in the highest concentration. The substances BPF, BPS and tetrabromobisphenol A (TBBPA) were all below the respective limit of detection (LOD) in all material samples.

The results of this study were compared to the results from previous studies. From the comparisons of phthalates and alternative plasticisers, it was shown that the substance DINCH has undergone the most significant increase in concentration. For the substances di(2-ethylhexyl)phthalate (DEHP), DiNP and DiDP, the comparison showed a steady downward trend in concentrations. For the analysed bisphenols, a downward trend in concentrations of all substances was observed. Regarding PFAS substances, a uniform trend could not be identified. Instead, an even distribution of decreasing and increasing concentrations depending on substance was observed. For example, an almost doubling in concentration of 8:2 PAP was noted, whereas the concentration of perfluorodecanesulfonic acid (PFDS) showed a significant decreased.

Comparisons of percentage change were also performed for the substance groups analysed in 2018 and 2023. The percentage comparisons for phthalates and alternative plasticisers showed that DINCH underwent the largest increase of 72%. For bisphenols, it was found that all analysed substances underwent a decrease of at least 40%. The PFAS substances show an even distribution of increase and decrease in concentrations for individual substances. For the majority of substances that increased in concentration, the increase was 95% or more. The largest increase was the concentration of perfluorohexanoic acid (PFHxA), which showed an increase in over 500% since 2018.

The most evident links between renovations and concentrations of the investigated potentially harmful substances were noted where floor renovations and total renovations of the preschools had been performed. A common feature of the renovated preschools is that the concentrations of DINCH often underwent a more significant increase compared to concentrations from the previous analytical studies of this substance.

Comparisons were also made to determine potential correlations between analysis results in dust and material samples. The comparisons showed that there is a correlation between analysed concentrations of substances in dust and material samples from the same preschools. With a higher concentration of a substance in the material sample, a higher concentration of the same substance in the corresponding dust sample was found. The same relationship was also identified for the substances that occurred in the lowest concentrations. However, these findings are derived from comparisons of only two material samples. It should be noted that comparisons with material samples from additional preschools are necessary to establish a relationship between dust and material samples with greater certainty.

Based on the results of this study, the following conclusions could be drawn. The concentrations of potentially harmful substances in preschools have undergone an apparent change when compared to previous studies. Depending on the group of substance, some substances have increased in concentration while others have decreased. This change also affects individual substances within each group of substance. The analysis of the percentage differences highlights the increased use of alternative substances in the indoor environment of preschools. This indicates a possible link between renovations and the concentrations of the potentially harmful substances analysed.

Based on the results of this study, it cannot be stated with certainty that the preschools in Stockholm are moving towards a less toxic environment. It is therefore of the utmost importance that environmental monitoring and evaluation of the presence of potentially harmful substances in the indoor environment of preschools continues, and that it remains a prioritised area.

Glossary

Abbreviation	Definition
LOD	Limit of detection
PFAS	Highly fluorinated organic substances
PVC	Polyvinyl chloride
SCCPs	Short-chain chlorinated paraffins
MCCPs	Medium-chain chlorinated paraffins
LCCPs	Long-chain chlorinated paraffins

Table of contents

1 Introduction

The work towards a non-toxic and sustainable society is extensive and ongoing. This work is particularly important when it comes to caring for the most vulnerable in society, especially children. It is therefore of the highest importance to ensure that children are in safe environments. In Sweden, we spend about 90 percent of our time indoors (Boverket, 2022). Therefore, the work on a good and healthy indoor environment is considered particularly important.

The focus of this study is the chemical safety of the indoor environment in preschools in Stockholm. In preschools, children come into contact with a variety of materials and chemicals in toys, carpets, furniture as well as chemical products such as soaps or disinfectants. Examining the chemical safety of this environment and investigating the potentially harmful substances that children are exposed to is therefore of great importance.

This study has focused on the investigation of potentially harmful substances in mainly dust samples from 19 participating preschools. Additionally, material samples have also been collected. All participating preschools have been assigned a specific code and are presented anonymously in this report. The choice to analyse dust is due to the fact that dust itself is a good indicator of chemical exposure in the indoor environment. In addition to inhalation of dust as a route of exposure to chemicals, absorption of chemicals can also occur through the skin via direct contact with materials. Therefore, a few material samples have also been collected in this study.

This report is intended for stakeholders for issues related to chemical exposure and quality aspects linked to chemical load in the indoor environment. For example, this report can be used as a basis for evaluation of chemical load in the indoor environment, evaluation of environmental requirements and their effects, or as a basis for prioritising further measures to reduce unwanted chemical exposure in preschools or equivalent indoor environments.

1.1 Objective

The aim of this study was to investigate the extent to which substances with potentially negative health effects are present in the preschools of Stockholm. The City of Stockholm conducts regular investigations of children's indoor environment and the several materials that children come into contact with. The purpose of this study was to revisit selected preschools to monitor the development of the chemical load in the indoor environment of these preschools.

The questions to be answered in this study were the following:

- Have the concentrations of potentially harmful substances changed in comparison with previous studies, and if so, in what way?
- Is it possible to find any correlation between the concentrations of the potentially harmful substances found in dust and any renovations carried out in the preschools?
- Is it possible through this study to determine whether the preschools in Stockholm are moving towards a more toxic-free environment?

2 Background

Health-related environmental toxicant monitoring of the indoor environment is very important as people spend most of their time indoors. Monitoring the indoor environment of children is even more important, as children are more exposed. Children are also likely to be exposed through different pathways than adults. The difference in exposure is mainly due to that children generally have a higher level of physical activity during the day, which leads to an increased breathing rate where a higher exposure to dust particles in the air occurs. Children also engage in many hand-to-mouth behaviours, which can lead to increased exposure. Children do not have a fully developed nervous, hormonal, or immune system, which leads to more serious health risks when exposed to toxicants compared to adults. Therefore, the issue of increased chemical exposure and children's exposure to hazardous substances must become a higher priority in the society. Efforts are required to identify measures that can lead to a reduction in exposure, especially for children.

Sources of harmful chemicals in the indoor environment can be substances in building materials, consumer goods and products or air, dust and dirt coming from the outdoor environment. Depending on their physicochemical properties, substances can be distributed in the gas phase, bound to particles suspended in air, or in solid form on surfaces and in dust.

The City of Stockholm is developing a systematic programme for conducting health-related environmental toxicant monitoring. The development of the monitoring programme is part of the City of Stockholm's environmental programme. Monitoring toxicants is a dynamic method for maintaining a continuous and up-to-date picture of the pollution situation. Information from monitoring is valuable, partly to provide a basis for determining which measures should be prioritised, and partly to enable follow-up of the effects of implemented measures. A monitoring programme is an effective tool for following developments over time and for drawing attention to new chemical trends. Additionally, it can be used for the long-term reduction of the chemical load in the city. This study aims to contribute to the planned monitoring programme.

In several follow-up studies, the City of Stockholm’s Environment and Health Department has carried out investigations of the indoor environment regarding exposure of potentially harmful substances. Previous studies have included analyses of air, dust and building and construction materials, as well as furnishing materials and goods. In this study, investigations and chemical analyses have been carried out in dust samples collected indoors in selected preschools, as well as individual material samples of PVC flooring.

The selection of preschools was made based on investigations carried out in the City of Stockholm’s Environment and Health Department previous studies: *"Dammprojekt 2015", "Dammprojekt uppföljning 2018", “Kemikaliebelastning i tre förskolors innemiljö 2016–2020"* and *"Ftalatinventering av PVC-mattor i 29 förskolor i Stockholm, 2015”.*

In the *City of Stockholm's chemicals plan*, children's everyday life is a prioritised action area, and groups of substances with a particular focus are described (City of Stockholm, 2020). These groups of substances have been the starting point for this follow-up study.

2.1 Alternative substances

In the construction industry, several alternative substances are used to enable phasing out substances with undesirable properties, such as endocrine disruptors and carcinogens. One of these alternative substances is DINCH, which is used as a plasticiser in floors made of polymeric materials instead of DiNP. Previous studies highlight DINCH as a good alternative to DiNP. At the same time, studies show that more data is needed on alternative substances

in general, as they are less studied in terms of their toxicological effects (Palm Cousins and Loh Lindholm, 2016, Kruopiené et al, 2020).

2.2 Occurrence in dust

The groups of substances analysed in this study are presented below. Additionally, previous studies carried out in the respective substance groups are also shown.

2.2.1 Phthalates

One of the more well-studied groups of substances reported in dust is phthalates. The presence of phthalates in dust has been studied in different settings, including dust in preschools in Denmark, France, Germany and Sweden (Bornehag *et al.*, 2005; Bekö *et al.*, 2013; Ma, Subedi and Kannan, 2014; Melymuk, Demirtepe and Jílková, 2020; Salthammer, 2020).

Some phthalates are considered as substances that should be phased out due to their properties (phase-out substances). One example of such a substance is DEHP. Other phthalates are considered as possible phase-out substances, such as DiNP, which is included in Region Stockholm's phase-out list (Stockholms läns landsting, 2017).

2.2.2 Bisphenols

For the substance group bisphenols, occurrence in dust has been analysed in several studies in parallel with phthalates (Wang *et al.*, 2015; Larsson *et al.*, 2017; Giovanoulis et *al.*, 2019). In two studies of bisphenols in dust at Swedish preschools, the concentrations of bisphenols were detected in µg/g concentrations (Larsson *et al.*, 2017; Giovanoulis *et al.*, 2019).

2.2.3 PFAS

Concentrations of hydrofluorocarbons (HFCs) in dust have been studied in various settings, including Swedish and American preschools (Giovanoulis *et al.*, 2019; Zheng *et al.*, 2020; Savvaides *et al.,* 2021). In the American preschools, 28 different PFAS were found in the dust (Zheng *et al.*, 2020). The most common type of PFAS was fluorotelomer alcohols. These accounted for 91% of the proportion of PFAS in dust. The average concentration of fluorotelomer alcohols was 390 ng/g (Zheng *et al.*, 2020).

2.2.4 Metals

Studies of metal concentrations in dust and associated health risks for children have been conducted both internationally and in Sweden (Berglund *et al.*, 2000; Tan *et al.,* 2016; Heo *et al.*, 2021). It has been found that concentrations of metals in dust are higher in urban environments, and that concentrations in school environments can contribute to cancer risks for children. Concentrations of lead in indoor dust are affected by the amount of traffic in the neighbourhood. Lead in indoor dust has been reported in µg/g concentrations (Berglund *et al.*, 2000; Tan *et al.*, 2016). In Stockholm, a study found that the concentration of lead in the blood of preschool children correlated to the concentration of lead in dust in the preschool, and whether or not the parents smoked (Berglund *et al.*, 2000).

2.2.5 Chlorinated paraffins

Concentrations of chlorinated paraffins have been reported in studies of dust in Australia, Belgium, Canada, China, Sweden, South Africa and the United Kingdom, among others (Wong *et al.*, 2017; Cao *et al.,* 2019; He *et al., 2019;* Shang *et al., 2019;* Brits *et al.,* 2020; McGrath, Covaci and Poma, 2022; McGrath et *al.,* 2022). One study found that long-chain chlorinated paraffins were most prevalent in dust in Sweden, while medium-chain chlorinated paraffins were most prevalent in Australia, Canada, China, and the United Kingdom (Wong *et al.*, 2017).

2.3 Renovation of preschools

Most of the participating preschools in this study have undergone either minor or major renovations since the last studies in 2018 and 2019. One preschool is new. One aim of this study was to identify correlations between concentrations of substances in dust and renovations. The renovations that have been carried out are described below in table 1.

Table 1. Overview of completed renovations.

Preschool	Renovations
F14	The ventilation system was replaced a few years ago.
F46	Completely rebuilt in 2022. Still has ongoing renovations.
F57	Completely new, built in 2022.
F60	Carried out floor renovations in all departments in 2023. The walls were repainted around 2018.
F101*	Newly laid carpets have resulted in problems with glue not drying.
F102	Expanded in 2010 and now has new carpets in the older part of the building.
F103	Completely renovated in 2018, including the replacement of all floors and ventilation equipment.

* Ongoing investigation regarding the indoor environment.

3 Methodology

This study included 19 preschools in Stockholm that were selected for site visits with sampling. The preschools were selected for follow-up based on previously conducted studies.

3.1 Dust sampling

Dust was collected from surfaces such as cabinets, shelves, mouldings, and windowsills. Collection was done on filters using a vacuum cleaner with a specially adapted nozzle. Dust samples were collected from surfaces at least 0.5 metres above the floor and up to 2.5 metres above the floor. Collection of dust from floors was excluded to avoid the risk of contamination. At which height the sample was collected, the type of material or substrate, and any other factors considered to be of particular interest was noted.

Before vacuum cleaner nozzles were reused for additional sampling, they were thoroughly cleaned by rinsing with plenty of water. The nozzles were allowed to air dry to avoid contamination from paper or textiles.

Blank samples were collected on five sampling occasions. When collecting the blank samples, the vacuum cleaner nozzle was pointed straight into the air and the vacuum cleaner was switched on for a few seconds before being switched off again. The analytical results for the blank samples can be found together with the rest of the analytical results in Appendix 2.

3.2 Material sampling

Material samples were collected from the floor in a secluded part of the room by carefully removing a narrow piece of carpet with a knife. The material was collected in places where it would not be visible, such as from the folded floor at the mouldings. Each sample collected was approximately 0.5 g.

Material samples were collected in preschools where major changes in indoor environment such as renovations or similar had taken place. Thus, only two material samples were analysed.

3.3 Substance groups analysed

One dust sample per preschool was analysed for the substance groups phthalates and alternative plasticisers, bisphenols and PFAS. Eight dust samples were analysed for chlorinated paraffins. Analysis of metals were carried out on seven dust samples. The reason why only some of the samples were analysed for chlorinated paraffins and metals was that the amount of dust collected from around half of the preschools was not sufficient for analysis of all substance groups. Therefore, a prioritisation was made. Two material samples were collected and analysed for the substance groups phthalates and alternative plasticisers, bisphenols and PFAS. See Appendix 1 for substances included in the substance groups.

All chemical analyses of dust and material samples were carried out by IVL Swedish Environmental Research Institute.

3.4 Analysis of data

For the calculation of difference in percentage between the studies in 2018 and 2023, the same method was used as by Giovanoulis et al. (2019) for the *"Dammprojekt 2018",* see equation below. The analysis in this study used the median concentration value.

$$\textit{Difference (\%)} = \frac{\left(C_{dust,2023} - C_{dust,2018}\right)}{C_{dust,2018}} x\ 100$$

This method was chosen to create comparability and consistency with previously conducted studies of the same substances. The raw data from Giovanoulis et al. (2019) was used in this study's analysis to determine differences between years.

4 Results

The analysis results are presented for both dust and material samples from the 19 participating preschools. Results for concentration of substances in dust and material samples are presented per substance group. All tables show calculated mean values, median values, minimum values, and maximum values for each substance group. For complete results and LOD for each substance, see Appendix 2.

4.1 Phthalates and alternative plasticisers

The analysis results for phthalates and alternative plasticisers in dust and flooring materials are presented below.

4.1.1 Phthalates and alternative plasticisers in dust

The analysis results for phthalates and alternative plasticisers in all dust samples are presented in Table 2. All phthalates and alternative plasticisers were detected in dust from all 19 preschools, except for DiDP which was detected in 18 out of 19 preschools.

The mean values show that the highest concentrations of phthalates and alternative plasticisers in dust are DINCH, DiNP and DEHT. The phthalates and alternative plasticisers with the lowest mean concentrations were DMP, TOTM and DEP.

Table 2. Analysed concentrations of phthalates and alternative plasticisers in dust, measured in µg/g. Compiled results from 19 analysed samples. All substances marked with a "<" in front of their value in the table were in one or more samples below the LOD, with the number of samples indicated in brackets.

Substance	Mean value	Median value	Minimum value	Maximum value
DMP	0.05	0.03	0.02	0.35
DEP	0.82	0.44	0.25	3.20
DiBP	1.95	0.62	0.12	15.62
DnBP	3.93	3.54	0.39	9.36
ATBC	13.58	2.69	0.17	86.09
BzBP	2.71	1.76	0.41	8.25
DEHA	4.47	3.31	1.58	10.64
DEHP	59.64	34.68	2.20	281.57
DINCH	324.36	100.15	2.37	1310.29
DEHT	118.86	109.31	30.76	334.67
DiNP	234.00	83.64	13.44	1034.52
DiDP	28.56	18.48	<0.02 (1)	224.24
DPHP	12.09	4.48	0.95	113.45
TOTM	0.03	0.01	0.002	0.28

4.1.2 Phthalates and alternative plasticisers in flooring materials

The analysis results for phthalates and alternative plasticisers in the material samples are shown in Table 3. Of the phthalates and alternative plasticisers analysed, all but two were detected in all material samples. DPHP and ATBC were the only substances below their respective LOD. This applied to 1 of 2 material samples for both DPHP and ATBC.

The substance detected in the highest mean concentration in all material samples was DINCH, which was significantly higher than the other analysed substances. The phthalates and alternative plasticisers detected in the lowest mean concentrations were DMP and DiDP.

Table 3. Analysed concentrations of phthalates and alternative plasticisers in material samples, measured in µg/g. Compiled results from two analysed material samples. All substances marked with a "<" in front of their value in the table were in one or more samples below the LOD, where the number of samples is given in brackets.

Substance	Mean value	Median value	Minimum value	Maximum value
DMP	0.01	0.01	0.01	0.02
DEP	0.24	0.24	0.20	0.28
DiBP	0.18	0.18	0.14	0.23
DnBP	0.39	0.39	0.34	0.44
ATBC	0.20	0.20	<0.00499 (1)	0.20
BzBP	0.54	0.54	0.53	0.55
DEHA	1.92	1.92	0.49	3.35
DEHP	0.55	0.55	0.47	0.62
DINCH	68061.28	68061.28	58404.89	77717.66
DEHT	0.65	0.65	0.26	1.04
DiNP	2.02	2.02	0.68	3.37
DiDP	0.24	0.24	0.06	0.42
DPHP	0.12	0.12	<0.0258 (1)	0.12
TOTM	0.16	0.16	0.14	0.18

4.2 Bisphenols

The analysis results for bisphenols in dust and flooring materials are presented below.

4.2.1 Bisphenols in dust

The results of the analysis of BPAF, BPF, BPA, BPS and TBBPA in all dust samples are presented in Table 4. BPAF, BPA and BPS were detected in dust from all preschools, while the concentrations of BPF and TBBPA were in most cases below the respective LOD. The bisphenol that occurred at the lowest concentration was BPF, which was only detected in 10 of 19 preschools. TBBPA was detected in 15 out of 19 preschools.

When comparing the mean values of the bisphenols in dust, BPA was present in the highest concentrations, followed by BPS. The bisphenols present in the lowest concentrations were BPAF and BPF.

Table 4. Analysed concentrations of bisphenols in dust, measured in µg/g. Compiled results from 19 analysed samples. All substances marked with a "<" in front of their value in the table were in one or more samples below the LOD, with the number of samples indicated in brackets.

Substance	Mean value	Median value	Minimum value	Maximum value
BPAF	0.07	0.03	0.014	0.63
BPF	0.01	0.004	<0.0005 (9)	0.09
BPA	0.85	0.74	0.178	2.60
BPS	0.26	0.20	0.042	0.79
TBBPA	0.19	0.13	<0.001 (4)	0.78

4.2.2 Bisphenols in flooring materials

The analysis results for bisphenols in the material samples are presented in Table 5. Only two of the analysed bisphenols (BPAF and BPA) were detected in the material samples. BPF, BPS and TBBPA were not detected.

BPA was present in the highest concentrations of the detected bisphenols.

Table 5. Analysed concentrations of bisphenols in material samples, measured in µg/g. Summarised results from two material samples. All substances marked with a "<" in front of their value in the table were in one or more samples below the LOD, where the number of samples is given in brackets.

Substance	Mean value	Median value	Minimum value	Maximum value
BPAF	0.004	0.004	0.003	0.005
BPF	<0.0005 (2)	<0.0005 (2)	<0.0005 (2)	<0.0005 (2)
BPA	0.118	0.118	0.092	0.144
BPS	<0.0005 (2)	<0.0005 (2)	<0.0005 (2)	<0.0005 (2)
TBBPA	<0.001 (2)	<0.001 (2)	<0.001 (2)	<0.001 (2)

4.3 Highly fluorinated organic substances (PFAS)

The analysis results for PFAS in dust and flooring materials are presented below.

4.3.1 Highly fluorinated organic substances (PFAS) in dust

The analysis results for PFAS in all dust samples are presented in Table 6. Of the 27 analysed PFAS, only six substances were detected in all dust samples. These substances were PFHxA, PFOA, PFOS, 6:2 FTS, 6:2 diPAP and 6:2/8:2 diPAP. The results also showed that seven PFAS substances could not be detected in any of the 19 dust samples. The substances that could not be detected were PFUnDA, PFHxS, FOSA, N-Me-FOSAA, FPrPA, FHpPA and 10:2 FTOH.

Based on the summarised mean values, it can also be seen that the PFAS substances present in the highest concentrations were 6:2 diPAP and 6:2 PAP. Of the substances that could be detected in one or more of the samples, 6:2 FTS and PFBS occurred at the lowest concentrations.

Table 6. Analysed concentrations of PFAS in dust, measured in ng/g. Compiled results from 19 analysed samples. All substances marked with a "<" in front of their value in the table were in one or more samples below the LOD, with the number of samples indicated in brackets.

Substance	Mean value	Median value	Minimum value	Maximum value
PFBA	6.33	6.72	<0.05 (13)	9.48
PFPeA	11.84	7.70	<0.05 (3)	86.96
PFHxA	138.85	53.39	12.45	765.65
PFHpA	7.25	6.36	<0.05 (6)	17.72
PFOA	20.61	19.15	3.02	52.71
PFNA	4.80	3.86	<0.05 (1)	13.75
PFDA	5.96	7.77	<0.05 (13)	9.24
PFUnDA	<0.05 (19)	<0.05 (19)	<0.05 (19)	<0.05 (19)
PFDoDA	14.07	14.07	<0.05 (17)	19.40
PFBS	3.48	3.48	<0.05 (18)	3.48
PFHxS	<0.11 (19)	<0.11 (19)	<0.11 (19)	<0.11 (19)
PFOS	18.33	14.91	6.97	68.23
PFDS	72.80	15.81	<0.05 (6)	532.10
FOSA	<0.05 (19)	<0.05 (19)	<0.05 (19)	<0.05 (19)
6:2 FTS	3.01	0.45	0.18	30.94
6:2 PAP	482.24	374.84	<0.20 (4)	1322.60
8:2 PAP	138.40	138.40	<0.12 (17)	173.84
6:2 diPAP	629.93	253.33	7.77	3861.81
6:2/8:2 diPAP	23.49	6.02	2.12	190.87
8:2 diPAP	13.75	5.97	<0.05 (7)	42.56
N-Me-FOSAA	<0.05 (19)	<0.05 (19)	<0.05 (19)	<0.05 (19)
N-Et-FOSAA	12.11	8.43	<0.05 (8)	64.46
8:2 FTS	8.37	1.17	<0.05 (4)	54.60
FPrPA	<0.05 (19)	<0.05 (19)	<0.05 (19)	<0.05 (19)
FPePA	6.79	4.43	<0.05 (11)	15.42
FHpPA	<0.05 (19)	<0.05 (19)	<0.05 (19)	<0.05 (19)
10:2 FTOH	<0.50 (19)	<0.50 (19)	<0.50 (19)	<0.50 (19)

4.3.2 Highly fluorinated organic substances (PFAS) in flooring materials

The analysis results of PFAS in the two material samples are presented in Table 7. These results show that none of the 27 analysed PFAS substances were detected in any of the material samples.

Table 7. Analysed concentrations of PFAS in material samples, measured in ng/g. Compiled results from two analysed material samples. All substances marked with a "<" in front of their value in the table were in one or more samples below the LOD, where the number of samples is given in brackets.

Substance	Mean value	Median value	Minimum value	Maximum value
PFBA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
PFPeA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
PFHxA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
PFHpA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
PFOA	<0.09 (2)	<0.09 (2)	<0.09 (2)	<0.09 (2)
PFNA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
PFDA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
PFUnDA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
PFDoDA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
PFBS	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
PFHxS	<0.11 (2)	<0.11 (2)	<0.11 (2)	<0.11 (2)
PFOS	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
PFDS	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
FOSA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
6:2 FTS	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
6:2 PAP	<0.20 (2)	<0.20 (2)	<0.20 (2)	<0.20 (2)
8:2 PAP	<0.12 (2)	<0.12 (2)	<0.12 (2)	<0.12 (2)
6:2 diPAP	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
6:2/8:2 diPAP	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
8:2 diPAP	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
N-Me-FOSAA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
N-Et-FOSAA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
8:2 FTS	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
FPrPA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
FPePA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
FHpPA	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.05 (2)
10:2 FTOH	<0.50 (2)	<0.50 (2)	<0.50 (2)	<0.50 (2)

4.4 Metals

Dust samples from seven preschools were also analysed for concentrations of various metals. These analysis results are illustrated in Table 8. All analysed metals were detected in the seven dust samples, except for cadmium which was detected in six out of seven samples.

From the summarised mean values, it is shown that zinc was the metal present in the highest concentration. The concentration was considerably higher than the concentrations of the other analysed metals. The metals with the lowest concentrations were cadmium and cobalt.

Table 8. Analysed concentrations of metals in dust, measured in µg/g. Compiled results from seven analysed samples. All substances marked with a "<" in front of their value in the table were in one or more samples below the LOD, with the number of samples indicated in brackets.

Substance	Mean value	Median value	Minimum value	Maximum value
Vanadium (V)	6.03	6.70	0.92	10.00
Chromium (Cr)	22.26	22.00	2.80	35.00
Manganese (Mn)	51.20	51.00	8.40	78.00
Cobalt (Co)	1.40	1.40	0.33	2.10
Nickel (Ni)	41.43	7.60	3.90	240.00
Copper (Cu)	48.43	48.00	12.00	81.00
Zinc (Zn)	240.86	190.00	46.00	470.00
Arsenic (As)	2.25	1.30	0.16	7.20
Cadmium (Cd)	0.16	0.14	<0.19 (1)	0.35
Lead (Pb)	5.77	4.80	2.50	11.00

4.5 Chlorinated paraffins

Dust samples from eight of the preschools were also analysed for chlorinated paraffins. The results of these analyses are shown in Table 9. All the chlorinated paraffins analysed were detected in all eight dust samples.

The summarised mean values show that medium-chain chlorinated paraffins were present in the highest concentrations. This can also be seen based on the calculated maximum values, where the maximum value for medium-chain chlorinated paraffins is considerably higher. The results from analysis of short-chain and long-chain chlorinated paraffins showed similar concentrations for both groups.

Tabell 9. Analysed concentrations of chlorinated paraffins in dust, measured in µg/g. Compiled results from eight analysed samples.

Substance	Mean value	Median value	Minimum value	Maximum value
∑SCCPs (C10-C13)	8.20	3.34	1.23	32.40
∑MCCPs (C14-C17)	37.50	23.10	8.45	108.40
∑LCCPs (C18-C21)	11.39	7.67	4.44	23.40

5 Discussion

Of the 19 preschools in this study, 11 of them also participated in the "*Dammprojekt 2015*" and "*Dammprojekt 2018*". Of the remaining eight *preschools,* three participated in the study "*Kemikaliebelastning i tre förskolors inomhusmiljö 2016–2020".*

For a comparison of the results between each study and per substance and substance group, see Appendix 2.

5.1 Comparison with previous studies

The main purpose of this study was to revisit selected preschools where sampling had previously been done to monitor the potential change in chemical load in the indoor environment. The illustrations below show how the concentrations of the potentially harmful substances have changed in comparison with previously conducted investigations. The comparisons are mainly showing results from the studies "*Dammprojekt 2015*" and "*Dammprojekt 2018*".

Figure 1 shows the median values of analysis results for the phthalates and alternative plasticisers. These substances were present in the highest concentrations in dust samples from the preschools that were evaluated in 2015, 2018 and this study in 2023. A steady downward trend in concentrations for DEHP, DiNP and DiDP were observed. A comparison of DINCH showed a different trend, where the concentration of DINCH has increased over the years. The concentration of DEHT shows a minor increase in concentration over the years.

The comparison of concentrations for the phase-out substances DEHP and DiNP as well as the alternative substance DINCH is of particular interest as it provides insight into the transition of replacing phase-out substances with alternative substances. This is illustrated shown in Figure 1, where the concentrations of DEHP and DiNP decrease over time, while DINCH increases.

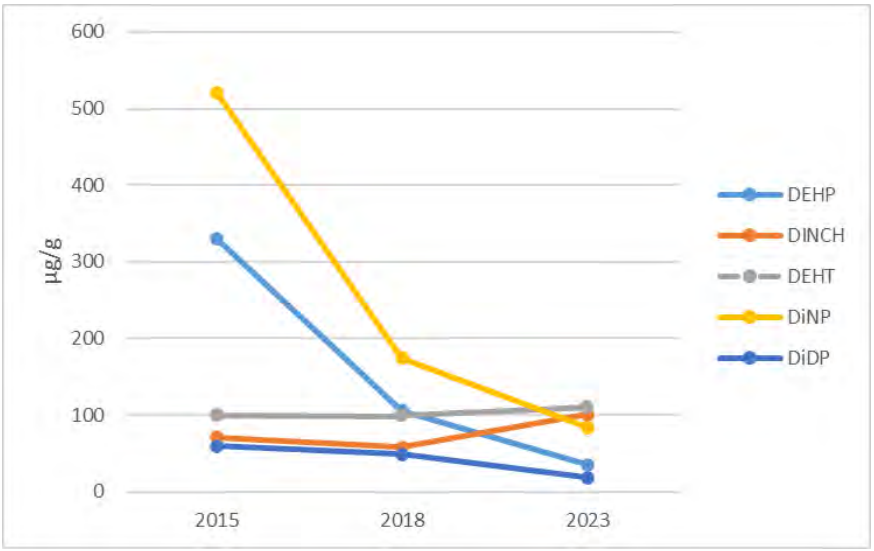

Figure 1. Median values for the phthalates and alternative plasticisers analysed in the highest concentrations in dust samples from selected preschools in 2015, 2018 and 2023.

Figure 2 illustrates the median values for the bisphenols analysed in dust samples from preschools on three different occasions. The results show a downward trend between 2018 and 2023 for the majority of the analysed substances. For BPA, neither a downward nor an

upward trend has been identified. Instead, the substance has remained at the same concentration. In 2018, BPAF could not be detected and is therefore marked with a dashed line in the graph.

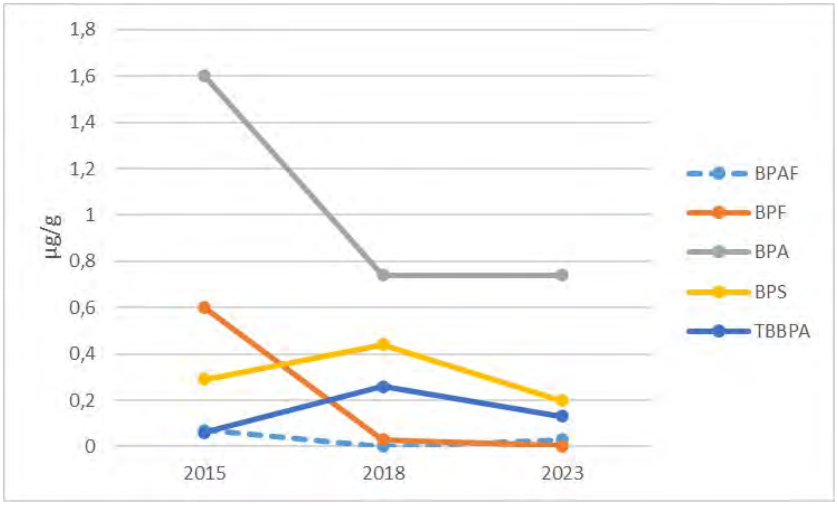

Figure 2. Median values for analysed bisphenols in dust samples from selected preschools in 2015, 2018 and 2023. The substance BPAF was not detected in 2018.

Figure 3 shows the median values of the analysed PFAS substances in dust samples from 2018 and 2023. No analysis of PFAS substances were carried out in the study in 2015. Several PFAS substances analysed in 2023 were not included in the study in 2018 and are therefore not included in the figure.

This diagram poses a difficulty in interpretation since the concentrations of 6:2 diPAP and 6:2 PAP are significantly higher than the remaining substances. For both 6:2 diPAP and 6:2 PAP, a major decrease in concentration between 2018 and 2023 was observed.

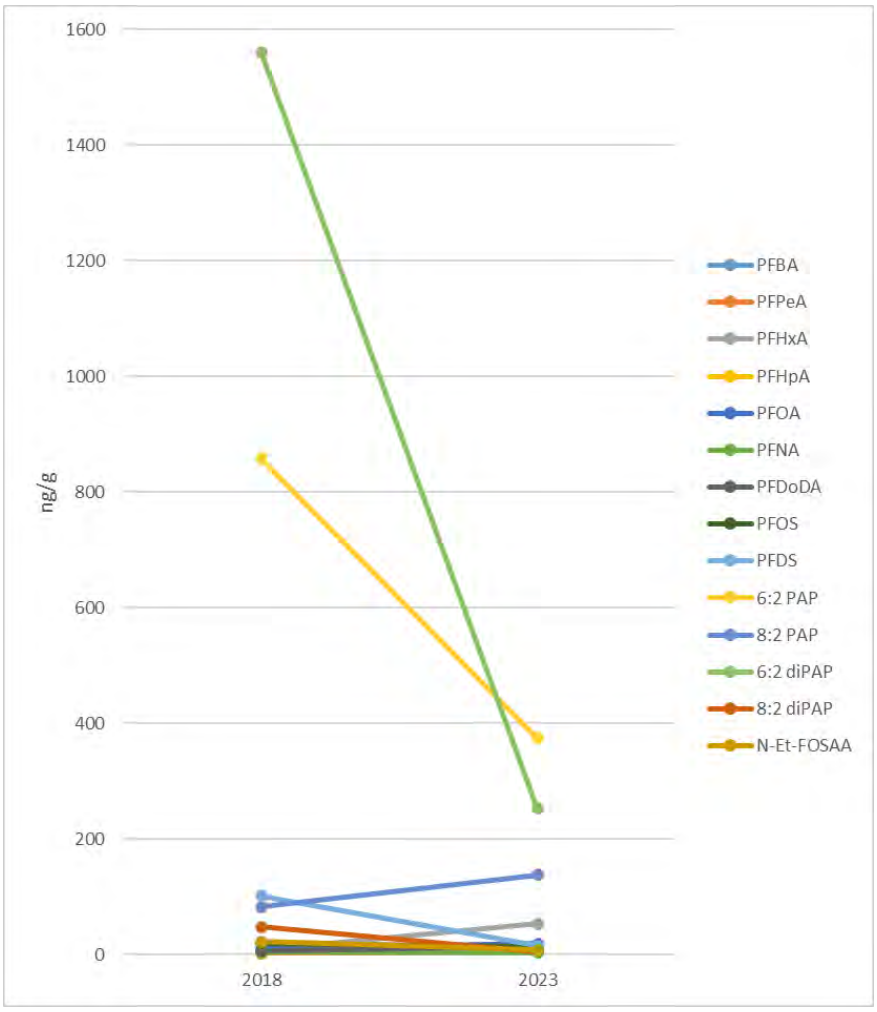

Figure 3. Median values for analysed PFAS substances in dust samples from selected preschools in 2018 and 2023. The diagram does only include substances detected in both studies.

In Figure 4, the two substances with the highest concentrations have been excluded. This diagram provides a clearer overview of the trends for the remaining analysed PFAS substances. The analysis results are shown to be scattered. There is neither a clear downward nor upward trend for any of the substances, but rather an even distribution of both trends. For example, one can see an almost doubling of the value for 8:2 PAP, while the value for PFDS has significantly decreased.

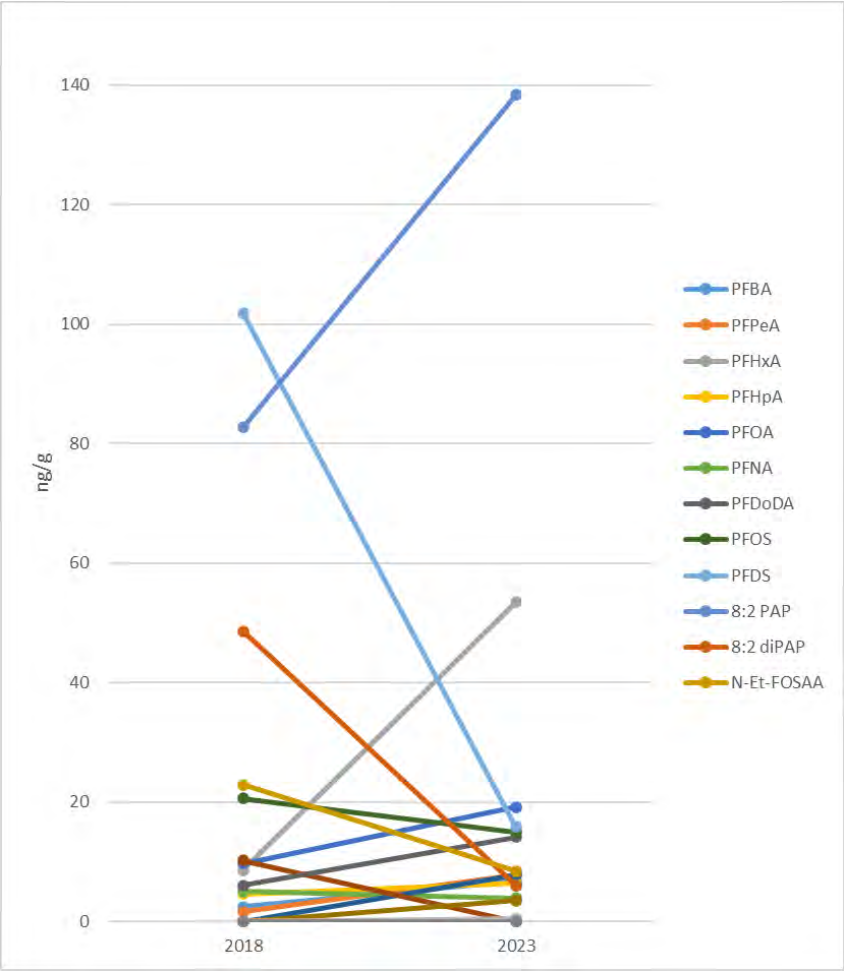

Figure 4. Median values for analysed PFAS substances in dust samples from selected preschools in 2018 and 2023, excluding the two substances in the highest concentrations. The diagram does only include substances detected in both studies.

Figure 5 illustrates the difference in percentage in median value between the 2018 and 2023 dust samples for the phthalates and alternative plasticisers. The results indicate a downward trend in concentration between 2018 and 2023 for the majority of the analysed substances. The substances that decreased in concentration all show a decrease of more than 40%. The two substances that show the largest decrease are benzyl butyl phthalate (BzBP) and diisobutyl phthalate (DiBP), which have both decreased in concentration by more than 80% since 2018.

The substances that increased between 2018 and 2023 are DPHP, DEHT, DINCH and DEP. Of the substances that increased, DINCH shows the largest increase of 72%.

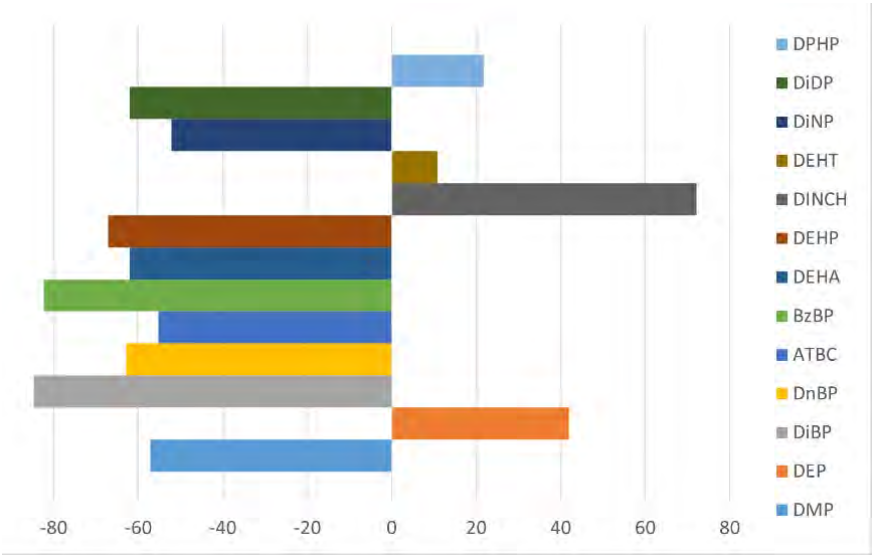

Figure 5. Difference in percentage for measured median values of analysed phthalates and alternative plasticisers in dust samples from selected preschools in 2018 and 2023. The graph does only include substances detected in both studies.

Figure 6 illustrates the difference in percentage for median value between the 2018 and 2023 dust samples for analysed bisphenols. The figure does not include those substances that were not detected in either one or both years, or where data are missing.

The results show a downward trend in concentration between 2018 and 2023 for all analysed substances except BPA. The percentage decrease for all substances but BPA was over 40%. BPF shows the largest decrease of 85% in concentration.

For BPA, neither a downward nor an upward trend was identified between 2018 and 2023, instead the substance remains at the same concentration.

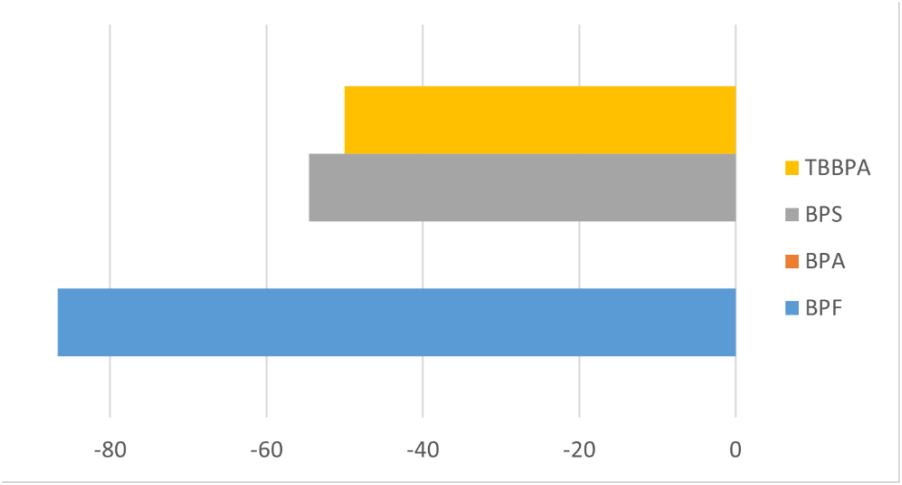

Figure 6. Difference in percentage for measured median values of analysed bisphenols in dust samples from selected preschools in 2018 and 2023. The graph does only include substances detected in both studies.

Figure 7 illustrates the difference in percentage for median value between the analysed 2018 and 2023 dust samples for the PFAS substances.

The results show an even distribution of substances that have decreased or increased in concentration between the studies in 2018 and 2023, with 7 substances increasing and 7 substances decreasing. This shows the wide variation in the use of chemicals, specifically PFAS substances, in the interior design and construction sectors. Most of the substances that show an increase in concentration have increased by 95% or more. The largest increase is PFHxA, which has increased by over 500%, and PFPeA, which has increased by almost 400%.

The substances showing the largest decrease are PFDS and 8:2 diPAP, both of which have decreased by over 80% since 2018.

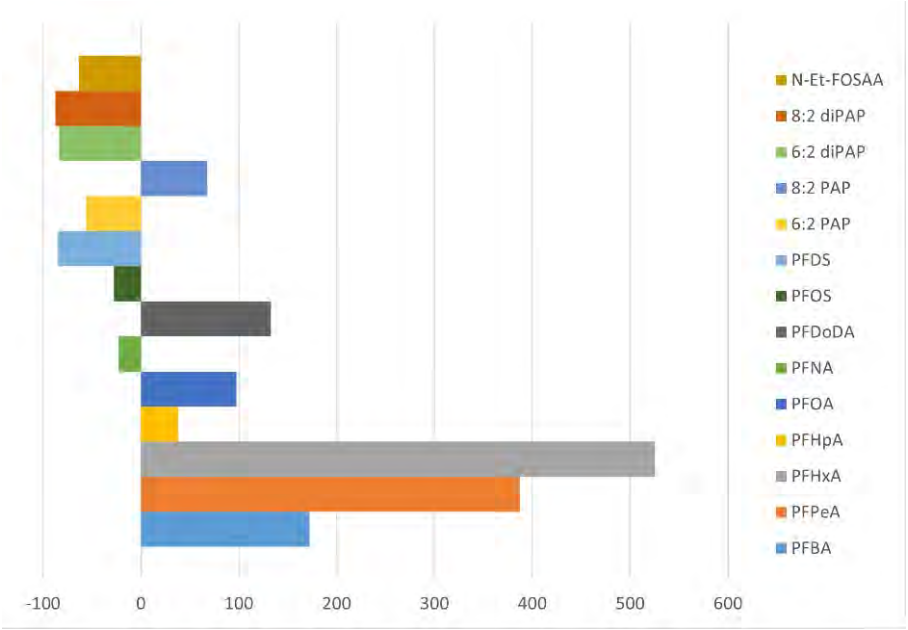

Figure 7. Difference in percentage for measured median values of analysed PFAS substances in dust samples from the selected preschools in 2018 and 2023. The graph does only include substances detected in both studies.

5.2 Connections to renovations

One of the questions for this study was to investigate whereas a connection between the concentrations of investigated substances in dust and any renovations carried out at the preschools was present. Based on the information received from the preschools regarding renovations as well as the analysis results, it was possible to draw a general conclusion. The most evident connections were noted in cases where floor renovations or total renovations had taken place. Total renovation means that the preschools have undergone for example replacement of all floors and ventilation equipment as well as repainting of wall surfaces. Floor renovation means that only the flooring materials have been replaced.

For preschools that have undergone total renovations since the last study, the concentration of several phthalates and alternative plasticisers show an increase in comparison to the preschools that have only undergone floor renovations. This applies both to substances that have increased in preschools after floor renovations, such as DINCH and DEHT, but also to DiNP, which has otherwise been observed to decrease in concentration. A general downward trend in the concentrations of PFAS substances has been noted as well.

In cases where the preschools have undergone floor renovations, most of the phthalates and alternative plasticisers have decreased in concentration. What these preschools also have in common is that the concentration of DINCH has increased the most. The substance shows a significant increase in concentration compared to the results from previous studies as well. DEHT has also increased, although not to the same extent as DINCH. The concentration of DiNP was reduced by almost half compared with the most recent studies. This can be seen as an indication that a transition from DiNP to the alternative plasticiser DINCH has begun. DiNP has been banned in for example toys that can be put in the mouth (Kemikalieinspektionen, 2023),

This significant change provides an overview how phase-out substances are replaced by alternative substances with similar properties. However, these alternative substances can often have similar toxic and harmful effects as the phase-out substances. Alternative substances have often not been studied to the same extent. A transition from phase-out substances to alternative substances does not automatically mean a step towards a more toxic-free indoor environment. These observations from this study justifies further studies of current alternative substances and continued environmental monitoring of the indoor environment.

5.3 Correlation between analytical results in dust and material samples

Another factor relevant to investigate was the comparison between concentrations of the same substance in dust samples and material samples from the same preschool. As only two material samples were collected during this study, comparisons have only been made for these preschools (F46 and F60). For complete results for the preschools, see Appendix 2. All analysis results for PFAS substances were below their respective LOD. Hence, no comparisons were made for this substance group. No analysis of metals were carried out for these preschools and this substance group is therefore also excluded from the comparisons.

Material samples were collected from these two preschools as total renovations have been carried out since the previous studies. The renovations have included complete floor renovations.

Tables 10 and 11 illustrate comparisons between analysed concentrations of five selected phthalates and alternative plasticisers in dust and material samples from preschool F46 and F60. The phthalates and alternative plasticisers included in the tables are the five substances that occurred in the highest concentrations based on compiled median values for all preschools. The two tables show a clear correlation that the substance that occurs in the highest concentration in dust samples also occurs in the highest concentration in material samples. This applies to both preschools. The substance with the highest concentration is in both cases DINCH. The same applies to the substance that occurs in the lowest analysed concentration, which in these two cases is DiDP.

Table 10. Comparison between analysed concentrations of five selected phthalates and alternative plasticisers in dust and material samples from preschool F46, measured in µg/g.

Substance	Concentration in dust sample	Concentration in material sample
DINCH	197.41	58404.89
DiNP	64.25	3.37
DEHT	30.76	1.04
DiDP	<0.016	0.42
DEHP	2.20	0.47

Table 11. Comparison between analysed concentrations of five selected phthalates and alternative plasticisers in dust and material samples from preschool F60, measured in µg/g.

Substance	Concentration in dust sample	Concentration in material sample
DINCH	341.74	77717.66
DiNP	147.03	0.68
DEHT	129.82	0.26
DiDP	21.28	0.06
DEHP	35.98	0.62

For the analysed concentrations of bisphenol, reported in tables 12 and 23, no evident relationship between the concentrations in the dust and material samples was observed. This is partly because there are a larger number of undetected substances, especially in the material samples. In addition, the analysis results for bisphenols show significantly lower concentrations. However, it is possible to detect a pattern similar to that for phthalates and alternative plasticisers, where higher concentrations of a substance in a material sample also indicate higher concentrations of the same substance in the corresponding dust sample. For example, BPA occurs in the highest concentration in the material samples for both preschools, which is reflected in the dust samples where BPA also occurs in the highest concentration.

Table 12. Comparison between analysed concentrations of bisphenols in dust and material samples from preschool F46, measured in µg/g.

Substance	Concentration in dust sample	Concentration in material sample
BPAF	0.030	0.003
GMP	0.003	<0.0005
BPA	0.943	0.144
BPS	0.247	<0.0005
TBBPA	0.006	<0.001

Table 13. Comparison between analysed concentrations of bisphenols in dust and material samples from preschool F60, measured in µg/g.

Substance	Concentration in dust sample	Concentration in material sample
BPAF	0.072	0.005
GMP	<0.0005	<0.0005
BPA	0.741	0.092
BPS	0.085	<0.0005
TBBPA	0.073	<0.001

These comparisons show that there is a correlation between analysed concentrations in dust and material samples from the same preschool. However, deviations may occur, and these findings are based on only two comparisons of material samples. In order to establish a correlation with greater certainty, comparisons with samples from additional preschools are necessary.

5.4 New groups of substances analysed in this study

Two of the substance groups analysed in this study have not been analysed in the previous studies. The two groups of substances concerned are metals and chlorinated paraffins. Therefore, there are no data available to evaluate and compare the development of the presence of these substance groups in dust in preschools. Instead, these groups of substances were evaluated individually within their respective groups, and briefly compared with previous research.

For the metals, it was noted that particularly harmful metals such as lead, arsenic and cadmium were also detected in the dust. Lead was measured at µg/g concentrations in this study, which is also consistent with results from previous research. Zinc was the metal measured in the highest concentrations and was significantly higher than the other metals analysed. However, this is not considered inconsistent in comparison with previous research.

Regarding chlorinated paraffins, short-, medium- and long-chain chlorinated paraffins were found in all 8 preschools in this study. According to previous research, long-chain chlorinated paraffins are the most common in dust in Sweden. In contrast, this study showed that medium-chain chlorinated paraffins were present in the higher concentrations in the collected samples.

6 Conclusions

Based on the results of this study, a few conclusions could be drawn. The concentrations of potentially harmful substances in preschools have undergone an evident change when comparing with the previous studies performed in 2015 and 2018. Depending on substance group, some concentrations of substances have increased while others have decreased. This change is also evident for individual substances within each substance group. A clear example of this is the substance group phthalates and alternative plasticisers, where the concentration of the alternative substance DINCH has increased significantly compared to the phase-out substances DEHP and DiNP. The two latter do in turn show a clear decrease in concentration.

The analysis of percentage change between the previous studies and this one also highlights the increased use of alternative substances in the indoor environment of preschools. This is indicative of a correlation between renovations and the reduction of levels of the potentially harmful substances investigated.

Although the levels of the banned and most harmful substances are decreasing as new legislation is introduced, it cannot be concluded with certainty that the City of Stockholm's preschools are moving towards a more toxic-free environment. This is due to the increased use of alternative substances, for which there is currently insufficient knowledge to evaluate their long-term toxic and harmful effects. It is therefore of utmost importance that environmental monitoring and evaluation of the presence of potentially harmful substances in the indoor environment of preschools continues and remains a prioritised area.

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Annex 1: Substances analysed

Substance name	Abbreviation	CAS number
Phthalate esters		
Dimethyl phthalate	DMP	131-11-3
Diethyl phthalate	DEP	84-66-2
Diisobutyl phthalate	DiBP	84-69-5
Di-n-butylphthalate	DnBP	84-74-2
Benzyl butyl phthalate	BzBP	85-68-7
Di(2-ethylhexyl)phthalate	DEHP	117-81-7
Diisononyl phthalate	DINP	28553-12-0
Diisodecyl phthalate	ISDP	26761-40-0
Di(2-propylheptyl)phthalate	DPHP	53306-54-0
Alternative plasticisers		
Acetyltributylcitrate	ATBC	77-90-7
Di(2-ethylhexyl)adipate	DEHA	103-23-1
Di(2-ethylhexyl)terephthalate	DEHT	6422-86-2
1,2-Cyclohexane dicarboxylic acid diisononyl ester	DINCH	166412-78-8
Trioctyl trimellitate	TOTM	3319-31-1
Bisphenols		
Bisphenol A	BPA	80-05-7
Bisphenol F	GMP	620-92-8
Bisphenol AF	BPAF	1478-61-1
Bisphenol S	BPS	80-09-1
Tetrabromobisphenol A	TBBPA	79-94-7
Poly- & perfluoroalkyl substances		
Perfluorobutanoic acid	PFBA	375-22-4
Perfluoropentanoic acid	PFPeA	2706-90-3
Perfluorohexanoic acid	PFHxA	307-24-4
Perfluoroheptanoic acid	PFHpA	375-85-9
Perfluorooctanoic acid	PFOA	335-67-1
Perfluorononanoic acid	PFNA	375-95-1
Perfluorodecanoic acid	PFDA	335-76-2
Perfluoroundecanoic acid	PFUnDA	2058-94-8
Perfluorododecanoic acid	PFDoDA	307-55-1
Perfluorobutanesulfonic acid	PFBS	375-73-5
Perfluoropentane sulfonic acid	PFPeS	2706-91-4
Perfluorohexanesulfonic acid	PFHxS	355-46-4
Perfluorooctanesulfonic acid	PFOS	1763-23-1
Perfluorodecanesulfonic acid	PFDS	335-77-3
Perfluorooctane sulfonamide	PFOSA	754-91-6
6:2 fluorotelomer sulfonic acid	6:2 FTS	27619-97-2
8:2 fluorotelomer sulfonic acid	8:2 FTS	39108-34-4
Pentafluoropropionic acid	FPrPA FPePA FHpPA	422-64-0
Perfluorooctane sulfonamido acetic acid	FOSAA	2806-24-8
Mono[2-(perfluorohexyl)ethyl] phosphate	6:2 PAP	57678-01-0
Mono[2-(perfluorooctyl)ethyl] phosphate	8:2 PAP	57678-03-2
Bis[2-(perfluorohexyl)ethyl] phosphate	6:2 diPAP	57677-95-9

	6:2/8:2 diPAP	
Bis[2-(perfluorooctyl)ethyl] phosphate	8:2 diPAP	678-41-1
N-methylperfluorooctane sulfonamidoacetic acid	N-Me-FOSAA	2355-31-9
N-ethylperfluoro-1-octanesulfonamidoacetic acid	N-Et-FOSAA	2991-50-6
	10:2 FTOH	
Metals		
Lead	Pb	7439-92-1
Cadmium	CD	7440-43-9
Nickel	Ni	7440-02-0
Arsenic	Ace	7440-38-2
Copper	Cu	7440-50-8
Zinc	Zn	7440-66-6
Chromium	Cr	7440-47-3
Vanadium	V	7440-62-2
Cobalt	Co	7440-48-4
Manganese	Mn	7439-96-5
Chlorinated paraffins		
Short Chained Chlorinated Paraffins (C10-C13)	∑SCCPs (C10-C13)	
Medium Chained Chlorinated Paraffins (C14-C17)	∑MCCPs (C14-C17)	
Long Chained Chlorinated Paraffins (C18-C21)	∑LCCPs (C18-C21)	

Annex 2: Analysis results

See separate Excel file for the analysis results.

		Preeschool	F14				F41			F43					F46				F48			F51						
		Sample type	Dust				Dust			Dust				Material	Dust			Material	Dust			Dust						Dust
		Year	2015	2018	Blanc 2023	2023	2015	2018	2023	2015	2018	Blanc 2023	2023	2015	2015	2018	2023	2023	2015	2018	2023	2015	2018	Blanc 2023	2023	2015	2018	Blanc 2023
		Project	/	/	GP 2023	GP 2023	IVL 2015	IVL 2018	GP 2023	IVL 2015	IVL 2018	GP 2023	GP 2023	WSP 2015	IVL 2015	IVL 2018	GP 2023	GP 2023	IVL 2015	IVL 2018	GP 2023	IVL 2015	IVL 2018	GP 2023	GP 2023	/	/	GP 2023
SUBSTANCE																												
Phthalates	**LOD (2023)**																											
Unit	*µg/g*				*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	%	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*			*µg/g*
DMP	0,00103				<0,00103	0,04	7,0	0,12	0,35	11	0,25	<0,00103	0,08	<LOD	0,11	0,03	0,03	0,02	0,22	0,03	0,02	1,1	0,04	<0,00103	0,07			<0,00103
DEP	0,00668				<0,00668	0,28	41	1,70	0,49	130	0,96	<0,00668	3,20	<LOD	53	0,25	0,32	0,20	5,7	0,27	0,30	<0,5	0,35	<0,00668	1,94			<0,00668
DiBP	0,00766				<0,00766	0,62	12	24,79	15,62	21	15,94	<0,00766	1,14	<LOD	17	5,46	0,12	0,14	2,9	0,81	0,37	28	6,33	<0,00766	1,10			<0,00766
DnBP	0,03693				<0,0369	6,47	39	43,32	9,29	57	27,73	<0,0369	3,54	<LOD	15	9,34	0,39	0,34	31	6,77	6,29	44	11,13	<0,0369	3,62			<0,0369
ATBC	0,00499				<0,00499	2,32	30	8,41	4,00	39	6,82	<0,00499	6,23	<LOD	2	2,21	0,99	0,20	7,3	2,04	1,16	5,2	2,94	0,02	0,17			0,01
BzBP	0,00522				<0,00522	4,04	6,6	13,41	2,61	19	9,49	<0,00522	1,80	0,01	19	14,37	0,89	0,53	9,1	6,77	3,70	7,1	4,81	<0,00522	8,25			<0,00522
DEHA	0,00893				<0,00893	6,80	2,8	3,37	1,74	61	15,81	<0,00893	3,99	<LOD	3,3	4,21	1,80	3,35	8,8	3,27	3,31	3,7	8,37	<0,00893	2,81			<0,00893
DEHP	0,01950				<0,0195	192,70	440	144,21	58,44	210	138,44	<0,0195	50,70	0,03	1900	70,77	2,20	0,47	290	105,53	34,68	150	225,08	<0,0195	55,37			<0,0195
DINCH	0,13768				<0,138	9,21	140	58,18	172,25	64	19,57	<0,138	32,27	0,14	29	26,56	197,41	58404,89	71	43,11	100,15	38	249,05	<0,138	53,10			<0,138
DEHT	0,01359				<0,0136	54,47	39	74,85	77,06	410	105,88	<0,0136	141,27	<LOD	20	98,46	30,76	1,04	210	139,25	175,46	100	73,17	<0,0136	35,21			<0,0136
DiNP	0,00873				0,018	24,89	250	116,09	57,79	1300	1111,37	0,011	1034,52	29,39	70	59,73	64,25	3,37	280	71,09	133,07	2600	94,28	0,01	13,44			0,01
DiDP	0,01602				<0,016	7,36	74	79,21	25,77	59	61,20	<0,016	32,52	0,63	26	24,53	<0,016	0,42	110	10,73	16,19	64	45,05	<0,016	3,11			<0,016
DPHP	0,02577				<0,0258	3,24	5,0	4,07	4,63	4	3,06	0,007	7,49	<LOD	1,6	3,63	4,14	0,12	3	1,96	3,56	5,2	2,06	<0,0258	0,95			<0,0258
TOTM	0,00209				<0,00209	0,003			0,012			<0,00209	0,019				0,007	0,14			0,008			<0,00209	0,002			<0,00209
Bisphenols																												
Unit	*µg/g*				*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*		*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*			*µg/g*
BPAF	0,0005				<0,0005	0,014	<0,13	<LOD	0,044	<0,13	<LOD	<0,0005	0,027		<0,13	<LOD	0,030	0,003	<0,13	<LOD	0,021	<0,065	<LOD	<0,0005	0,024			<0,0005
BPF	0,0005				<0,0005	0,015	<0,12	0,018	<0,0005	<0,12	0,023	<0,0005	<0,0005		<0,12	<LOD	0,003	<0,0005	<0,12	<LOD	<0,0005	0,11	0,021	<0,0005	<0,0005			<0,0005
BPA	0,0005				<0,0005	0,512	1,6	0,969	1,055	1,2	6,147	<0,0005	0,519		0,21	0,828	0,943	0,144	1,8	0,201	0,255	1,8	1,423	<0,0005	1,433			<0,0005
BPS	0,0005				0,001	0,671	<0,12	0,934	0,792	0,37	0,677	<0,0005	0,259		<0,12	0,443	0,247	<0,0005	<0,12	0,135	0,109	0,25	0,371	0,005	0,042			0,001
TBBPA	0,001				<0,001	0,244	0,0625	0,261	0,010	1,2	1,633	<0,001	0,176		0,58	0,259	0,006	<0,001	0,026	<LOD	0,002	0,050	0,026	<0,001	<0,001			<0,001
PFAS																												
Unit	*ng/g*				*ng/g*	*ng/g*		*ng/g*	*ng/g*		*ng/g*	*ng/g*	*ng/g*			*ng/g*	*ng/g*	*ng/g*		*ng/g*	*ng/g*		*ng/g*	*ng/g*	*ng/g*			*ng/g*
PFBA	0,05				<0,05	<0,05		<LOD	<0,05		<LOD	<0,05	<0,05			<LOD	<0,05	<0,05		<LOD	<0,05		<LOD	<0,05	<0,05			<0,05
PFPeA	0,05				<0,05	12,52		<LOD	8,42		<LOD	<0,05	3,20			<LOD	3,64	<0,05		<LOD	2,7		<LOD	<0,05	<0,05			<0,05
PFHxA	0,05				<0,05	102,35		12,80	176,37		<LOD	<0,05	40,34			<LOD	34,15	<0,05		<LOD	33,33		<LOD	<0,05	251,75			<0,05
PFHpA	0,05				<0,05	5,80		7,64	12,38		4,60	<0,05	<0,05			<LOD	<0,05	<0,05		<LOD	4,20		<LOD	<0,05	<0,05			<0,05
PFOA	0,09				<0,09	18,36		27,70	30,35		16,32	<0,09	22,78			3,99	3,02	<0,09		<LOD	16,81		13,00	<0,09	14,61			<0,09
PFNA	0,05				<0,05	4,13		8,31	11,57		5	<0,05	0,48			<LOD	2,55	<0,05		<LOD	4,53		2,08	<0,05	1,12			<0,05
PFDA	0,05				<0,05	<0,05		<LOD	9,08		<LOD	<0,05	<0,05			<LOD	<0,05	<0,05		<LOD	0,12		<LOD	<0,05	<0,05			<0,05
PFUnDA	0,05				<0,05	<0,05		<LOD	<0,05		<LOD	<0,05	<0,05			<LOD	<0,05	<0,05		<LOD	<0,05		<LOD	<0,05	<0,05			<0,05
PFDoDA	0,05				<0,05	<0,05		8,25	<0,05		<LOD	<0,05	<0,05			<LOD	<0,05	<0,05		<LOD	<0,05		<LOD	<0,05	<0,05			<0,05
PFBS	0,05				0,55	<0,05		<LOD	<0,05		<LOD	1,54	<0,05			<LOD	<0,05	<0,05		<LOD	<0,05		<LOD	0,13	<0,05			0,32
PFHxS	0,11				<0,11	<0,11		<LOD	<0,11		<LOD	<0,11	<0,11			<LOD	<0,11	<0,11		<LOD	<0,11		<LOD	<0,11	<0,11			<0,11
PFOS	0,05				0,94	9,58		29,07	30,24		<LOD	0,12	17,40			22,81	14,13	<0,05		49,80	14,91		31,24	0,19	68,23			0,41
PFDS	0,05				<0,05	22,87		96,71	48,17		23,05	<0,05	15,81			<LOD	<0,05	<0,05		<LOD	8,26		107,06	<0,05	207,31			<0,05
FOSA	0,05				<0,05	<0,05		0,08	<0,05		<LOD	<0,05	<0,05			0,06	<0,05	<0,05		0,29	<0,05		<LOD	<0,05	<0,05			<0,05
6:2 FTS	0,05				<0,05	30,94		<LOD	2,19		<LOD	<0,05	0,50			<LOD	0,51	<0,05		<LOD	0,39		<LOD	<0,05	6,87			<0,05
6:2 PAP	0,20				<0,20	759,51		1632,92	960,87		2775,62	<0,20	1239,13			1820,74	57,14	<0,20		858,63	510,59		410,83	<0,20	374,84			<0,20
8:2 PAP	0,12				<0,12	<0,12		427,95	173,84		<LOD	<0,12	<0,12			53,42	<0,12	<0,12		85,49	<0,12		323,65	<0,12	<0,12			<0,12
6:2 diPAP	0,05				0,26	3861,81		7555,01	783,72		39158,81	<0,05	1985,65			42444,98	88,42	<0,05		24074,31	1492,87		640,39	<0,05	432,76			<0,05
6:2/8:2 diPAP	0,05				<0,05	4,12			83,34			<0,05	5,68				6,02	<0,05			14,69			<0,05	190,87			<0,05
8:2 diPAP	0,05				<0,05	4,76		384,22	42,56		37,29	<0,05	<0,05			48,55	1,45	<0,05		158,14	7,18		229,76	<0,05	41,41			<0,05
N-Me-FOSAA	0,05				<0,05	<0,05		<LOD	<0,05		<LOD	<0,05	<0,05			<LOD	<0,05	<0,05		<LOD	<0,05		<LOD	<0,05	<0,05			<0,05
N-Et-FOSAA	0,05				<0,05	2,18		283,41	12,63		22,61	<0,05	1,07			93,31	<0,05	<0,05		72,06	13,79		281,31	<0,05	64,46			<0,05
8:2 FTS	0,05				<0,05	54,60			10,77			<0,05	1,53				<0,05	<0,05			9,68			<0,05	28,87			<0,05
FPrPA	0,05				<0,05	<0,05			<0,05			<0,05	<0,05				<0,05	<0,05			<0,05			<0,05	<0,05			<0,05
FPePA	0,11				<0,05	4,38			10,31			<0,05	<0,05				<0,05	<0,05			<0,05			<0,05	<0,05			<0,05
FHpPA	0,05				<0,05	<0,05			<0,05			<0,05	<0,05				<0,05	<0,05			<0,05			<0,05	<0,05			<0,05
10:2 FTOH	0,05				<0,05	<0,50			<0,50			<0,50	<0,50				<0,50	<0,50			<0,50			<0,50	<0,50			<0,50
Metals																												
Unit	*µg/g*								*µg/g*																			
Vanadium (V)	0,003								5,50																			
Chromium (Cr)	0,02								21,00																			
Manganese (Mn)	0,01								78,00																			
Cobalt (Co)	0,002								1,30																			
Nickel (Ni)	0,03								7,30																			
Copper (Cu)	0,05								35,00																			
Zinc (Zn)	0,30								430,00																			
Arsenic (As)	0,01								7,20																			
Cadmium (Cd)	0,002								0,35																			
Lead (Pb)	0,01								11,00																			
Chlorinated paraffins																												
Unit	*µg/g*								*µg/g*																			
ΣSCCPs (C10-C13)	0,25								9,61																			
ΣMCCPs (C14-C17)	0,25								72,6																			
ΣLCCPs (C18-C21)	0,5								18,9																			

F52							F57				F60				F61			F65						F70						
	Material				Dust			Material			Dust			Material	Dust			Dust				Dust			Material					
2023	2015	2015	2015	2015	2018	2023	2015	2015	2015	2015	2018	2023	2023	2015	2018	2023	2015	2018	2023	2015	2018	2023	2015	2015	2015	2015	2015	2015	
GP 2023	WSP 2015	WSP 2015	WSP 2015	/	/	GP 2023	WSP 2015	WSP 2015	WSP 2015	IVL 2015	IVL 2018	GP 2023	GP 2023	IVL 2015	IVL 2018	GP 2023	IVL 2015	IVL 2018	GP 2023	/	/	GP 2023	WSP 2015	WSP 2015	WSP 2015	WSP 2015	WSP 2015	/	
	Sample 1	Sample 2	Sample 3				Sample 1	Sample 2	Sample 3														Sample 1	Sample 2	Sample 3	Sample 4	Sample 5		
µg/g	%	%	%			µg/g	%	%	%	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g			µg/g	%	%	%	%	%		
0,02	<LOD	<LOD	<LOD			0,02	<LOD	<LOD	<LOD	0,03	0,17	0,03	0,01	<0,02	<LOD	0,03	0,22	0,19	0,02			0,02	<LOD	<LOD	<LOD	<LOD	<LOD		
0,28	<LOD	<LOD	<LOD			0,25	<LOD	<LOD	<LOD	<0,5	5,71	0,85	0,28	<0,5	0,27	2,60	<0,5	0,52	0,72			0,69	<LOD	<LOD	<LOD	<LOD	<LOD		
1,05	<LOD	<LOD	0,01			0,25	<LOD	<LOD	<LOD	4,7	2,86	0,61	0,23	23	2,00	0,25	9,7	30,75	1,69			0,85	0,01	0,01	<LOD	<LOD	0,01		
1,61	<LOD	0,04	0,17			1,00	<LOD	0	0,02	24	19,90	9,36	0,44	12	4,39	2,71	16	552,26	2,21			5,68	0,01	0,11	0,01	0,01	0,02		
1,91	<LOD	<LOD	<LOD			4,06	<LOD	<LOD	<LOD	7,7	40,22	1,72	<0,00499	1,1	4,61	65,03	3,4	30,83	4,48			8,05	<LOD	<LOD	<LOD	<LOD	<LOD		
1,57	0	0,03	5,11			0,76	<LOD	<LOD	0,01	4	20,90	5,37	0,55	4,4	39,50	7,63	3,1	5,76	0,41			5,75	0,02	0,31	0,03	0,07	<LOD		
2,22	0,04	0,01	0,06			1,94	<LOD	0,02	0	170	8,73	3,28	0,49	13	3,34	2,73	6	8,70	1,58			2,38	0	0,02	0,02	0	0		
18,95	0,13	15,57	19,8			4,87	<LOD	0,01	19,26	410	167,80	35,98	0,62	82	138,95	15,73	370	71,35	12,16			281,57	0,23	17,5	16,56	17,88	18,2		
23,97	<LOD	0,16	<LOD			714,70	0,03	20,46	0,19	22	60,69	341,74	77717,66	29	56,27	17,26	150	76,10	2,37			55,89	0,12	<LOD	<LOD	<LOD	<LOD		
76,92	<LOD	<LOD	<LOD			74,73	<LOD	<LOD	<LOD	56	97,94	129,82	0,26	37	126,76	87,76	32	98,65	196,33			155,20	<LOD	<LOD	<LOD	<LOD	<LOD		
678,05	37,99	<LOD	<LOD			24,11	14,16	<LOD	<LOD	250	394,18	147,03	0,68	520	174,72	14,48	120	1579,61	723,28			16,56	30,62	<LOD	<LOD	<LOD	<LOD		
20,77	0,07	<LOD	1,92			8,37	0,35	<LOD	<LOD	22	61,03	21,28	0,06	25	15,47	2,48	17	87,72	22,92			2,89	<LOD	<LOD	<LOD	<LOD	<LOD		
4,22	<LOD	<LOD	0,01			3,43	<LOD	<LOD	<LOD	1,7	3,68	8,97	<0,0258	5,1	2,77	1,28	2,5	16,31	4,48			1,73	<LOD	<LOD	<LOD	<LOD	<LOD		
0,014						0,014						0,004	0,183			0,011			0,010			0,010							
µg/g						µg/g				µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g			µg/g							
0,033						0,628				<0,13	<LOD	0,072	0,005	<0,13	<LOD	0,02	0,07	<LOD	0,021			0,018							
0,006						0,002				<0,12	0,015	<0,0005	<0,0005	<0,12	0,125	0,09	<0,10	0,049	0,008			<0,0005							
0,424						0,526				0,62	0,744	0,741	0,092	0,49	0,241	0,18	2,2	0,693	0,888			0,970							
0,571						0,611				0,23	0,100	0,085	<0,0005	0,33	0,150	0,22	0,23	0,965	0,199			0,067							
0,437						0,104				0,90	0,360	0,073	<0,001	0,02	<LOD	<0,001	0,02	0,069	0,130			<0,001							
ng/g						ng/g					ng/g	ng/g	ng/g		ng/g	ng/g		ng/g	ng/g			ng/g							
<0,05						1,55					<LOD	<0,05	<0,05		<LOD	<0,05		2,47	<0,05			<0,05							
2,31						4,47					<LOD	12,45	<0,05		<LOD	<0,05		1,97	3,57			<0,05							
59,62						53,39					<LOD	12,45	<0,05		<LOD	92,84		10,53	53,11			18,11							
10,34						1,13					<LOD	6,36	<0,05		<LOD	<0,05		1,57	<0,05			<0,05							
17,34						10,63					6,38	22,38	<0,09		0,36	4,85		14,07	9,76			11,20							
8,26						3,44					<LOD	7,66	<0,05		<LOD	<0,05		58,54	13,75			0,44							
6,45						<0,05					<LOD	<0,05	<0,05		<LOD	<0,05		<LOD	<0,05			<0,05							
<0,05						<0,05					<LOD	<0,05	<0,05		<LOD	<0,05		10,18	<0,05			<0,05							
<0,05						<0,05					<LOD	<0,05	<0,05		3,85	<0,05		<LOD	<0,05			<0,05							
<0,05						<0,05					<LOD	<0,05	<0,05		<LOD	<0,05		<LOD	3,48			<0,05							
<0,11						<0,11					<LOD	<0,11	<0,11		<LOD	<0,11		<LOD	<0,11			<0,11							
11,79						7,08					13,43	18,20	<0,05		23,16	29,40		11,22	7,05			12,58							
<0,05						<0,05					212,38	532,10	<0,05		<LOD	<0,05		<LOD	<0,05			50,46							
<0,05						<0,05					0,13	<0,05	<0,05		<LOD	<0,05		<LOD	<0,05			<0,05							
0,34						0,18					<LOD	10,46	<0,05		<LOD	0,18		<LOD	0,20			0,35							
1322,60						<0,20					1088,28	942,85	<0,20		<LOD	<0,20		23,19	505,14			191,01							
<0,12						<0,12					43,41	102,96	<0,12		<LOD	<0,12		<LOD	<0,12			<0,12							
565,74						16,28					7950,33	1473,95	<0,05		134,94	7,77		113,06	277,62			253,33							
7,97						2,61						57,98	<0,05			2,19			2,12			6,66							
9,24						<0,05					34,53	26,88	<0,05		29,60	<0,05		49,66	<0,05			1,67							
<0,05						<0,05					<LOD	<0,05	<0,05		<LOD	<0,05		<LOD	<0,05			<0,05							
<0,05						<0,05					22,90	18,41	<0,05		44,66	8,43		8,62	<0,05			10,20							
0,70						<0,05						10,89	<0,05			<0,05			0,26			0,38							
<0,05						<0,05						<0,05	<0,05			<0,05			<0,05			<0,05							
3,36						<0,05						<0,05	<0,05			0,41			2,04			<0,05							
<0,05						<0,05						<0,05	<0,05			<0,05			<0,05			<0,05							
<0,50						<0,50						<0,50	<0,50			<0,50			<0,50			<0,50							
µg/g						µg/g													µg/g										
6,70						8,00													6,80										
19,00						35,00													22,00										
51,00						72,00													49,00										
1,80						1,80													1,40										
6,20						240,00													7,60										
57,00						81,00													48,00										
230,00						190,00													160,00										
1,30						2,80													1,20										
0,11						<0,19													0,08										
4,80						5,40													4,30										
µg/g						µg/g													µg/g										
11,4						3,05													2,45										
108,4						28,5													17,7										
23,4						15,5													6,56										

F85		F87				F94				F99				F101		F102			F103							
Dust		Dust			Material	Dust				Dust			Material	Dust		Dust			Dust							
2018	2023	2015	2018	2023	2015	2015	2018	Blanc 2023	2023	2015	2018	2023	2015	2016	2023	2016	2019	2023	2016	2018	2019	2023				
/	GP 2023	IVL 2015	IVL 2018	GP 2023	WSP 2015	IVL 2015	IVL 2018	GP 2023	GP 2023	IVL 2015	IVL 2018	GP 2023	WSP 2015	IVL 2020	GP 2023	IVL 2020	IVL 2020	GP 2023	IVL 2020	IVL 2020	IVL 2020	GP 2023				
														newly constructed		before measures	after measures		before renovation	after renovation	1 year after renovation					Dust 2023
																								Mean value	Median Value	Min Value
	µg/g	µg/g	µg/g	µg/g	%	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	%	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g		µg/g	µg/g	µg/g
	0,02	0,1	0,04	0,02	<LOD	0,04	0,10	<0,00103	0,02	<0,02	0,02	0,02	<LOD	0,13	0,03	0,018	0,001	0,03	0,013	0,028	0,081	0,07		0,05	0,03	0,02
	0,42	<0,5	0,17	0,50	<LOD	<0,5	0,26	<0,00668	0,44	0,28	0,31	1,12	<LOD	0,50	0,40	0,35	0,10	0,35	0,10	0,32	0,10	0,43		0,82	0,44	0,25
	5,04	8,7	2,04	0,36	<LOD	3	0,80	<0,00766	0,32	4,5	4,05	0,48	0,12	1,60	0,47	2,50	7,50	2,70	0,40	1,80	0,15	4,09		1,95	0,62	0,12
	7,13	15	9,53	4,33	<LOD	3	8,61	<0,0369	2,35	6,6	2,63	1,14	<LOD	0,86	0,70	3,10	0,25	3,31	3,90	1,90	0,25	3,61		3,93	3,54	0,39
	60,29	5,2	6,01	1,22	<LOD	59	8,88	0,01	1,91	25	5,44	0,61	<LOD	55,00	86,09	36,00	28,00	5,03	3,00	2,80	4,40	2,69		13,58	2,69	0,17
	1,76	28	<LOD	0,57	<LOD	47	10,38	<0,00522	1,27	33	2,80	2,47	0	0,77	0,55	2,70	3,90	1,55	2,10	1,70	1,90	0,56		2,71	1,76	0,41
	10,64	2,5	28,63	8,05	0,5	5,3	13,55	0,04	7,59	13	44,74	4,57	0,03	7,70	4,14	18,00	19,00	9,76	1,60	7,40	4,20	5,64		4,47	3,31	1,58
	21,82	330	86,24	35,42	0,16	420	30,18	<0,0195	22,11	98	71,34	19,61	0,08	52,00	4,89	115,00	55,00	59,99	87,00	67,00	46,00	206,02		59,64	34,68	2,20
	839,51	3100	1860,71	1063,92	23,59	5200	494,44	<0,138	1310,29	90	31,62	22,63	<LOD	1407,00	456,74	85,00	41,00	51,12	10,00	175,00	119,00	698,24		324,36	100,15	2,37
	129,53	150	124,73	48,72	<LOD	400	59,34	<0,0136	109,31	140	225,37	111,01	<LOD	55,00	78,38	165,00	88,00	211,66	28,00	158,00	189,00	334,67		118,86	109,31	30,76
	96,27	880	382,81	83,64	3,5	1200	26,89	0,01	140,46	1200	1066,06	603,49	14,62	129,00	25,97	1790,00	915,00	498,41	185,00	130,00	139,00	66,28		234,00	83,64	13,44
	12,23	48	48,56	13,46	<LOD	250	9,32	<0,016	32,88	220	62,10	224,24	0,17	29,00	9,43	178,00	46,00	26,14	18,00	55,00	33,00	32,00		28,56	18,48	<0,016
	4,93	16	5,78	2,91	<LOD	260	14,36	<0,0258	24,00	21	6,77	113,45	<LOD	7,60	5,65	17,00	5,10	8,94	1,00	19,00	14,00	21,64		12,09	4,48	0,95
	0,00			0,01				<0,00209	0,028			0,025			0,009			0,022				0,277		0,03	0,01	0,00
	µg/g	µg/g	µg/g	µg/g		µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g		µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g		µg/g	µg/g	µg/g
	0,024	<0,065	<LOD	0,033		<0,065	<LOD	<0,0005	0,039	<0,03	<LOD	0,196		<0,01	0,025	<0,01	0,02	0,018	<0,01	<0,01	0,02	0,043		0,07	0,03	0,014
	<0,0005	<0,1	0,033	<0,0005		4,4	0,258	<0,0005	0,001	0,6	0,034	<0,0005		<0,06	0,0003	<0,06	<0,06	0,003	<0,06	0,14	<0,06	0,006		0,01	0,004	<0,0005
	0,285	1,7	0,812	1,437		3,8	0,368	<0,0005	0,955	1,4	0,725	0,622		0,86	0,537	1,65	0,52	1,290	1,37	0,73	0,25	2,600		0,85	0,74	0,178
	0,122	0,33	0,952	0,202		0,82	0,432	0,002	0,123	0,23	0,439	0,067		0,45	0,115	0,76	0,68	0,098	<0,07	0,67	0,95	0,356		0,26	0,20	0,042
	<0,001	0,09	0,355	0,074		0,05	0,196	<0,001	0,223	2,4	1,107	0,003			0,780			0,205				0,407		0,19	0,13	<0,001
	ng/g		ng/g	ng/g			ng/g	ng/g	ng/g		ng/g	ng/g			ng/g			ng/g				ng/g		ng/g	ng/g	ng/g
	<0,05		<LOD	<0,05			<LOD	<0,05	5,21		<LOD	6,09			8,30			9,48			7,34		6,33	6,72	<0,05
	86,96		<LOD	8,21			1,20	<0,05	7,20		<LOD	3,30			11,43			10,44			8,69		11,84	7,70	<0,05
	705,78		5,12	79,12			7,32	<0,05	71,04		8,54	17,25			765,65			38,02			33,58		138,85	53,39	12,45
	17,72		<LOD	8,46			<LOD	<0,05	7,61		<LOD	6,64			6,24			3,56			3,75		7,25	6,36	<0,05
	52,71		5,42	20,56			1,18	<0,09	27,10		35,49	50,41			19,15			19,68			19,81		20,61	19,15	3,02
	5,06		<LOD	3,52			<LOD	<0,05	4,83		3,55	3,58			3,56			5,31			2,66		4,80	3,86	<0,05
	9,24		<LOD	1,69			<LOD	<0,05	<0,05		<LOD	9,16			<0,05			<0,05			<0,05		5,96	7,77	<0,05
	<0,05		<LOD	<0,05			<LOD	<0,05	<0,05		<LOD	<0,05			<0,05			<0,05			<0,05		<0,05	<0,05	<0,05
	8,74		<LOD	<0,05			<LOD	<0,05	<0,05		<LOD	19,40			<0,05			<0,05			<0,05		14,07	14,07	<0,05
	<0,05		<LOD	<0,05			<LOD	0,21	<0,05		<LOD	<0,05			<0,05			<0,05			<0,05		3,48	3,48	<0,05
	<0,11		<LOD	<0,11			<LOD	<0,11	<0,11		<LOD	<0,11			<0,11			<0,11			<0,11		<0,11	<0,11	<0,11
	12,45		7,99	24,32			18,32	0,40	19,17		12,37	15,02			12,71			6,97			17,14		18,33	14,91	6,969
	24,09		<LOD	12,42			<LOD	<0,05	5,27		<LOD	6,03			<0,05			7,04			6,62		72,80	15,81	<0,05
	<0,05		<LOD	<0,05			<LOD	<0,05	<0,05		<LOD	<0,05			<0,05			<0,05			<0,05		<0,05	<0,05	<0,05
	1,63		<LOD	0,47			<LOD	<0,05	0,70		<LOD	0,25			0,24			0,30			0,45		3,01	0,45	0,175
	173,79		<LOD	<0,20			269,67	<0,20	44,20		53,52	8,83			<0,20			125,51			17,64		482,24	374,84	<0,20
	<0,12		<LOD	<0,12			<LOD	<0,12	<0,12		79,93	<0,12			<0,12			<0,12			<0,12		138,40	138,40	<0,12
	69,77		119,96	29,56			1561,02	<0,05	85,03		241,68	21,73			13,89			489,66			19,03		629,93	253,33	7,770
	19,65			5,01				<0,05	3,58			17,80			4,18			6,86			5,03		23,49	6,02	2,124
	3,88		32,98	<0,05			26,80	<0,05	<0,05		132,11	22,83			0,50			2,63			<0,05		13,75	5,97	<0,05
	<0,05		<LOD	<0,05			<LOD	<0,05	<0,05		<LOD	<0,05			<0,05			<0,05			<0,05		<0,05	<0,05	<0,05
	0,40		9,55	0,94			11,38	<0,05	0,74		8,25	<0,05			<0,05			<0,05			<0,05		12,11	8,43	<0,05
	4,38			0,85				<0,50	0,85			<0,05			1,17			0,36			0,22		8,37	1,17	<0,05
	<0,05			<0,05				<0,05	<0,05			<0,05			<0,05			<0,05			<0,05		<0,05	<0,05	<0,05
	13,91			15,42				<0,50	4,47			<0,05			<0,05			<0,05			<0,05		6,79	4,43	<0,05
	<0,05			<0,05				<0,05	<0,05			<0,05			<0,05			<0,05			<0,05		<0,05	<0,05	<0,05
	<0,50			<0,50				<0,50	<0,50			<0,50			<0,50			<0,50			<0,50		<0,50	<0,50	<0,50
															µg/g			µg/g				µg/g		µg/g	µg/g	µg/g
															4,30			0,92				10,00		6,03	6,70	0,92
															29,00			2,80				27,00		22,26	22,00	2,80
															32,00			8,40				68,00		51,20	51,00	8,40
															1,10			0,33				2,10		1,40	1,40	0,33
															10,00			3,90				15,00		41,43	7,60	3,90
															44,00			12,00				62,00		48,43	48,00	12,00
															160,00			46,00				470,00		240,86	190,00	46,00
															0,97			0,16				2,10		2,25	1,30	0,16
															0,16			0,077				0,18		0,16	0,14	<0,19
															4,70			2,50				7,70		5,77	4,80	2,50
															µg/g			µg/g				µg/g		µg/g	µg/g	µg/g
															1,23			3,62				32,4		8,20	3,34	1,23
															8,45			9,47				39,4		37,50	23,10	8,45
															7,23			4,44				8,11		11,39	7,67	4,44

		Dust 2018					Dust 2015					Material 2023			
Max Value		Mean value	Median Value	Min Value	Max Value		Mean value	Median Value	Min Value	Max Value		Mean Value	Median Value	Min Value	Max Value
µg/g		*µg/g*	*µg/g*	*µg/g*	*µg/g*		*µg/g*	*µg/g*	*µg/g*	*µg/g*		*µg/g*	*µg/g*	*µg/g*	*µg/g*
0,35		0,10	0,07	0,02	0,25		2,20	0,22	0,03	11,0		0,014	0,014	0,009	0,018
3,20		1,05	0,31	0,17	5,71		46,00	41,00	0,28	130,0		0,240	0,240	0,204	0,276
15,62		9,38	4,05	0,80	30,75		12,23	9,70	2,90	28,0		0,181	0,181	0,136	0,225
9,36		69,12	9,53	2,63	552,26		23,87	16,00	3,00	57,0		0,390	0,390	0,338	0,442
86,09		11,38	6,01	2,04	40,22		16,81	7,30	1,10	59,0		0,201	0,201	<0,00499	0,201
8,25		9,85	9,93	2,80	39,50		16,39	9,10	3,10	47,0		0,542	0,542	0,532	0,552
10,64		13,94	8,70	3,27	44,74		26,31	6,00	2,50	170,0		1,918	1,918	0,491	3,346
281,57		111,09	105,53	30,18	225,08		427,27	330,00	82,00	1900,0		0,546	0,546	0,468	0,624
1310,29		292,00	58,18	19,57	1860,71		812,09	71,00	22,00	5200,0		68061,275	68061,275	58404,890	77717,661
334,67		109,76	98,65	59,34	225,37		144,91	100,00	20,00	410,0		0,652	0,652	0,263	1,042
1034,52		490,21	174,72	26,89	1579,61		788,18	520,00	70,00	2600,0		2,022	2,022	0,677	3,367
224,24		48,94	48,56	9,32	87,72		83,18	59,00	17,00	250,0		0,237	0,237	0,058	0,416
113,45		6,17	3,68	1,96	16,31		29,55	5,00	1,60	260,0		0,116	0,116	<0,0258	0,116
0,28												0,160	0,160	0,138	0,183
µg/g		*µg/g*	*µg/g*	*µg/g*	*µg/g*		*µg/g*	*µg/g*	*µg/g*	*µg/g*		*µg/g*	*µg/g*	*µg/g*	*µg/g*
0,63		<LOD	<LOD	<LOD	<LOD		0,07	0,07	0,07	0,07		0,004	0,004	0,003	0,005
0,09		0,06	0,03	0,01	0,26		1,70	0,60	0,11	4,40		<0,0005	<0,0005	<0,0005	<0,0005
2,60		1,29	0,74	0,20	6,15		1,53	1,60	0,21	3,80		0,118	0,118	0,092	0,144
0,79		0,54	0,44	0,10	0,97		0,35	0,29	0,23	0,82		<0,0005	<0,0005	<0,0005	<0,0005
0,78		0,47	0,26	0,03	1,63		0,49	0,06	0,02	2,40		<0,001	<0,001	<0,001	<0,001
ng/g		*ng/g*	*ng/g*	*ng/g*	*ng/g*							*ng/g*	*ng/g*	*ng/g*	*ng/g*
9,48		2,47	2,47	<LOD	2,47							<0,05	<0,05	<0,05	<0,05
86,96		1,58	1,58	<LOD	1,97							<0,05	<0,05	<0,05	<0,05
765,65		8,86	8,54	<LOD	12,80							<0,05	<0,05	<0,05	<0,05
17,72		4,60	4,60	<LOD	7,64							<0,05	<0,05	<0,05	<0,05
52,71		13,73	9,69	<LOD	35,49							<0,09	<0,09	<0,09	<0,09
13,75		15,50	5,00	<LOD	58,54							<0,05	<0,05	<0,05	<0,05
9,24		<LOD	<LOD	<LOD	<LOD							<0,05	<0,05	<0,05	<0,05
<0,05		10,18	10,18	<LOD	10,18							<0,05	<0,05	<0,05	<0,05
19,40		8,25	6,05	<LOD	8,25							<0,05	<0,05	<0,05	<0,05
3,48		<LOD	<LOD	<LOD	<LOD							<0,05	<0,05	<0,05	<0,05
<0,11		<LOD	<LOD	<LOD	<LOD							<0,11	<0,11	<0,11	<0,11
68,23		21,81	20,57	<LOD	49,80							<0,05	<0,05	<0,05	<0,05
532,10		109,80	101,89	<LOD	212,38							<0,05	<0,05	<0,05	<0,05
<0,05		0,14	0,10	<LOD	0,29							<0,05	<0,05	<0,05	<0,05
30,94		<LOD	<LOD	<LOD	<LOD							<0,05	<0,05	<0,05	<0,05
1322,60		992,60	858,63	<LOD	2775,62							<0,20	<0,20	<0,20	<0,20
173,84		168,97	82,71	<LOD	427,95							<0,12	<0,12	<0,12	<0,12
3861,81		12385,95	1561,02	113,06	42444,98							<0,05	<0,05	<0,05	<0,05
190,87												<0,05	<0,05	<0,05	<0,05
42,56		113,40	48,55	26,80	384,22							<0,05	<0,05	<0,05	<0,05
<0,05		<LOD	<LOD	<LOD	<LOD							<0,05	<0,05	<0,05	<0,05
64,46		81,34	22,90	8,25	283,41							<0,05	<0,05	<0,05	<0,05
54,60												<0,05	<0,05	<0,05	<0,05
<0,05												<0,05	<0,05	<0,05	<0,05
15,42												<0,05	<0,05	<0,05	<0,05
<0,05												<0,05	<0,05	<0,05	<0,05
<0,50												<0,50	<0,50	<0,50	<0,50
µg/g															
10,00															
35,00															
78,00															
2,10															
240,00															
81,00															
470,00															
7,20															
0,35															
11,00															
µg/g															
32,40															
108,40															
23,40															

Occurrence of substances of concern in Stockholm Stormwater

Appendix 5B

City of Stockholm

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NHC3 GoA2.1. Deliverable D.2.1

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Contents

Abbreviations

Definitions of all abbreviations that are used or mentioned in the report, for example different chemical substances

6:2 FTS (6:2 fluorotelomer sulfonate)

DEHP (Diethylhexyl phthalate)

DEHT (Diethylhexyl terephthalate)

DEP (Diethyl phthalate)

DiBP (Diisobutyl phthalate)

DiDP (Diisodecyl phthalate)

DINCH (Diisononylcyclohexane-1,2-dicarboxylate)

DiNP (Diisononyl phthalate)

DMP (Dimethyl phthalate)

DnBP (Dibutyl phthalate)

DPHP (Di(2-propylhexyl) phthalate)

HVAC Heating, Ventilation, and Air Conditioning

PFBA (perfluorobutanoic acid)

PFBS (perfluorobutanesulfonic acid)

PFCA (perfluorocarboxylic acid)

PFHxA (perfluorohexanoic acid)

PFHxS (perfluorohexanesulfonic acid)

PFHpA (perfluoroheptanoic acid)

PFNA (perfluorononanoic acid)

PFOA (perfluorooctanoic acid)

PFOS (perfluorooctanesulfonic acid)

PFPeA (perfluoropentanoic acid)

PFSA (perfluorosulfonic acid)

Introduction

Construction materials, whether used indoors or outdoors, may contain chemical substances that risk endangering human health and the environment. Hazardous compounds found in outdoor materials can leach into rainwater, ultimately reaching water bodies or soil through runoff. Stormwater, formed by surface runoff during precipitation events and snowmelt, is widely acknowledged as a pathway for transporting pollutants from land-based sources in urban areas to receiving water bodies (Müller et al., 2020). For example, Müller et al. (2019 and 2023) examined common building surface materials and found that they when exposed to wash-off by rainwater or snowmelt release e.g. metals, nonylphenols and phthalates that risk being transported downstream by stormwater. In line with this several biocides, chlorinated paraffins and flame retardants have been found in European stormwater (Birch et al., 2011; Mertens et al., 2018; Paijens et al., 2020). However, more knowledge is needed about building material related hazardous compounds in stormwater.

We analysed different groups of chemicals associated with outdoor building materials in stormwater samples from seven different sites (ponds and ditches) all located in the city of Stockholm. Our aim was to study the occurrence of substances of concern in stormwater.

Substance screening

In this study of the occurrence of hazardous chemical substances from construction materials in stormwater was investigated. The selection of substances for analysis was decided collectively by the working group. The stormwater sampling was carried out together with the city owned water and waste company Stockholm Vatten och Avfall AB's (SVOA) regular monitoring program. The additional substance analyses within the NonHazCity 3 project were a complement to the analyses included in the monitoring, for more details on routine monitoring and results refer to SVOA (2024). The substances analysed included biocides, phthalates, organophosphate flame retardants, chlorinated paraffins and PFAS including assay of Total Oxidizable Precursor (TOP).

Biocides are predominantly used on the exterior surfaces of buildings to prevent damage from microbial growth, and can also be included in paint to prevent microbial growth in the paint can. They can be found in paints and are often included in wood used in exterior parts of buildings as wood preservative biocides. For example Müller et al. (2022) found that bitumen-based roofing contribute biocides in runoff. The biocides can either be mixed with the material or added as a surface treatment (Paijens et al. 2020). Many biocides do not have a specific target species, and thus also affect other species in the environment. The effect depends on the specific compound. Several biocides used in construction materials are toxic to aquatic organisms. Some are also carcinogenic, mutagenic and toxic to reproduction (NHC3, 2023).

Phthalates, used as plasticizers, are mostly found in various PVC materials. Uses that are relevant for stormwater include roofs, skylights on terraces and in various pipes. For example Müller et al. (2019) found PVC roof materials contributed to DNOP, DEHP, DIDP and DINP in runoff. While phthalates degrade easily in the environment, they are used and released in high quantities, which keeps their concentrations in the environment on a high level. They are therefore sometimes called *pseudo-persistant*. Many phthalates have endocrine disrupting qualities and some are toxic to aquatic organisms (NHC3, 2023).

Organophosphate esters (OPEs) are added to products to decrease their flammability and are used as substitutes for restricted brominated flame-retardants. These substances can also be used as

plasticizers. They do not form a chemical bond with the products that they are added to, which means that they are emitted to the environment during use of the product. OPEs have been associated with e.g. neurotoxicity, developmental toxicity, damage to the reproductive function, endocrine disruption and carcinogenicity. OPEs are less persistent than the brominated flame retardants they replace, but they are often found in the environment in higher concentrations than the brominated compounds (NHC3, 2023).

Chlorinated paraffins, used as plasticizers and flame retardants, are found in plastics (mostly PVC), rubbers, paints, sealants, and polyurethane foams (Danish Environmental Protection Agency 2014, Brandsma et al. 2021). Chlorinated paraffins are persistent and toxic (NHC3, 2023). Short-chain chlorinated paraffins (SCCP) belong to the Stockholm Convention's list of substances to be phased out. The ban on SCCPs has led to their replacement by medium chain chlorinated paraffins (MCCP). MCCPs have been proposed for inclusion in the Stockholm Convention. The leaching of chlorinated paraffins into storm water is largely unstudied.

Per- and polyfluoroalkyl substances (PFAS) are a large and complex group of substances. PFAS are extremely persistent in the environment, and they either do not degrade, or they degrade into persistent PFAS. Some PFAS are also bioaccumulative. The adverse effects of many PFAS are poorly studied, but certain PFAS are known to e.g. be reprotoxic or carcinogenic (NHC3, 2023). PFAS substances are commonly used for their grease, water, and dirt repellent properties. They can be used in a variety of products, including building materials such as textile materials including carpets and upholstery, wood boards, chipboards, insulation materials, electronic equipment, floorings such as resilient linoleum and laminated plastic floor coverings, plastic piping, mounting foams, indoor and outdoor paints, plaster, coatings, sealants, architectural foils and HVAC-systems (NHC3, 2023).

Methodology

Sampling sites

Stormwater is recognised as a pathway through which particles and pollutants that have accumulated on streets and other urban surfaces during dry weather enter water systems. The pollutants in stormwater can be derived from several different sources and activities in the urban environment, including buildings and construction materials.

Stormwater samples were collected from seven locations (Table 1 and Figure 1-7) in the city of Stockholm during November and December 2023. Generally, these stormwater management facilities are designed to treat stormwater from relatively large catchment areas with mixed land use, addressing a diverse range of pollutants from various sources. The mixed urban land use within these drainage areas means they include different environments, such as roads with different traffic intensities, residential areas with different population densities, commercial zones, and areas with lighter industry activities.

Table 1. List of sampling locations and number of samples collected from each location.

Sampling location	Area characteristics	No. of samples	Sample collected from	Coordinates (Sweref 99 TM N, E)	
Magelungen	Mixed urban land-use incl. e.g. residential areas and green/nature areas	2	Outlet	6570336	677643
Mårtensdal	Mixed urban land-use incl. e.g. roads, relatively densely built-up area (recently built high-rise building).	2	Stormwater basin	6577711	675475
Sundbydammen	Mixed urban land-use incl. e.g. residential areas	2	Pond outlet	6584838	666236
Bergslagsdammen	Mixed urban land-use incl. e.g. lighter industries, commercial activities and residential areas	1	Pond outlet	6584182	662561
Kräppladiket	Mixed urban land-use incl. e.g. residential areas, local roads and green areas	2	Culvert/channel outlet	6571915	672621
Hjulstadammen	Mixed urban land-use incl. e.g. residential areas.	1	Pond outlet	6588048	663501
Flatendiket	Mixed urban land-use incl. e.g. residential area and roads.	2	Ditch/swale	6573067	678897

Figure 1.Orthophoto showing sampling location Magelungen (samples MA1 and MA2). Surrounding catchment area is characterised by a mixed urban land-use including e.g. residential areas with primary small houses, and green/nature areas.

Figure 2. Orthophoto showing sampling location Mårtensdal (samples MD1 and MD2). Surrounding catchment area is characterised by urban land-use including roads, relatively densely built-up area with e.g. a recently built high-rise building, within the area there are also smaller green areas.

Figure 3. Orthophoto showing sampling location Sundbydammen (samples SU1 and SU2). Surrounding catchment area is characterised by a mixed urban land-use including residential areas.

Figure 4. Orthophoto showing sampling location Bergslagsdammen (sample BE1). Surrounding catchment area is characterised by mixed urban land-use including an area with lighter small industries and commercial activities and another area with a combination of residential areas with apartment buildings and a smaller center.

Figure 5 Orthophoto showing sampling location Kräppladiket (samples KR1 and KR2). Surrounding catchment area is characterised by urban land-use with a primarily residential catchment e.g. including local roads and green areas.

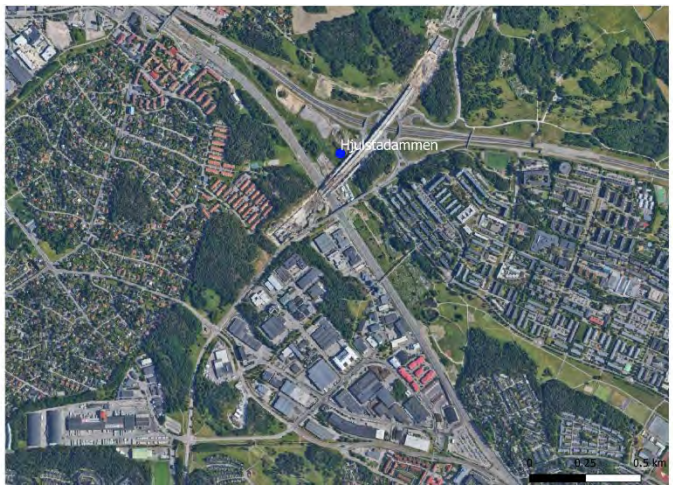

Figure 6. Orthophoto showing sampling location Hjulstadammen (sample HJ1). Surrounding catchment area is characterised by mixed urban land-use including e.g. residential areas.

Figure 7. Orthophoto showing sampling location Flatendiket (samples FL1 and FL2). Surrounding catchment area is characterised by mixed urban land-use with mainly residential area but also a relatively high traffic road. The sampling location is located next to allotment gardens with small cottages.

Sample collection

Stormwater was sampled using a manual sampling approach, which provides a snapshot of the stormwater quality at that specific moment. This is a practical and cost-effective method for

assessing stormwater quality by collecting water samples directly from the sampling points. By analysing these samples we can receive some understanding of the substances present in stormwater, but for an assessment of the pollutant transport via stormwater a more sophisticated sampling approach is needed. A total of 12 stormwater samples were collected from 7 different locations, with each location sampled on one or two occasions, as detailed in Table 1. At two of the locations, Bergslagsdammen and Hjulstadammen, only one sample could be collected due to winter weather conditions that resulted in ice, preventing a second round of sampling.

During the sample collection process a beaker attached to an extension shaft was used, enabling the safe retrieval of water samples from potentially hard-to-reach areas. An example of this sampling setup is illustrated in Figure 8.

Figure 8. Examples of sampling locations and equipment used for stormwater sampling.

Table 2 provides information on the types of substances analysed, the volume of samples, and the types of bottles used for each analysis. For each substance listed, all samples were placed in designated lab-provided bottles. This ensures that each type of substance is stored in the appropriate container prior to analysis.

Table 2. Substance analysis packages

Substance analysis package	Analysed from	Bottle volume (ml)	Bottle material
Phtalates	All samples	1000	Glass
Chlorinated paraffins	All samples	1000	Glass
Organophosphates	All samples	1000	Glass
PFAS 22 (including TOP)	All samples	2 * 100	Plastic
Biocides/pesticides	All samples	250	Plastic (special bottle for biocide and pesticide analysis)

The stormwater sampling was carried out together with the city owned water and waste company Stockholm Vatten och Avfall AB's (SVOA) regular monitoring program. The substance analysis packages in table 2 were a complement to the analyses included in the monitoring. Additional results from analysis within the monitoring will be evaluated and discussed in this report.

Results and discussion

PFAS

PFAS were detected in all stormwater samples. Most commonly found compound was PFOS, PFOA and PFHpA, which were found in all samples, followed by PFPeA and PFHxA found in 11 of 12 samples, Figure 9 and Table 3. The sum concentrations of PFAS varied between samples and sights with concentrations of PFAS 22 in the range 22-79 ng/l, Table 3. In general, higher sum concentrations were observed in three locations, Bergslagsdammen, Flatendiket and Hjulstadammen with concentrations ranging 48-79 ng/l, compared to the other four locations with concentrations ranging from 22-34 ng/l. However, it has not been possible to relate these concentrations to specific sources within these different catchment areas.

Among the highest individual PFAS concentrations was 23 ng/l of PFOS in Hjulstadammen (HJ1), this is higher than the PFOS concentrations of 4.3-8.9 ng/l previously found in this pond in Stockholm water and wastes monitoring. The reason for this higher concentration is not known. However, even this concentration of PFOS was below the Maximum Allowed Concentration Environmental Quality standard (MAC-EQS) for inland surface waters of 36 µg/l, given in the Water Framework Directive (Directive 2000/60/EC). All PFOS concentrations exceed the Annual Average (AA) EQS of 0.65 ng/l given in the Water Framework Directive.

The following PFAS were below the laboratory reporting limit in all samples: PFDoA, PFDoS, PFDS, PFHpS, PFNS, PFPeS, PFTrDA, PFTrDS, PFUdA and PFUnDS.

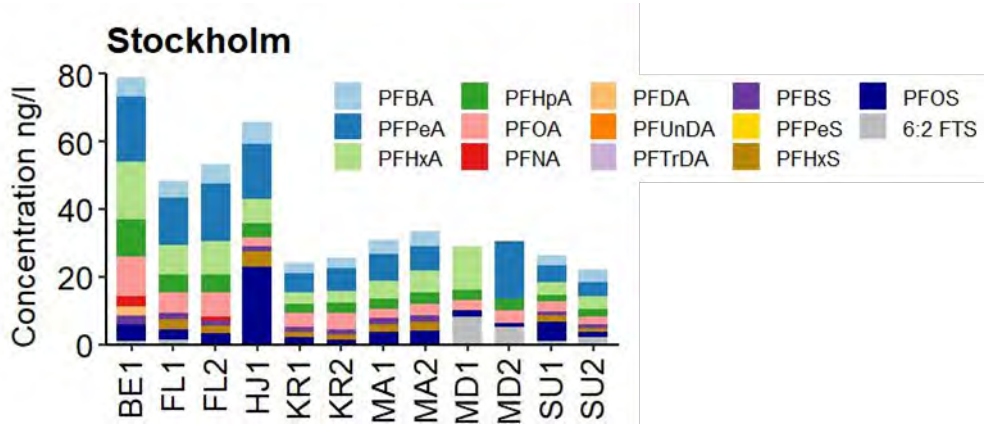

Figure 9. PFAS concentration in stormwater collected from Hjulstadammen (HJ1), Sundbydammen (SU1 and SU2), Mårtensdal (MD1 and MD2), Bergslagsdammen (BE1), Magelungen (MA1 an MA2), Flaten diket (FL1 and FL2) and Kräppladiket (KR1 and KR2).

Table 3. PFAS found in one or more samples with detected concentrations marked in bold. PFAS names coloured according to the colour coding in figure 9. Samples collected from Hjulstadammen (HJ1), Sundbydammen (SU1 and SU2), Mårtensdal (MD1 and MD2), Bergslagsdammen (BE1), Magelungen (MA1 an MA2), Flatendiket (FL1 and FL2) and Kräppladiket (KR1 and KR2). Note, that the reporting limit for some PFAS substances is elevated for samples collected from Mårtensdal (MD1 and MD2)

	Unit	HJ 1	SU 1	SU 2	MD 1	MD 2	BE 1	MA 1	MA 2	FL 1	FL 2	KR 1	KR 2
6:2 FTS	ng/l	<1.0	**1.2**	**2.1**	**8.3**	**5.1**	**1.2**	<1.0	<1.0	**1.5**	<1.0	<1.0	<1.0
PFBA	ng/l	**6.6**	**3.0**	**3.5**	<20	<20	**5.9**	**4.1**	**4.4**	**5.1**	**5.6**	**3.1**	**3.2**
PFBS	ng/l	**1.4**	**1.1**	**1.1**	<10	<1.0	**2.4**	**1.6**	**1.9**	**1.9**	**1.7**	**1.5**	**1.6**
PFDA	ng/l	<1.0	<1.0	<1.0	<1.0	<1.0	**2.9**	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
PFHpA	ng/l	**4.2**	**2.1**	**2.3**	**2.7**	**3.4**	**11**	**2.9**	**3.3**	**5.2**	**5.3**	**2.7**	**3.0**
PFHxA	ng/l	**7.2**	**3.5**	**3.6**	**13**	<10	**17**	**5.3**	**6.4**	**8.6**	**9.9**	**3.2**	**3.4**
PFHxS	ng/l	**4.5**	**1.9**	**1.2**	<1.0	<1.0	<1.0	**2.4**	**2.9**	**2.7**	**2.2**	**1.5**	**1.6**
PFNA	ng/l	<1.0	<1.0	<1.0	<1.0	<1.0	**2.7**	<1.0	<1.0	<1.0	1.0	<1.0	<1.0
PFOA	ng/l	**2.8**	**2.9**	**2.3**	**3.1**	**3.6**	**12**	**2.9**	**3.3**	**6.3**	**7.1**	**4.2**	**4.9**
PFOS	ng/l	**23**	**5.6**	**1.5**	**1.9**	**1.4**	**4.9**	**3.7**	**3.9**	**3.1**	**3.3**	**2.3**	**1.4**
PFPeA	ng/l	**16**	**5.0**	**4.5**	<10	**17**	**19**	**8.0**	**7.4**	**14**	**17**	**5.6**	**6.7**
Sum PFAS 4	ng/l	30	10	5.0	5.0	5.0	20	9.0	10	12	14	8.0	7.9
Sum PFAS 11	ng/l	66	26	22	29	31	79	31	34	48	53	24	26
Sum PFAS20 (EU) 2020/2184	ng/l	66	25	20	21	25	78	31	34	47	53	24	26
Sum PFAS (22)	ng/l	66	26	22	29	31	79	31	34	48	53	24	26

The Total Oxidizable Precursor (TOP) Assay is another method used for PFAS analysis. The TOP assay was first developed in 2012 as a method for identifying non-target PFAS. Comparing the results of a PFAS analysis and a PFAS TOP Assay can provide a more comprehensive understanding of the extent of PFAS contamination. However, it is important to note that the TOP assay is not a predictor of the endpoint of abiotic and biotic breakdown in the field. Therefore, the implications of comparing these results should be considered with caution, taking into account the limitations of each method.

As illustrated in Table 4 the sums of PFAS analysed with TOP compared to the regular analysis indicate an increase after oxidation for most of the samples, indicating that there are more PFAS compounds present in the samples than those covered by the PFAS 22 analysis. In Figure 11, sum PFAS 11 (PFBS, PFHxS, PFHxA, PFHpA, PFOA, PFNA,PFDAm 6:2 FTS, PFBA, PFPeA and PFOS) is used to illustrate the difference in sum concentrations between the two methods.

Table 4. Comparison between sum concentrations of PFAS 22 analysed with standard analysis method and PFAS analysed with TOP Assay. Samples collected from Hjulstadammen (HJ1), Sundbydammen (SU1 and SU2), Mårtensdal (MD1 and MD2), Bergslagsdammen (BE1), Magelungen (MA1 an MA2), Flaten diket (FL1 and FL2) and Kräppladiket (KR1 and KR2).

	Unit	HJ1	SU1	SU2	MD1	MD2	BE1	MA1	MA2	FL1	FL2	KR1	KR2
Sum PFAS 22 (standard)	ng/l	66	26	22	29	31	79	31	34	48	53	24	26
Sum PFAS 22 (TOP)	ng/l	82	47	35	84	87	130	41	31	63	60	31	25

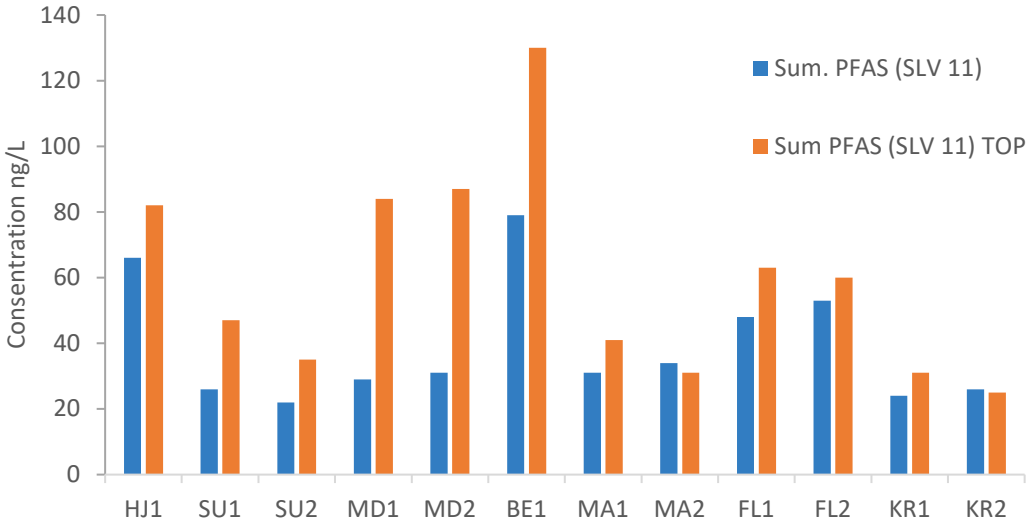

Figure 10. Sum PFAS 11 (SLV) including: PFBS, PFHxS, PFHxA, PFHpA, PFOA, PFNA,PFDAm 6:2 FTS, PFBA, PFPeA and PFOS analysed with standard method (blue bars) and PFAS TOP Assay (orange bars). Samples collected from Hjulstadammen (HJ1), Sundbydammen (SU1 and SU2), Mårtensdal (MD1 and MD2), Bergslagsdammen (BE1), Magelungen (MA1 and MA2), Flatendiket (FL1 and FL2) and Kräppladiket (KR1 and KR2).

Organophosphates

Nine analysed organophosphate esters (OPEs) (Octicizer, TDCPP, TBEP, Tri(2-etylhexyl)phosphate, TCEP, TCPP, TBP, TPhP, TCPP) were included in the analysis. Out of these two were quantified in one or more of the samples (please refer to Table 5 for details). Most commonly detected was TCPP (tris(2-chloro-1-methylethyl) phosphate), found in five samples (HJ1, SU1, BE1, MD1 and MD2). The highest concentration were found in Mårtensdal (MD) with approximately 0.4 µg/l on both sampling occasions. In one sample, (SU1) tributylphosphate (TBP) was found with a concentration of 0.17 µg/l.

TCPP is one of the organophosphates that occur in the highest concentrations in indoor environment (Langer et al., 2020; Zhou. et al., 2017) as well as domestic wastewater in Stockholm (Appendix 5C Domestic Wastewater - organic micro pollutants).

Table 5. TCPP and TBP, the organophosphates detected in in one or more samples, with LOQ <0.10 µg/L. Samples collected from Hjulstadammen (HJ1), Sundbydammen (SU1 and SU2), Mårtensdal (MD1 and MD2), Bergslagsdammen (BE1), Magelungen (MA1 an MA2), Flaten diket (FL1 and FL2) and Kräppladiket (KR1 and KR2).

	Unit	HJ1	Su1	SU2	MD1	MD2	BE1	MA1	MA2	FL1	FL2	KR1	KR2
TCPP	µg/L	0.15	0.29	<LOQ	0.4	0.44	0.25	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
TBP	µg/L	<LOQ	0.17	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ

Biocides/pesticides

The stormwater samples were analysed with regards to 51 different biocides/pesticides, full list in Annex I. Out of these, five were quantified in one or more of the samples, Table 6. The highest individual biocide concentration observed was 0.06 µg/L of mecoprop, which was found in a sample from the Bergslagsplan (BE1). Among the quantified substances, dichlorobenzoamide (BAM) was the most common, detected in four of the samples, followed by Terbutylazin-2-hydroxy detected in three samples. Specifically, BAM (Dichlorobenzoamide) was detected in samples from three different locations: Sundbydammen (SU2), Flatendiket (FL1) and Kräppladiket (KR1 and KR2), with the highest

observed concentration for this substance of 0.02 µg/L. Terbutylazin-2-hydroxy was detected in samples from two different locations: Sundbydammen (SU1) and Mårtensdal (MD1 and MD2). Similar to dichlorobenzoamide, the highest concentration observed for Terbutylazin-2-hydroxy was also 0.02 µg/L.

Diuron and mecoprop are recognised as additives in construction materials potentially linking their presence in stormwater to urban infrastructure. Notably, concentrations of diuron and mecoprop were higher in combined sewer overflows (CSOs) compared to wastewater, suggesting a significant contribution from stormwater runoff, with buildings identified as a potential primary source (Paijens et al., 2020).

Degradation products of pesticides that are not commonly used for construction material were also observed: BAM (dichlorobenzoamide), a derivative from the plant treatment of the PFAS fungicide fluopikolide and 2-hydroxyterbutylazine, derived from terbutylazine.

Table 6. Biocides/pesticide quantified in one or more samples, with LOQ <0.10 µg/L. Samples collected from Hjulstadammen (HJ1), Sundbydammen (SU1 and SU2), Mårtensdal (MD1 and MD2), Bergslagsdammen (BE1), Magelungen (MA1 and MA2), Flaten diket (FL1 and FL2) and Kräppladiket (KR1 and KR2).

	Unit	HJ1	SU1	SU2	MD1	MD2	BE1	MA1	MA2	FL1	FL2	KR1	KR2
Diuron	µg/L	<LOQ	0.01	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Mecoprop	µg/L	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.06	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Metamitron	µg/L	<LOQ	<LOQ	<LOQ	<LOQ	0.02	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Dichloro-benzoamide	µg/L	<LOQ	<LOQ	0.01	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.01	<LOQ	0.02	0.01
Terbutylazin-2-hydroxy	µg/L	<LOQ	0.02	<LOQ	0.02	0.02	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ

Chlorinated paraffins

The stormwater samples were analysed for chlorinated paraffins (SCCP and MCCP). However, concentrations were below LOQ in all samples.

Phthalates

Concentrations of phthalates (BBP, DEEP, DEHP, DMEP, DBEP, DMPP, DBP, DCHP, DEP, DHXP, DIBP, DIDP, DINP, DMP, DNOP, DPeP, Dipropyl Phthalate, Hexyl-2-ethylhexyl phthalate) were below the laboratory reporting limit in all samples.

Contrary to expectations, phthalates were not found in any of the samples. Previous studies have found phthalates e.g. DEHP, DIDP and DINP in stormwater samples collected in Stockholm and Gothenburg (Björklund et al., 2007). A previous study found phthalates in stormwater ponds sediments from Stockholm (including Bergslagsdammen, Mårtensdal and the pond by Kräppladiket) (Flanagan et al., 2021). For example, Flanagan et al., (2021) found that DEHP was the most frequently quantified phthalate in stormwater sediment samples, DiNP was less frequently but reached higher concentrations than DEHP. This indicates a presence of phthalates, at least in some of the sampled stormwater ponds, although they were not detected in the stormwater phase in the current sampling campaign.

Other substance groups that are analysed within the monitoring (SVOA, 2024)

PCB: PCB (PCB 101, PCB 118, PCB 138, PCB 153, PCB 180, PCB 28, PCB 52) have been analysed in at total of 12 samples during 2022-2023 (four sampling occasions each collected from the ponds Hjulstadammen, Sundbydammen and Mårtensdal). No detectible concentrations have been found in any of the samples.

Brominated flame retardants: Brominated flame retardants were also analysed in 12 samples (four sampling occasions each collected from the ponds Hjulstadammen, Sundbydammen and Mårtensdal). Levels above the LOQ have only been found in one of the samples (from Hjulstadammen, June 2023), where 0,209 ng/l of PBDE 28 was found.

Organotin compounds: Tributyltin (TBT) were also analysed in 12 samples (four sampling occasions each collected from the ponds Hjulstadammen, Sundbydammen and Mårtensdal) with concentrations in all samples below laboratory reporting limit. For two samples collected from Hjulstadammen and Sundbydammen in December 2022, an extended analysis was carried out (including: TPhT, MBT, DBT, DPhT, TTBT, TCHT, MPhT, MOT, DOT and TBT). In one of these (Sundbydammen), MBT, DBT and MOT were found with concentrations of 6.9, 1.2 and 1.3 ng/l respectively.

Metals: Metals are analysed monthly in samples from the ponds: Hjulstadammen (HJ1), Mårtensdal (MD1 and MD2) and Sundbydammen (SU1 and SU2). Table 7 and Figure 11 illustrates results of metal analysis for the samples that coincide with the extended sampling carried out within this NonHazCity 3 project. Metals were found in all samples. E.g. zinc, copper, nickel, chromium and lead have been found to be leached from metallic exterior building materials (Müller et al. 2020, 2019). However, it has not been possible to distinguish the main sources of the metals found in the stormwater samples and it may be something other than building materials, such as emissions from traffic.

Table 7. Results of metal analysis in Hjulstadammen (HJ1), Mårtensdal (MD1 and MD2) and Sundbydammen (SU1 and SU2)

Element	unit	HJ1	SU1	SU2	MD1	MD2
Arsenic, As	µg/L	0.6	0.64	< 0.50	3.5	3.2
Barium, Ba	µg/L	50	19	22	24	25
Lead, Pb	µg/L	1.8	1.2	< 0.50	0.65	0.53
Cobalt, Co	µg/L	0.83	0.57	< 0.50	2.3	2.4
Copper, Cu	µg/L	17	5.7	2.2	13	14
Chrome, Cr	µg/L	2.1	1.2	< 0.50	2	2.1
Nickel, Ni	µg/L	2.7	2.2	2.8	6.8	6.1
Vanadium, V	µg/L	2.3	1.6	< 0.50	17	14
Zinc, Zn	µg/L	48	31	13	30	25

Conclusions

This screening of substances of concern in Stockholm stormwater revealed the ubiquitous presence of per- and polyfluoroalkyl substances (PFAS), specifically highlighting PFOS, PFOA, and PFHpA as the most commonly detected compounds, present in all analysed samples. The PFAS total oxidizable precursor (TOP) assay indicated an increase in the total PFAS concentrations post-oxidation for most samples, suggesting the presence of additional PFAS compounds not detected by standard analysis methods.

Moreover, biocides were quantified in the screening of stormwater. Specifically, diuron and mecoprop which were found in one sample each. These substances are known additives in construction materials, implying a potential link between their presence in stormwater and urban infrastructure. This finding highlights the potential impact of construction materials on urban water quality. Additionally, organophosphates, a group of substances primarily used as flame retardants and plasticizers in plastics, were found in stormwater. Specifically, TCPP was found in five stormwater samples indicating its widespread occurrence in the urban environment. Phthalates or chlorinated paraffins were not quantified in any of the stormwater samples. This absence suggests that these particular contaminants may not be as prevalent or detectable in the sampled stormwater under the conditions of this study.

Overall, the findings indicate that substances with adverse health and environmental affect may be released from building materials into stormwater. These findings highlight that material choices may impact the amounts of hazardous substances leached into stormwater and transported further downstream to receiving water bodies. Continued monitoring and source tracking is needed to fully understand the spectrum of contaminants in urban stormwater.

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Annex I

List of substances included in pesticide/biocide analysis package

D -2,4
Diclorprop
2,6-Diklorbenzamid
Atrazine
Atrazine-desisopropyl
Atrazine-desethyl
Bentazone
Cyanazine
Dimethoate
Ethofumesate
Fenoxaprop
Fluroxypyr
Imazapyr
Isoproturon
Klopyralid
Klorsulfuron
Kvinmerac
MCPA
Mekoprop
Metamitron
Metazaklor
Metribuzin
Metsulfuron-metyl
Simazine
Terbuthylazine
Atrazin-2-hydroxy
Hexazinone
Kloridazon
Pirimicarb
Propiconazole
Diuron
2,4,5-T
2(4-Klorfenoxy)propionsyra (4-CPP)
Fenhexamid
1-(3,4-Diklorfenyl)urea
1-(3,4-Diklorfenyl)-3-metylurea
Terbutylazin-2-hydroxy
Simazin-2-hydroxy
Metribuzin-diketo
Metribuzin-desamino-diketo
Iprodione
Imazalil
DMST
Carbendazim
Boscalid
Bitertanol
Azoxystrobin
Terbutylazin-desetyl
Tifensulfuron-metyl
Imidacloprid
Prochloraz

Occurrence of substances of concern in domestic wastewater

Appendix 5C

City of Stockholm

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NHC3 GoA2.1. Deliverable D.2.1

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Contents

Abstract

This study aimed to get more knowledge about organic micropollutants in domestic wastewater with the focus on substances commonly used indoor construction materials such as phthalates, chlorinated paraffins, organophosphate esters and per- and polyfluoroalkyl substances (PFAS). Targeted pollutant screenings in wastewater from two residential areas in Stockholm City, and influent wastewater of the receiving wastewater treatment plant (WWTP) as a point of reference, were performed. The main difference between the two residential areas is that the one in Skarpnäck is older (constructed in the 1980s) and the area in Norra Djurgårdsstaden (NDS) is newly developed and is included in an urban development area with a sustainability-profile. The main finding was that DEHP and SCCPs show decreasing concentrations in domestic wastewater from Skarpnäck in the period 2014-2023. This could probably be attributed to the regulation of DEHP in REACH Authorisation List (Annex XIV) and SCCPs by the POPs regulation. DEHP and SCCPs are also found in lower concentrations in the wastewater in the newly developed residential area in Norra Djurgårdsstaden. The substances that are found in highest concentrations in both residential areas in respective substance group are the phthalate DINP, the medium-chain chlorinated paraffins (MCCP) and the organophosphate ester TCCP. PFAS is detected in domestic wastewater from both areas and there are some indication that the detection rate of PFAS in NDS is lower than for Skarpnäck. However, to be able to conclude this with certainty more data is required. PFOS is still one of the most abundant PFAS in domestic wastewater and there are no evidence of a reducing trend of PFOS in wastewater from Skarpnäck.

Abbreviations

Definitions of all abbreviations that are used or mentioned in the report, for example different chemical substances

AOX: Adsorbable organic halides

BBP: Butyl benzyl phthalate (BBP)

DBEP: Dibutoxyetyl phthalate

DBP: Dibutyl phthalate

DCHP: Dicyclohexyl phthalate

DEEP: Di(2-etoxyetyl) phthalate

DEHP: Diethylhexyl phthalate

DEP: Diethyl phthalate

DHXP: Di-n-hexyl phthalate

DIBP: Diisobutyl phthalate

DIDP: Di-iso-decyl phthalate

DIHP: Diisohexyl phthalate

DINP: Di-iso-nonyl phthalate

DMEP: Di(2-metoxyetyl) phthalate

DMP: Dimethyl phthalate

DNOP: Di-n-oktyl phthalate

DPeP: Dipentyl phthalate

EOX: Extractable organic halides

EtFOSA: N-Ethylperfluorooctanesulfonamide

EtFOSE: N-Ethylperfluorooctanesulfonamidoethanol

HFPO-DA: 2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propionic acid (GenX)

LOD: Limit of detection

LOQ: Limit of quantification

MCCP: medium-chain chlorinated paraffin's

MeFOSA: N-Methylperfluorooctanesulfonamide

MeFOSE: N-Methylperfluorooctanesulfonamidoethanol

NaDONA: Sodium dodecafluoro-3H-4,8-dioxa- nonane-1-sulfonate

ND: Not detected

NDS: Norra Djurgårdsstaden (Stockholm Royal Seaport)

NP: Nonylphenols

OPE: Organophosphate ester

PBT: Persistent, bioaccumulative and toxic

PBDE: Polybrominated diphenyl ethers

PCDD/F: Polychlorinated dibenzo-p-dioxins and dibenzofurans

PFAS: Per- and polyfluoroalkyl substances

PFBS: Perfluorobutanesulfonic acid

PFBA: Perfluorobutanoic acid

PFCA: Perfluorocarboxylic acid

PFHpA: Perfluoroheptanoic acid

PFHxS: Perfluorohexanesulfonic acid

PFHxA: Perfluorohexanoic acid

PFHxDA: Perfluorohexadecanoic acid

PFNA: Perfluorononanoic acid

PFOA: Perfluorooctanoic acid

PFOcDA: Perfluorooctadecanoic acid

PFOS: Perfluorooctanesulfonic acid

PFOSA: Perfluorooctanesulfonamide

PFOSAA: Perfluorooctanesulfonamidoacetate

PFPeA: Perfluoropentanoic acid

PFSA: Perfluorosulfonic acid

PFTeDA: Perfluorotetradecanoic acid

PFTrDA: Perfluorotridecanoic acid

PFTrDS: Perfluorotridecanesulfonic acid

PFUdA: Perfluoroundecanoic acid

PFUnDS: Perfluoroundecane sulfonic acid

PNEC: Predicted no effect concentration

POPs: Persistent Organic Pollutants

SCCP: Short-chain chlorinated paraffin's

TBEP: Tris (2-butoxyethyl) phosphate

TBP: Tri-n-butyl phosphate

TCEP: Tris(2-chloroethyl) phosphate

TCIP: Tris(2-chlorisopropyl)phosphate

TCP: Tricresyl phosphate (TCP)

TCPP: tris(2-chloro-1-methylethyl) phosphate

TDCPP: Tris(1,3-dichloro- 2-propyl) phosphate

TEP: Triethyl phosphate

TEHP: Tris (2-ethylhexyl)-phosphate

TMCP: Tris-m-kresylphosphate

TNBP: Tri-n-butyl phosphate

TOCP: Tri-o-cresyl phosphate

TPCP: Tris-p-cresyl phosphate

TPP: Triphenyl phosphate

vPvB: very Persistent and very Bioaccumulative

WWTP: Wastewater treatment plant

4:2 FTS: 4:2 fluorotelomer sulfonic acid

6:2 FTS: 6:2 fluorotelomer sulfonic acid

8:2 FTS: 8:2 fluorotelomer sulfonic acid

10:2 FTS: 10:2 fluorotelomer sulfonic acid

Introduction

Building materials and other products such as electronics, furniture etc. may contain substances that risk endangering human health and the environment if they are emitted from the materials. Some of these substances can be detected in domestic wastewater. Conventional wastewater treatment plants (WWTP) are currently not able to eliminate all substances from wastewater and as a consequence micropollutants are released to our water bodies via the WWTP effluent or farmland via sewage sludge (Y. El Hammoudani, 2024).

Stockholm Water and Waste has since 1995 collected and analysed samples of domestic wastewater twice a year from Skarpnäck, a residential area in Stockholm, to investigate the contribution of metals, nutrient salts and organic material from domestic wastewater to the WWTP (Ljung & Lagerqvist, 2020). During 2014-2016 organic micropollutants were included to the study (Wahlberg, 2018). The results show that domestic wastewater is a pathway of many heavy metals. The domestic wastewater contributes with more than 50% of cadmium, copper, zinc, molybdenum and tin, while the contribution for lead, chromium, nickel, cobalt and tungsten is less than 30% (Ljung & Lagerqvist, 2020). The results of organic micropollutants are based on less data than for the heavy metals, which gives less certainty. Nevertheless, results indicates that domestic sources account for a large part of substances as PCDD/F, SCCP, EOX and several of the phthalates and slightly less of PBDE, NP, certain organotin compounds and AOX (Wahlberg, 2018).

In this study the aim was to continue to collect data and gain more knowledge of organic micropollutants in domestic wastewater. Samples from two residential areas has been analysed, from Skarpnäck and Stockholm Royal Seaport (Norra Djurgårdsstaden), both located in the city of Stockholm. In the study from 2018 (Wahlberg, 2018) the residential area Hammarby Sjöstad with a strong environmental profile was studied in comparison to Skarpnäck. In the current study the newly developed area Norra Djurgårdsstaden (NDS) was selected to represent an urban renewal district in Stockholm with a strong environmental profile. The hypothesis that the contribution of some micropollutants from this area is lower due to the active work to reduce hazardous chemical substances used in construction materials in this residential area.

Substance screening

The selection of substances were based on previous studies on domestic wastewater (Wahlberg, 2018), discussions with experts and previous research on the chemical composition of building materials and their presence in wastewater.

Altogether 16 domestic wastewater samples were collected from the two selected residential areas. During the same period weekly composite samples from the influent and effluent at Henriksdals WWTP were collected as point of reference. The substances analysed in the samples are presented in Table 1.

Table 1. Substances analysed in this study. Substances followed by "" were analysed in the samples from 2020 and substances followed by "**"were analysed in 2021.*

Substance group	Substance
Phthalates	Butyl benzyl phthalate (BBP Di-2-etylhexyl phthalate (DEHP) Dibutyl phthalate (DBP) Diethyl phthalate (DEP) Di-iso-decyl phthalate (DIDP) Di-iso-nonyl phthalate (DINP) Dimetyl phthalate (DMP) Di-n-oktyl phthalate (DNOP) Di(2-etoxyetyl) phthalate (DEEP) Di(2-metoxyetyl) phthalate (DMEP) Dibutoxyetyl phthalate (DBEP) Dicyclohexyl phthalate (DCHP) Diisobutyl phthalate (DIBP) Diisohexyl phthalate (DIHP) Di-n-hexyl phthalate (DHXP) Dipentyl phthalate (DPeP) Dipropyl phthalate Hexyl-2-etylhexyl phthalate
Chlorinated paraffins	S:a C10-C13 Chlorinated paraffins (SCCP) S:a C14-C17 Chlorinated paraffins (MCCP)
Organophosphate esters	2-ethylhexyl diphenyl phosphate (Octicizer) Tri(1,3-dichloroisopropyl)phosphate (TDCPP) Tri(2-butoxyethyl) phosphate (TBEP) Tri(2-ethylhexyl) phosphate Tri(2-chloroethyl) phosphate (TCEP) Tri(2-chloroisopropyl) phosphate (TCPP) Tributyl phosphate (TBP) Triphenyl phosphate (TPhP) Tricresyl phosphate (TCP)
PFAS	4:2 FTS** 6:2 FTS 8:2 FTS* 10:2 FTS* EtFOSA* EtFOSE* HFPO-DA** MeFOSA* MeFOSE* NaDONA** PFBA PFBS PFDA PFDoA PFDoS PFDS PFHpA PFHpS PFHxA PFHxDA* PFHxS PFNA PFNS PFOA PFOcDA* PFOS PFOSA* PFOSAA* PFPeA PFPeS PFTeDA* PFTrDA PFTrDS PFUdA PFUnDS

Phthalates

Phthalates, used as plasticizers and especially found in various PVC materials can make up as much as half of the material. Phthalates can be found in a variety of consumer products, including flooring, cables, and wall coverings. Their ability to leach into the environment and affect human health makes them a substance of concern. Phthalates are found in various environmental matrices e.g., aquatic, sediment, soil, and sewage sludge (H. T. Tran, 2022). Several phthalates DEHP, BBP, DBP and DIBP are regulated by the REACH Authorisation List (Annex XIV). Other phthalates DINP, DIDP and DNOP monitored in this study, are restricted in toys and childcare articles.

Chlorinated paraffins

Chlorinated paraffins are another group of substances that are used as plasticizers but also as flame retardants, and are found in plastics, rubbers, paints, lubricants, sealants, and polyurethane foams. They belong to an emerging class of persistent organic pollutants widely detected in environmental matrices and human samples (J-W. Huang, 2023). Chlorinated paraffins are chlorinated hydrocarbon chains that are divided into short, medium and long chains depending on the length of the carbon chain. Short-chain have 10 to 13 carbon atoms (C10-C13), medium-chain 14 to 17 carbon atoms, and long-chain have more than 17 carbon atoms. Short-chain chlorinated paraffins (SCCP) are regulated globally by the Stockholm Convention through the POPs regulation (Persistent Organic Pollutants) and included on the list of the European water framework directive to be monitored in water. Medium-chain chlorinated paraffins (MCCP) are on the REACH candidate list and the so-called CoRAP list to be evaluated over a three-year period and are candidates from inclusion to the Stockholm Convention. MCCPs are classified as hazardous to health and the environment and recognized in the EU as persistent, bioaccumulative and toxic (PBT). In this study SCCP and MCCP were monitored in wastewater.

Organophosphate esters

Organophosphate esters (OPEs) are a group of substances that are primarily used as flame retardants and plasticizers in plastics in various products. The usage of OPEs has increased in recent years, due to the phase-out of other flame retardant formulations (e.g. polybrominated diphenyl ethers). OPEs have been associated with e.g. neurotoxicity, developmental toxicity, damage to the reproductive function, endocrine disruption and carcinogenicity. They are less persistent than the brominated flame retardants, but they are often found in the environment in higher concentrations than the brominated compounds (von Knorre, o.a., 2023) Some organophosphate esters are considered for potential authorisation at EU level in the European chemicals legislation Reach, e.g. TCEP is on the Reach candidate list, TPP, TCP and TDCPP are on the Reach CoRAP list.

Per- and polyfluoroalkyl substances

Per- and polyfluoroalkyl substances (PFAS) are a large and complex group of substances. They are used in a variety of industrial applications for their resistance to mechanical stress, heat, water, and oil. PFAS are very persistent in the environment. Due to the widespread use and ability to disperse over long distances through air and water have led to their frequent detection in the environment, causing growing concerns over their impact on human health (Forever chemicals: the persistent effects of perfluoroalkyl and polyfluoroalkyl substances on human health, 2023). The adverse effects of many PFAS are poorly studied, but there is evidence that some PFAS present a health hazard; for example, PFOS and PFOA, which are classified as reproductive toxins and suspected carcinogens. PFOS and its derivatives have been included in the international Stockholm Convention to eliminate their use since 2009 and restricted in the EU for more than 10 years under the Persistent Organic

Pollutants (POPs) Regulation. The Stockholm Convention also regulates the global elimination of PFOA, its salts and PFOA-related compounds. PFOA has been banned under the POPs Regulation since 4 July 2020. Latest inclusion in the POPs regulation the 28 August 2023 is PFHxS, its salts and related compounds. The national authorities of Germany, Denmark, the Netherlands, Norway and Sweden have submitted a proposal to ECHA with a restriction covering a wide range of PFAS uses. They submitted their proposal to ECHA in January 2023, and ECHA's scientific committees are now evaluating it (ECHA publishes PFAS restriction proposal, 2023).

Methodology

Sampling sites

The residential areas that were chosen have duplicate sewage systems and almost exclusively consist of household wastewater. Wastewater from both residential areas is diverted to Henriksdal WWTP via Sickla inlet tunnel (SIN), one of two inlet tunnels with roughly equal flows.

The residential area in Skarpnäck was developed in the 1980s and the catchment area consists of eight blocks, with 714 apartments, six day care centres, a school, a collective housing, a grocery store and some smaller businesses. In 2023, the residential area had approximately 2100 inhabitants. More information about the residential area can be found in Ljung, A., et.al (2020).

Stockholm Royal Seaport (Norra Djurgårdsstaden) is the largest urban development area in Sweden (Stockholm Royal Seaport Sustainability Report, u.d.). Stockholm Royal Seaport is a sustainability-profiled area, at least 12,000 new homes and 35,000 new workplaces are planned. The area is being transformed into a sustainable urban district with schools, preschools, parks. Occupancy in the area started at the end of 2012 and it is planned to be fully developed around 2030. The chosen residential area where samples of domestic wastewater were collected currently inhabits around 3700 people. Samples were collected in a pumping station called Teknikhuset.

Sampling

The sampling in Skarpnäck and Norra Djurgårdsstaden (NDS) was carried out by mProv consultant, on behalf of Stockholm Water and Waste.

In Skarpnäck, a sampling well was installed with a connecting pipe to the well in the pavement at the intersection of Pilvingegatan and Horisontvägen (Figure 1). During the sampling, vacuum samplers of the AquaCell type were used, which took a partial sample every 10 cubic meters. Flow was measured with a temporarily mounted Doppler-type flowmeter (Nivus PCM-F). Sampling took place at the existing temperature in the installation (outdoor temperature), the sampling well was emptied every to every 3 day and samples were then stored in a freezer (-18 deg). The sub-samples were mixed proportionally into a weekly composite sample. A 24-hour sample was taken during each week for analysis of suspended substances, BOD7 and TOC.

Figure 1. Sampling equipment, Skarpnäck

In NDS vacuum samplers of the AquaCell type were used during the sampling. The sampling was carried out level-controlled and a sample was taken every other pump occasion from the pumping station, which in principle can be considered as flow-proportional sampling. Samples were stored at ambient temperature in the pumping station during sampling and the sampling well was emptied every to every 3 day and the collected samples were stored in a freezer (-18 deg). The sub-samples were then mixed proportionally into a weekly composite sample. A 24-hour sample was taken each week for analysis of suspended substances, BOD7 and TOC. Flow data have been retrieved from the pumping station's control system.

Analysis

Most of the analyses of the wastewater samples were carried out by Eurofins Environment Testing Sweden AB or by Eurofins subcontractors listed in Table 2. PFAS analysis from 2020-2021 where carried out by Swedish University of Agricultural Sciences (SLU) at the Department of Aquatic Sciences and Assessment.

Table 2. Laboratory and analysis methods

Substances analysed	**Laboratory and method**
Phthalates	Eurofins Miljø, DENMARK, DS EN ISO/IEC 17025 DANAK 168, Internal method 0250
Chlorinated paraffins	Eurofins GfA Lab Service GmbH (Hamburg), GERMANY, DIN EN ISO/IEC 17025:2018 Dakks D-PL-14629-01-00
Organophosphate esters	PiCA Prüfinstitut Chemische Analytik GmbH, GERMANY, DIN EN ISO/IEC 17025:2005 D-PL-19569-02-00, DIN EN ISO/IE
PFAS21	Eurofins Food & Feed Testing Sweden (Lidköping), SWEDEN, ISO/IEC 17025:2017 SWEDAC 1977, DIN38407-42, UNEP Chemicals Branch 2015 mod.
PFAS*	Department of Aquatic Sciences and Assessment, SLU. Samples extracted by SPE (solid phase extraction) and analyzed by LC-MS/MS.

**In 2020 following 19 PFAS were analysed: PFUdA, PFDoA, PFTrA, PFTeDA, PFHxDA, PFOcDA, PFBS, PFHxS, PFOS, PFDS, MeFOSE, EtFOS, FOSA, FOSAA, MeFOSAA, EtFOSAA, 6:2 FTS, 8:2 FTS and 10:2 FTS. In 2021 following 26 PFAS were analysed: PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTriDA, PFTeDA, PFBS, PFPeS, PFHxS, PFHpS, PFOS, PFNS, PFDS, FOSA, MeFOSAA, EtFOSAA, 4:2 FTS, 6:2 FTS, 8:2 FTS, HFPO-DA and NaDONA.*

Results and Discussion

Phthalates

Although many of the phthalates have been regulated for several years, they are detected in wastewater from residential areas and incoming wastewater to the WWTP (Figure 2). Of the regulated phthalates, DEHP occurs in the highest concentration. The highest concentration is measured in wastewater from Skarpnäck (11 µg/l) and somewhat lower levels in NDS (6.8 µg/l), which may be due to the fact that DEHP was not present in the newer building materials in NDS but is still present in the older residential area in Skarpnäck. There are additional phthalates where the results indicate that they occur in higher concentrations in the wastewater from Skarpnäck than in NDS and these include DBP, DEP, BBP and DIBP (Figure 3). The same pattern was seen in the previous survey, i.e. that the same phthalates were found in lower concentrations in Hammarby Sjöstad than in Skarpnäck. However, it is only for DEHP that one can see an indication that the concentration in domestic wastewater is decreasing (Figure 4). DINP is the phthalate (not regulated) that occurs in the highest concentrations in domestic wastewater in both Skarpnäck (20 µg/l) and NDS (22 µg/l), the same concentration levels were seen in the results from 2014-2016 (Wahlberg, 2018).

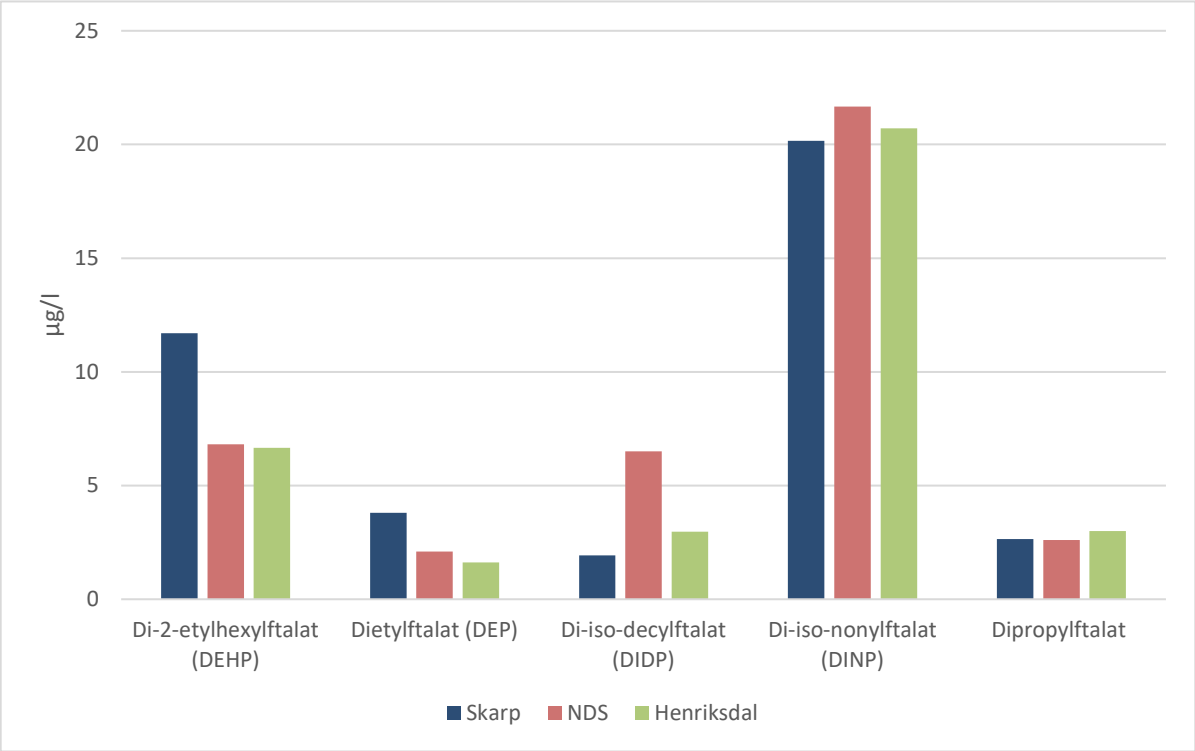

Figure 2. The concentration of phthalates in domestic wastewater from Skarpnäck, NDS and influent to Henriksdal WWTP 2020-2023 (the influent to Henriksdal WWTP is included as a point of reference).

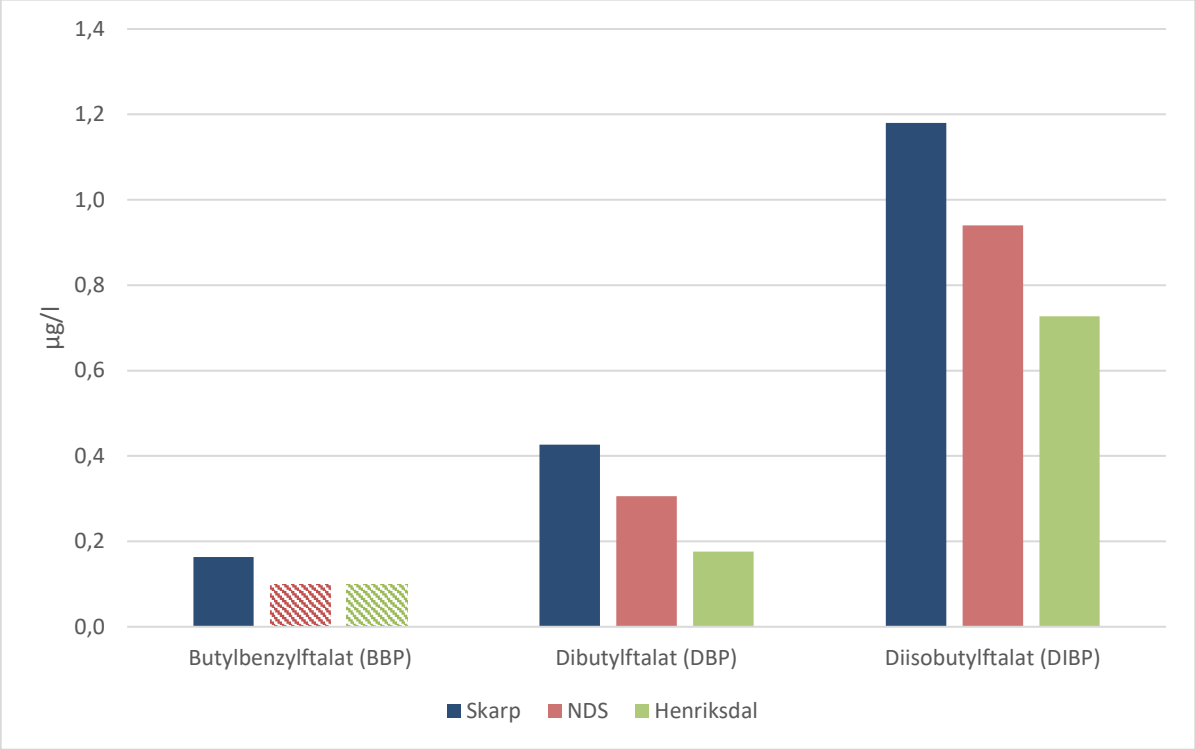

Figure 3. The concentration of phthalates in domestic wastewater from Skarpnäck, NDS and influent to Henriksdal WWTP 2020-2023 (the influent to Henriksdal WWTP is included as a point of reference). The striped bars show the limit of quantification (LOQ).

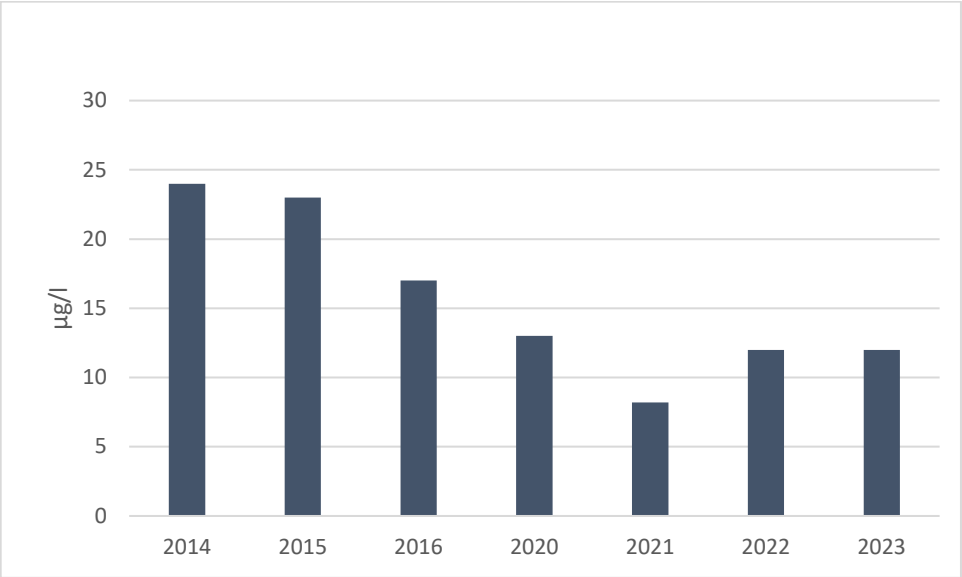

Figure 4. The concentration of DEHP in domestic wastewater from Skarpnäck 2014-2023.

Chlorinated paraffins

Short chain chlorinated paraffins (SCCP) and medium chain chlorinated paraffins (MCCP) were analysed in this study. The results shows that the levels of SCCPs are at similar concentrations in domestic wastewater in both Skarpnäck and NDS (Figure 5). MCCPs occurs in higher concentrations

than SCCPs and if you compare NDS and Skarpnäck, the concentrations of MCCPs are slightly lower in NDS. If we compare with previous study from 2014-2016 where only SCCPs were analysed, we can see that the levels of SCCPs in domestic waste water from Skarpnäck have decreased since 2014 (Figure 6), which is probably due to the ban that was introduced through the POPs regulation in 2017.

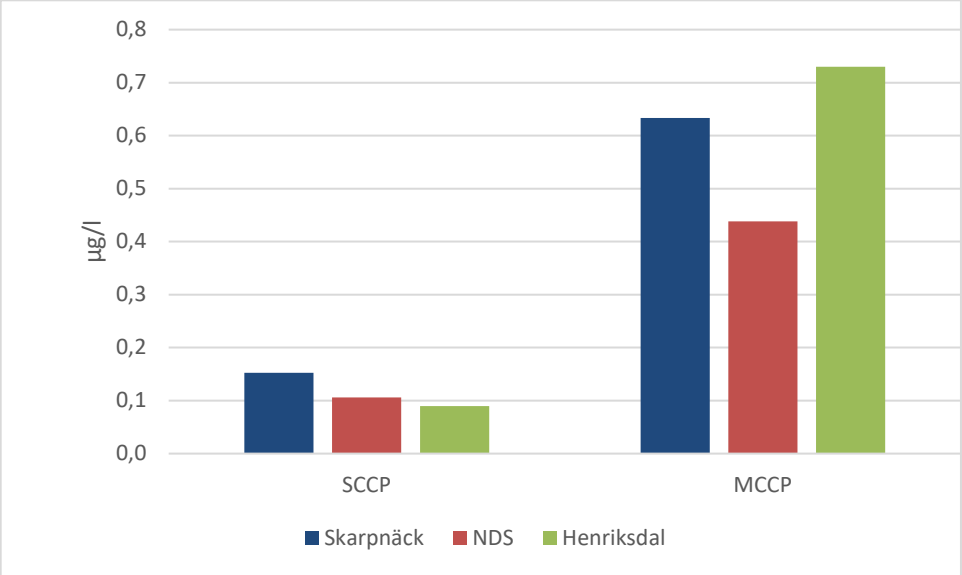

Figure 5. The concentration of SCCP and MCCP in domestic wastewater from Skarpnäck, NDS and influent to Henriksdal WWTP 2020-2023.

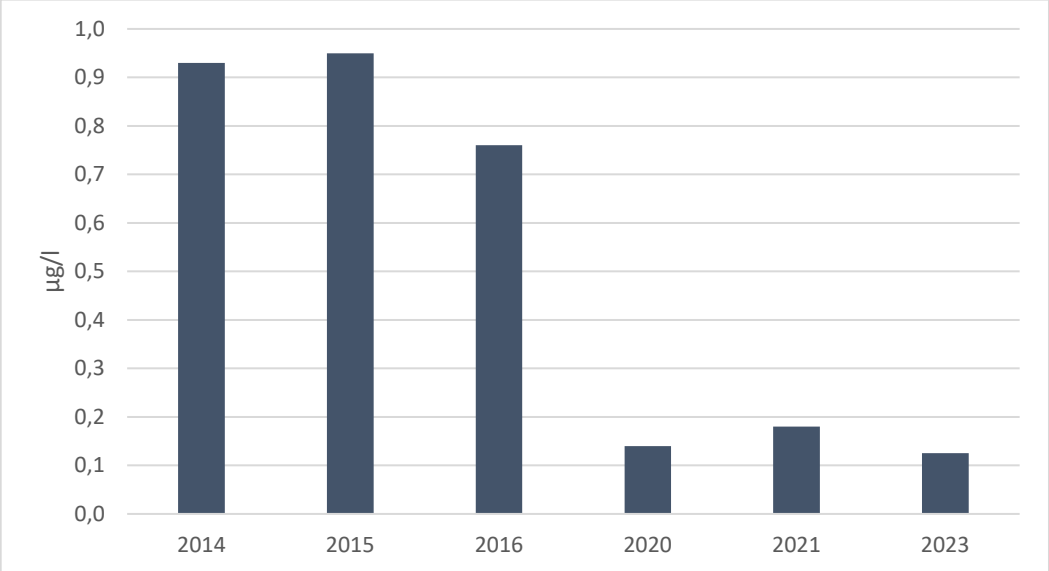

Figure 6. The concentration of SCCP in domestic wastewater from Skarpnäck 2014-2023

Organophosphate esters

Of the nine OPEs (Octicizer, TDCPP, TBEP, Tri(2-etylhexyl)phosphate, TCEP, TCPP, TBP, TPhP, TCPP) analyzed, it was TDCPP, TBEP and TCPP that could be quantified in domestic wastewater and influent wastewater to Henriksdal WWTP (Figure 7). For the other five OPEs, more than half of the samples

were below the quantification limit (<LOQ). In previous screening studies carried out on behalf of the Swedish Environmental Protection Agency (Haglund & Marklund, 2009) OPEs have been investigated in different indoor environments, incoming and outgoing wastewater from Henriksdal WWTP and shows that TDCPP, TBEP and TCPP are the OPEs that occur in the highest concentrations in indoor environments together with TCEP. This study also indicate that the same OPEs also dominate in domestic wastewater, except TCEP, where all samples show concentrations below LOQ. TCPP is one of the main substances to have replaced TCEP, which the results in domestic wastewater also show and TCPP is one of the predominant OPEs in this study. OPEs were not included in the study from 2014-2016.

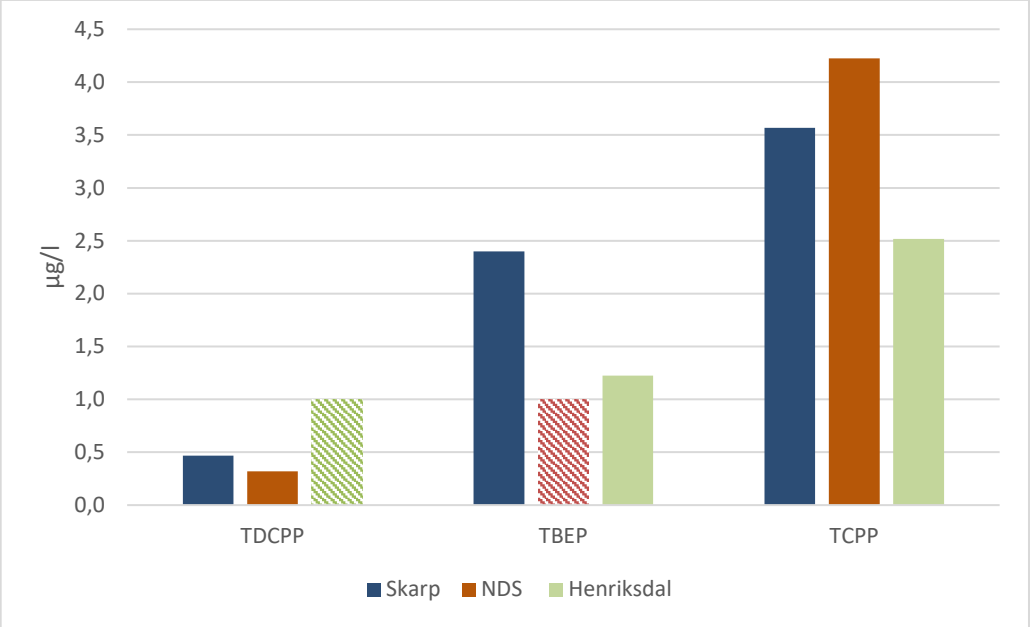

Figure 7. The concentration of organophosphates in domestic wastewater from Skarpnäck, NDS and influent to Henriksdal WWTP. The striped bars show the limit of quantification (LOQ).

PFAS

PFAS was detected in all wastewater samples analysed. Out of the 21 PFAS analysed, 9 PFAS were quantified in wastewater from Skarpnäck in more than half of the samples analysed (n=9), figure 8. In wastewater from NDS only 4 PFAS were quantified in more than half of the samples (n=7), Table 3. The results indicates that the wastewater from NDS contains less PFAS than the wastewater from NDS but to be able to conclude this more data would be needed. The concentrations of all the PFAS varies and are in the range between 0.21-11 ng/l and the quantification limits (LOQ) varies between the individual samples. The two PFAS that are detected in the highest concentration are PFOS (11 ng/l, NDS 2021) and PFBA (9.6 ng/l, Skarpnäck 2020). It is difficult to observe any temporal trends for PFAS in domestic wastewater. Previous study from 2014-2016 shows similar results and even though PFOS have been regulated by the POPs regulation over 10 years there is no decrease in concentrations in either domestic wastewater or influent wastewater to the WWTP.

Table 3. Mean concentrations of PFAS between 2020-2023 in wastewater from Skarpnäck, NDS and influent to Henriksdal WWTP.

	Mean conc. (ng/l)		
PFAS	**Skrapnäck**	**NDS**	**Henriksdal influent**
6:2 FTS	<1,0	<1,0	1,3
PFBA	4,2	<3,0	4,5
PFBS	1,7	<10	2,5
PFDA	<1,0	<1,0	0,9
PFDoA	<1,0	<1,0	<1,0
PFDoS	<1,0	<1,0	<1,0
PFDS	<1,0	<1,0	<1,0
PFHpA	1,1	1,5	2,3
PFHpS	<1,0	<1,0	<1,0
PFHxA	1,9	2,4	3,1
PFHxS	2,4	<1,0	2,4
PFNA	0,48	<1,0	0,57
PFNS	<1,0	<1,0	<1,0
PFOA	2,4	2,9	4,2
PFOS	3,1	3,0	3,6
PFPeA	2,0	<1,0	3,1
PFPeS	<1,0	<1,0	<1,0
PFTrDA	<1,0	<1,0	<1,0
PFTrDS	<1,0	<1,0	<1,0
PFUdA	<1,0	<1,0	<1,0
PFUnDS	<1,0	<1,0	<1,0
Sum PFAS21	19	10	28
Sum PFAS11	19	10	28
Sum PFAS4	8,4	5,9	11

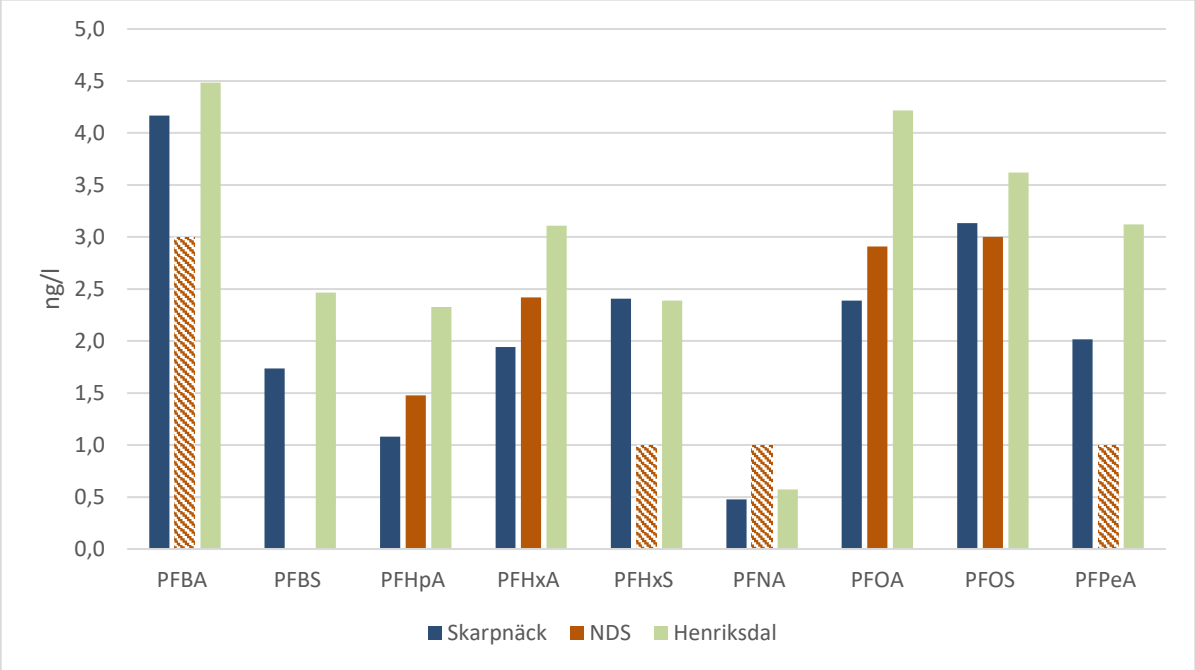

Figure 8. The concentration of PFAS in domestic wastewater from Skarpnäck, NDS and influent wastewater to Henriksdal WWTP 2020-2023. The striped bars show the limit of quantification (LOQ). For PFBS in wastewater from NDS 4 out of 7 samples were <LOD.

Conclusions

Even though wastewater from Skarpnäck still show relatively high concentrations of DEHP there are indications of a decrease since 2014. Another indication that DEHP is decreasing in the indoor environment is that DEHP is found in lower concentrations in wastewater from the residential area in NDS, together with other Annex XIV regulated phthalates such as DBP, BBP and DIBP. SCCPs are showing a similar trend, the concentrations in wastewater from NDS is somewhat lower than from Skarpnäck and the concentrations have decreased in wastewater in Skarpnäck since 2014. For PFAS there is a lower detection rate of PFAS in wastewater from NDS than from Skarpnäck and the sum concentration of PFAS21 is lower. Nevertheless it is difficult to draw any conclusions regarding PFAS because of the variation in concentration in the individual samples together with a variation of LOQ that often is close to the actual concentrations. Interesting conclusion is that although PFOS has been prohibited by the POPs regulation since 2009 the concentration in wastewater from Skarpnäck is not decreasing and PFOS is still one of the PFAS detected in highest concentrations.
Substances found in highest concentrations in both residential areas in respective substance group are the phthalate DINP, the medium-chain chlorinated paraffins (MCCP) and the organophosphate ester TCCP.

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Appendix 5D.

Analysis of biocides and other additives in building materials

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2024-05-31

Interreg Baltic Sea Region
Co-funded by the European Union
SUSTAINABLE WATERS
NonHazCity 3
goodpoint
Part of the Semcon Group

Summary

Moving towards a non-toxic and sustainable society is an ongoing process. It covers many areas, both nationally and internationally, and cooperation is a cornerstone for success. One area of particular interest is additives in different types of goods and products. They all have different properties, and therefore different health and environmental impacts. As part of the EU project NonHazCity3, the City of Stockholm is conducting a study of biocides and additives, such as for example PFAS, in building materials.

This study investigates the presence of biocides and other additives in building materials, with a focus on chemical safety specifically linked to building materials. The aim was to study substances present in building materials, in what concentrations they are present, and their potential impact on health and the environment.

The methodology for this project involved an analysis of paints and roofing felt materials. In total, 12 different materials were analysed with the aim of identifying biocides and additives, and to investigate their environmental and health effects. The groups of substances investigated included metals, pesticides, isothiazolinones, PFAS TOP, phthalates and alternative plasticisers. The results will for example contribute to the EU project NonHazCity3, which aims to reduce harmful substances in building materials.

Based on the results, it can be concluded that biocides and other additives are present in building materials, but that the presence of these substances varies in different types of materials. Moreover, the presence of biocides and other additives has been shown to vary even within specific groups of building materials. This means that the content may vary from product to product even within a product group. It is therefore of great importance to continue to examine larger quantities of different types of building materials.

The fact that lead was detected in most of the paints, despite its ban, shows that strict and clear requirements for allowed contents must be determined. Furthermore, it is of great importance to carry out follow-ups to ensure that these requirements are met. Working towards a non-toxic and sustainable society requires avoiding harmful chemicals and making informed choices in building and construction. Adaptation and awareness in each individual situation are important, both in terms of the materials or products used and the potential risks they pose.

Glossary

Abbreviation	Definition
CLP	Classification, Labelling and Packaging Regulation
LOD	Limit of detection
LTU	Luleå University of Technology
PFAS	Highly fluorinated organic substances

Table of contents

1 Introduction

Moving towards a non-toxic and sustainable society is an ongoing process. It covers many areas, both nationally and internationally, and cooperation is a cornerstone for success. One area of particular interest is additives in different types of goods and products, all of which have different properties and therefore different health and environmental impacts.

For this project, the focus was on chemical safety in relation to building materials. Building materials are widely used in society, and of a particular focus since societies are growing over time. It is therefore a topical area to study. Many additives are used in building materials with the aim of for example increasing the service life or inhibiting growth of microorganisms (Swedish Procurement Agency, n.d.). These additives risk ending up in the environment, where they can have a potentially harmful impact on health and the environment. It is therefore considered to be of great importance to investigate which additives are present in building materials, in what concentrations they are present and what their potential impact on the environment is.

This project includes the investigation of potentially harmful substances in different building materials. The materials studied are different types of paints and roofing felt materials. In total, 12 different materials were analysed.

The results from this project will be used within the EU project NonHazCity3. In parallel with this project, leaching studies of biocides in building materials have been carried out at LTU.

This report is aimed at stakeholders with a focus on issues related to chemical exposure in building materials. The report can be used as a basis for evaluation of chemical exposure related to building materials, evaluation of environmental requirements and their effect, or as a basis for prioritisation of further measures to reduce unwanted chemical exposure in the outdoor environment.

1.1 Objective

The purpose of this project was to investigate the extent to which substances with potentially negative environmental and health-related properties are present in building materials.

The aim was to carry out investigations and chemical analyses of different types of building materials to examine which biocides and other additives are present in the materials, and what effects these may have on humans and the surrounding environment if exposure occurs.

The questions to be answered in this project were the following:

- Can biocides and other additives be found in different types of building materials?
- Do harmful substances remain in paint after curing?
- How do the results of this study compare with previous research?

2 Background

One of the activities in the City of Stockholm is health-related monitoring of environmental toxicants. Monitoring of environmental toxicants is a dynamic method for maintaining a continuous and up-to-date picture of the pollution situation. Information from monitoring is very useful, partly to provide a basis for determining which measures are most urgent to prioritise, and partly to enable follow-up of the effects of implemented measures. Monitoring is also a good tool for following developments over time, for drawing attention to new trends in chemicals and in the long term, making it possible to reduce the chemical load in the city.

As part of the EU project NonHazCity3, the City of Stockholm is investigating biocides and additives, such as PFAS, in building materials. The aim of the study is to determine the presence of these substances in selected materials and chemical products used in construction. The investigation will also examine whether any substances in the materials are spread to the surrounding environment and therefore pose a risk for human exposure.

The NonHazCity3 project runs from 2023-01-01 until 2026-01-01 and the City of Stockholm's role within the project is as project partner through the Environment and Health Department. The focus of the project is "Reducing hazardous substances in construction to safeguard the aquatic environment, protect human health and achieve more sustainable buildings". The project will focus on the link between the circular economy, climate neutrality and procurement of construction materials. Partner organisations from eight different countries are working together, learning from each other, and raising awareness of hazardous substances in construction materials across the Baltic Sea region.

NonHazCity3 builds on the previous projects NonHazCity1 (2016 - 2019) and NonHazCity2 (2019 - 2021), which aimed to demonstrate opportunities to reduce emissions of harmful substances to the Baltic Sea at the source. The main focus was on emissions from small-scale emitters in urban areas, such as private households, municipal entities and businesses. The project's activities included contributing to the development of chemical action plans for cities, information campaigns and training for various stakeholders, including raising awareness among residents in the partner cities.

2.1 Selected substance groups

2.1.1 Metals

Traditionally, paints can contain inorganic colour pigments that in turn can contain metals. Inorganic pigments can contain titanium dioxide, iron oxides, aluminium, and mica flakes. Heavy metals that could be present in paint are for example cadmium, mercury, and lead.

The health effects of the accumulation of heavy metals in the body are numerous. Some are linked to organ damage, respiratory and nervous system damage and some are linked to tumour development and complications in foetal development. For example, it is known that mercury exposure can lead to foetal damage and cadmium is a known carcinogen that can have toxic effects on the kidneys, bones, and respiratory system (Paints for life, 2022).

Today, some metals such as mercury and lead are no longer allowed to be used in paints (EWG, 2019) (KEMI, 2022). Other metals such as cadmium and chromium can still be present in pigments (EWG, 2019).

Over the last few decades, titanium dioxide powder has started to be used in many applications. This is mainly due to its white colour and that it imparts opacity to products such as paints, papers, and cosmetics. Its high technical attractiveness stems from its light-scattering properties and very high refractive index, which means that relatively low levels of

the pigment are required to achieve a white, opaque coating. The amount of light scattered depends on the particle size. Many technological improvements based on titanium dioxide in the form of nanoparticles have been introduced that enable its use in for example building facades and paints (Skocaj, et al, 2011). Titanium dioxide in powder form was classified as a suspected carcinogen by inhalation through the 14th technical adaptation of CLP (ATP14). This applies only to powders containing 1% or more of particles with an aerodynamic diameter equal to or less than 10 micrometres (KEMI, 2023).

2.1.2 Biocides/Pesticides

Pesticides, a form of biocides, are widely used in building materials to inhibit the growth of microorganisms (Paijens et al, 2022). Building materials usually contain biocides that are customised to the use and properties of the material. This means that there is wide range of biocides on the market (Reiß F, Kiefer N, Noll M, Kalkhof S., 2021). Commonly used biocides include diuron, isoproturon, terbutryn, cybutryn, propiconazole, tebuconazole, carbendazim, iodopropynyl butylcarbamate (IPBC) and mecoprop (Paijens et al, 2022). The individual biocides are used for different applications. A summary of the uses and properties of the biocides above is shown below.

Diuron and isoproturon are two very similar biocides. They are used in for example facade paints and various types of coatings. Despite the similarities of diuron and isoproturon, isoproturon is used to a much lesser extent (Uhr H, Mielke B, Exner O, Payne KR, Hill E., 2013). However, once detected, isoproturon is often found in high concentrations, and often found in combination with diuron (Bester K, Vollertsen J, Bollmann UE...), 2014). Some studies have shown that the concentration of isoproturon in facade paint is about one to two orders of magnitude lower compared to diuron (Wicke, D. et al. 2022). Both diuron and isoproturon have significant environmental and health impacts as both are classified as seriously hazardous to health and the environment (European Chemicals Agency, 2024a).

Terbutryn is commonly used in paint products, but also in products aimed at finishing roof tiles (Paijens et al, 2022). Cybutryn is a similar biocide that is only used in facade paints and various coatings. Depending on the size of the building, up to several kilograms of cybutryn can be applied to the external surfaces of buildings through these products (Burkhardt, M. et al. 2007). Both terbutryn and cybutryn are readily degradable by photolysis, which means that these substances can be present as emissions in the form of various transformed products (Reiß F, Kiefer N, Noll M, Kalkhof S., 2021). Terbutryn and cybutryn are classified as harmful and dangerous to the environment and are highly toxic to aquatic organisms (European Chemicals Agency, 2024a).

Propiconazole and tebuconazole have similar uses. These are mainly used as wood preservatives, but they can also be found in many paint products. Both propiconazole and tebuconazole are classified as seriously hazardous to health, harmful and harmful to the environment, and they are also suspected of being toxic to reproduction (European Chemicals Agency, 2024a).

Carbendazim is one of the most persistent biocides. It is mainly used in different types of paint products (Bollmann UE, Vollertsen J, Carmeliet J, Bester K., 2014). This biocide is classified as seriously hazardous to health, harmful and dangerous for the environment. Carbendazim can also cause genetic defects and is suspected of being toxic for reproduction (European Chemicals Agency, 2024a).

IPBC has a wide range of uses and is used as a wood preservative and in paint products, among other applications (Paijens et al, 2022). IPBC is classified as corrosive, seriously hazardous to health, environmentally hazardous and acutely toxic. It is also suspected of being an endocrine disruptor (European Chemicals Agency, 2024a).

Mecoprop is a biocide that is intended to be used as a plant protection product. In today's society, the substance is used three times more in construction than in agriculture (Paijens et al, 2022). Mecoprop is almost exclusively used for flat roofs, mainly asphalt-impregnated roof tiles, as well as in sealing membranes in house foundations (Reiß F, Kiefer N, Noll M, Kalkhof S., 2021). Research has shown that this biocide is often used in abundance, although it is rarely necessary to add it to materials (Paijens et al, 2022). In some studies, mecoprop concentrations have been found to be so high that they are over an order of magnitude greater than the concentrations of biocides from paint products and plasters (Burkhardt, M. et al. 2011). Mecoprop is classified as corrosive, harmful and dangerous to the environment (European Chemicals Agency, 2024a).

2.1.3 Isothiazolinones

Due to their antimicrobial properties, isothiazolinones are a group of substances commonly used as biocides for many purposes (Tjus S, 2014). The most used isothiazolinones are methylisothiazolinone (MIT), benzoisothiazolinone (BIT), octylisothiazolinone (OIT), methylchloroisothiazolinone (CMIT) and dichlorooctylisothiazolinone (DCOIT) (Uhr H, Mielke B, Exner O, Payne KR, Hill E., 2013).

The individual isothiazolinones have different uses. Mainly, isothiazolinones are used in paint products and plasters, wood treatments, roof coatings, sealants and masonry such as brick, cement and concrete (Paijens et al, 2022).

Isothiazolinones have been detected to varying degrees in studies. The majority of isothiazolinones have a high water solubility and low hydrophobicity, which means that they are easily leached in the form of single emissions. One-time emissions can also occur for example through abrasion of the material in question (Bester K, Vollertsen J, Bollmann UE., 2014).

Although the isothiazolinones are largely very similar, the individual isothiazolinones have different properties. This means that the isothiazolinones have different classifications. In general, it can be said that all isothiazolinones are environmentally hazardous and corrosive. The majority are also acutely toxic, harmful, or seriously hazardous to health (European Chemicals Agency, 2024a).

2.1.4 PFAS

Both fluoropolymers and short-chain PFASs are used in coatings, paints, and varnishes, but they all have different functions. Typically, fluoropolymers are added to coatings, paints, and varnishes to provide resistance to corrosion, weather, abrasion and scratches, UV, and to increase the overall durability.

Fluoropolymers used include polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF) and, to a lesser extent, fluoroethylene vinyl ether (FEVE). The fluoropolymers used are additives such as binders in paints as they give the paints protective properties such as durability, weatherability and resistance to corrosion and dirt accumulation. They can also act as a barrier to UV degradation and providing a soft feel as "texturiser" for some applications. The fluoropolymers commonly used in paints are mainly based on PVDF, but can also be PTFE, fluorinated ethylene propylene (FEP), ethylene tetrafluoroethylene (ETFE) and FEVE. Usually, the fluoropolymers concentrations, such as PTFE, are less than 3% of the wet (or formulated paint for powder coatings).

Short-chain PFAS used include perfluoroalkyl sulfonic acids (PFSA) with carbon chain lengths of 5 and less, perfluoroalkyl carboxylic acids (PFCA) with carbon chain lengths of 7

and less, C4-fluorinated polyethers, silicone polymers blended with fluoropolymers and substances based on perfluorobutane sulfonic acid (PFBS). The short-chain PFAS used generally act as levelling and wetting agents, have anti-blocking properties, or provide oil and water repellence (OECD, 2022).

PFAS is a much-debated topic around the world a general ban on PFAS is currently being discussed. The proposal to restrict and ban all PFAS goes under the EU REACH regulation and would mean that the possibility of using PFAS could be drastically reduced in the future. A ban would also increase the need for enforcement in verifying compliance in the area (Swedish Environmental Protection Agency, 2024).

2.1.4.1 PFAS substances in household paints

Short-chain PFAS surfactants in paints are used for their levelling and wetting properties rather than for corrosion or weather resistance properties. Therefore, these paints are less likely to be used in industrial applications and more likely to be used in general household and indoor applications, where corrosion resistance and weatherability are less important than overall aesthetics.

Short-chain PFASs that are commercially available include PFASs based on a four-carbon chain PFBS, such as fluorosurfactants that exhibit a comparable low surface tension to FP used in architectural paints (OECD, 2022).

Manufacturers claim that very little fluorosurfactant is required to achieve a significant reduction in surface tension, while hydrocarbon and silicone alternatives require more product to significantly reduce surface tension and achieve the required wetting and levelling effects (3M, 2016).

2.1.4.2 PFAS substances in paints for building/architectural use

For exterior paints used in architecture, weather resistance effects comes from several components. FP paints are UV-resistant, which means they degrade minimally under UV light and can withstand high UV values, for example in environments with high-intensity sunlight. This degradation is often related to 'chalking', where a chalk-like surface forms on top of the paint, requiring it to be repainted. Degradation can also be seen in terms of gloss retention, which measures the ability of the paint to retain its glossy surface. FP paints are also stated to be corrosion resistant and can therefore withstand harsh weather conditions, for example on bridges over waters where the salinity is high (OECD, 2022).

2.1.4.3 Previous studies

A variety of weather resistance tests have been carried out on for example FEVE by AGC (2020) and Daikin (2020). In these tests, FEVE was compared with non-fluorinated alternatives and with other PFAS coatings.

Daikin's (2020) study showed that their FP coating not only needed to be initially applied in a thinner layer (45 µm) than the non-PFAS alternatives, but also that after 2000 hours, there was no thickness reduction. With polyurethane, the coating had to be applied in an 82 µm layer and the thickness had reduced to 68 µm after 2000 hours. Scanning electron microscope (SEM) images of weathered coatings showed that the FP coating applied initially was much smoother than the non-PFAS alternative acrylic urethane. This suggests that the smoothing and wetting of the FP coating was more effective than in the non-PFAS coating. Secondly, after 6 years, the FP coating had remained unchanged according to the SEM images, while after 3 years, the acrylic urethane coating had significantly deteriorated.

Table 1. Use of PFAS in paints (OECD, 2022)

OECD product category	Applications	Example of use	PFAS substance	Other, non-polymeric PFAS substances
Aerosol spray paints	Vehicle paint	Painting of cars	PTFE	None identified
	• Architecture • Chemical industry	• Architecture: bridges and buildings • Chemical industry: protection of metal surfaces/goods	PVDF, PTFE, FEVE	None identified
Water-based colours Solvent-based colours	• Architecture • Chemical industry • Household use	• Architecture: bridges and buildings • Chemical industry: lining of ships, protection of metal surfaces/goods	PVDF, FEVE, ECTFE, PTFE, FEP	C4-PFBS and C4-fluorinated ethers, C6-based PFAS.

Table 2. Functions of PFAS substances and their non-fluorinated alternatives in paints (OECD, 2022)

Function	PFAS substances	Alternative substances
Corrosion resistance	PVDF, PTFE, FEVE, ECTFE, FEP	Epoxy, polyurethane, polyolefin, polysilozane, aliphatic diisocyanate-based polyurethane
Weather resistance	PVDF, PFTE, FEVE, ECTFE, FEP	Acrylic, polyurethane, polyester, polysiloxane, epoxy, silicone polymers, alkyds, phenolic or silicone alkyds, phenol, polysilozane, aliphatic diisocyanate-based polyurethane and vinyl
Sustainability **Abrasion resistance** **Scratch resistance** **UV resistance**	PVDF, PTFE, FEVE	Polyurethane, polyester, polysiloxane, polysilozane, aliphatic diisocyanate-based polyurethane
Lubricity	PTFE	HDPE-based products containing nanoceramics and nanoaluminium oxide
UV "cool-roof" properties	PVDF	None identified
Levelling and wetting agents	C4-PFBS and C4-fluorinated ethers, C6-based PFAS.	Silica-based and sulphosuccinates
Anti-blocking properties	C6 short chain	None identified
Oil repellent	C6 short chain	None identified

2.1.5 Phthalates

Phthalates are used as for example plasticisers in paints (KEMI, 2023). These are added to increase the flexibility of the paint. When the paint dries, phthalates can be released to the air or stick to dust particles. One type of phthalate that can be used in paint, dibutyl phthalate (DBP), is suspected of causing endocrine disruption (EWG, 2019), for example by damaging fertility (MSB, 2024). DBP is included on the Candidate List, the Authorisation List, the Restriction List and is also regulated by the RoHS Directive (KEMI, 2024).

The use of the most harmful phthalates is regulated in the EU through bans or restrictions. However, products manufactured outside the EU or older products can still contain phthalates that are considered harmful (Nordic Ecolabelling, 2024). What determines how harmful a phthalate can be is depending on how many carbon atoms are in the side chains that bind to the main group. In general, phthalates with a shorter side chain are more harmful than phthalates with longer side chains. Several of the short-chain phthalates are classified as toxic to reproduction as in the examples of di(2-ethylhexyl) phthalate (DEHP), DBP and (diisobutyl phthalate) DIBP (KEMI, 2024).

Phthalates can be divided into three groups:

- High molecular weight phthalates
    - Phthalates that have long side chains, resulting in a high molecular weight. Examples include diisononyl phthalate (DINP), diisodecyl phthalate (DIDP) and di(2-propylheptyl) phthalate (DPHP). Of these three phthalates, DINP and DIDP are on the restricted list (KEMI, 2024) and DPHP is currently being evaluated by ECHA for its potential endocrine disrupting properties (European Chemicals Agency, 2024b).
- Low molecular weight phthalates
    - Phthalates that have a shorter side chain, resulting in a low molecular weight. Examples include DEHP, DBP, DIBP and benzyl butyl phthalate (BBP). All four of these phthalates are on the Candidate List, the Authorisation List, the Restriction List and are also regulated by the RoHS Directive (KEMI, 2024).

- Other phthalates
    - Phthalates with a very low molecular weight. For example, dimethyl phthalate (DMP) and diethyl phthalate (DEP) (KEMI, 2024). DEP is currently being evaluated by ECHA for its potential endocrine disrupting properties (European Chemicals Agency, 2024c).

According to KEMI (2023), there are several alternatives to phthalates that are safer for health and the environment. One alternative is a group called special plasticisers. These usually have a slightly narrower range of use than phthalates. They are also slightly more expensive. However, they are expected to become cheaper as their use increases.

3 Methodology

The purpose of this project was to select different materials related to construction and civil engineering to analyse their contents. The project was primarily interested in investigating biocides. Therefore, these substances were prioritised for analysis. The selection of the biocides to be analysed was based on the thesis that formed the basis for the project (Öhman, 2023) and in conjunction with LTU. Analyses were also performed for additional substance groups that were of interest, as well as three individual substances.

The basis for this project consisted of a master's thesis and studies carried out in scientific reports.

After conducting a survey based on the data, the selection could be narrowed down to 12 products. The final selection resulted in eight paints and four roofing felt materials chosen for analysis.

The selection of paints and roofing felt materials for the project was done continuously and in agreement with LTU based on their leaching studies. The aim of the selection was to as far as possible perform material analysis on the same products used in the leaching studies. This would facilitate comparisons between contents and leaching. However, due to factors such as differences in available suppliers, some substitutions had to be made. The input material for this project and LTU's leaching studies therefore do not completely align.

All materials were analysed for the following groups of substances:

- Metals
- Pesticides
- Isothiazolinones
- PFAS
- Phthalates

All paints were also analysed for the following substances. The roofing felt materials were only analysed for IPBC:

- 3-Iodo-2-propynyl butylcarbamate (IPBC)
- 2,4,7,9-tetramethyl-5-decyne-4,7-diol
- Benzamide, 2,2'-dithiobis[nmethyl-benzamide]

The associated safety data sheets of the paints were used as a basis for deciding which groups of substances to include in the analysis. The individual substances were found in the lists of contents on the cans of some of the paints and were therefore also considered to be of interest for analysis. See Appendix 1 for an overview of all individual substances included in the groups of substances.

Prior to analysis, all paints were painted on cleaned glass slides and left to dry at room temperature. The procedure was repeated for another layer to mimic normal recommended use. The dried paint was then scraped off to be further sample processed for analysis.

All chemical analyses of the material samples were performed by Eurofins.

3.1 PFAS TOP

PFAS TOP, or "Total Oxidizable Precursors", is an analytical method used to assess the potential formation of highly fluorinated organic substances from precursor compounds.

Precursors are a broad group of PFAS compounds that are both known and unknown, and which can then be transformed upon degradation into substances with specific environmental and health impacts. Thus, these precursors are relevant and useful for investigating future dispersion and exposure (Eurofins, n.d.).

This method is used to break down PFAS compounds into measurable substances. This is done by oxidising unknown PFAS precursors and intermediates and converting them into stable PFAS compounds. This helps to identify potential future problems related to PFAS contamination (Ateia et al, 2023).

3.2 Purchased paints and roofing felt materials

The paints and roofing felt materials included in the project are listed below by name and image. All paint cans were purchased in the lowest volume that could be obtained to avoid waste. The four roofing felt materials were obtained from LTU who shared their already purchased products.

Safety data sheets were collected for all paints. The safety data sheets provide an overview of the substance content of the paints, which is also presented below. Roofing felt materials are not chemical products and therefore do not require safety data sheets. As a result, it is not possible to determine as clearly for roofing felt materials whether a substance identified during the analysis is not presented in the publicly published content.

Most of the paints list substances on the cans that are not presented in section 3 of the safety data sheets. This may be because the substance does not have a harmonised classification or does not need to be included under section 3 according to the legal requirements that apply to safety data sheets. The legal requirements are linked to for example the concentration of the substance in the product. However, the substances listed on the cans were also chosen to be analysed in this study.

The paints and substances concerned are as follows:

- Paint 3 and the topic OIT
- Paint 5 and the substance IPBC
- Paints 6 and 7 and the substance DCOIT
- Paint 8 and the substance 2,4,7,9-tetramethyldec-5-yn-4,7-diol

In section 4, the results of the analyses are presented.

3.2.1 Paint 1: Träfasad V Pro

Purchased at: Biltema
Brand: Biltema
Colour: White
Volume: 5 litres

Figure 1. Paint 1, Träfasad V Pro from the Biltema brand.

Table 3. Summary of the content of Träfasad V Pro including substance name, CAS number and concentration. The information has been taken from the product's safety data sheet.

Substance	CAS number	Concentrations
1,2-benzisothiazol-3(2H)-one (BIT)	2634-33-5	0 - <0.05%
Diuron (ISO)	330-54-1	0 - <0.02%
3-Iodo-2-propynyl butylcarbamate (IPBC)	55406-53-6	0 - <0.015%
2-octyl-2H-isothiazol-3-one (OIT)	26530-20-1	0 - <0.015%
5-chloro-2-methyl-2H-isothiazol-3-one [EC No 247-500-7] and 2-methyl-2H-isothiazol-3-one [EC No 220-239-6] (3:1) (CMIT/MIT)	55965-84-9	0 - <0.0015%

3.2.2 Paint 2: Facade Paint

Purchased at: Jula
Brand: Hard Head
Colour: White
Volume: 3 litres

Figure 2. Paint 2, Facade Paint from the Hard Head brand.

Table 4. Summary of the content of Facade Paint including substance name, CAS number and concentration. The information has been taken from the product's safety data sheet.

Substance	CAS number	Concentrations
1,2-benzisothiazol-3(2H)-one (BIT)	2634-33-5	<0.05%
Diuron (ISO)	330-54-1	<0.02%
3-Iodo-2-propynyl butylcarbamate (IPBC)	55406-53-6	<0.015%
2-octyl-2H-isothiazol-3-one (OIT)	26530-20-1	<0.015%
5-chloro-2-methyl-2H-isothiazol-3-one [EC No 247-500-7] and 2-methyl-2H-isothiazol-3-one [EC No 220-239-6] (3:1) (CMIT/MIT)	55965-84-9	<0.0015%

3.2.3 Paint 3: Murtex Siloxane

Purchased at: Nordsjö Professionals
Brand: Nordsjö
Colour: White
Volume: 2,5 litres

Figure 3. Paint 3, Murtex Siloxane from the Nordsjö brand.

Table 5. Summary of the contents of Murtex Siloxane including substance name, CAS number and concentration. The information has been taken from the product's safety data sheet.

Substance	CAS number	Concentrations
Titanium dioxide	13463-67-7	≥15 - ≤20%
2-(2-butoxyethoxy)ethanol	112-34-5	≤0.3%
3-Iodo-2-propynyl butylcarbamate (IPBC)	55406-53-6	<0.1%
1,2-benzisothiazol-3(2H)-one (BIT)	2634-33-5	<0.05%
Isoproturon	34123-59-6	≤0.05%
Bronopol (INN)	52-51-7	≤0.1%
Terbutryn	886-50-0	≤0.016%
5-chloro-2-methyl-2H-isothiazol-3-one [EC No 247-500-7] and 2-methyl-2H-isothiazol-3-one [EC No 220-239-6] (3:1) (CMIT/MIT)	55965-84-9	<0.0015%

3.2.4 Paint 4: One Super Tech

Purchased at: Nordsjö Professionals
Brand: Nordsjö
Colour: White
Volume: 1 litre

Figure 4. Paint 4, One Super Tech from the Nordsjö brand. (Beijer Byggmaterial; Fasadfärg One Super Tech, n.d.).

Table 6. Summary of the contents of One Super Tech including substance name, CAS number and concentration. The information has been taken from the product's safety data sheet.

Substance	CAS number	Concentrations
Titanium dioxide	13463-67-7	≥10 - ≤15%
3-Iodo-2-propynyl butylcarbamate (IPBC)	55406-53-6	<1%
1,2-benzisothiazol-3(2H)-one (BIT)	2634-33-5	<0.05%
Bronopol (INN)	52-51-7	≤0.1%
Benzamide, 2,2'-dithiobis[nmethyl-benzamide]	2527-58-4	≤0.084%
5-chloro-2-methyl-2H-isothiazol-3-one [EC No 247-500-7] and 2-methyl-2H-isothiazol-3-one [EC No 220-239-6] (3:1) (CMIT/MIT)	55965-84-9	<0.001%
2-methyl-l,2-benzothiazol-3(2H)-one (MBIT)	2527-66-4	<0.0015%
2-octyl-2H-isothiazol-3-one (OIT)	26530-20-1	<0.001%

3.2.5 Paint 5: Intact Total

Purchased at: -
Brand: Caparol
Colour: White
Volume: 1 litre

Figure 5. Paint 5, Intact Total from the Caparol brand.

Table 7. Summary of the contents of Intact Total including substance name, CAS number and concentration. The information has been taken from the product safety data sheet.

Substance	CAS number	Concentrations
Titanium dioxide	13463-67-7	≥10 - <20%
Propylidynetrimethanol	77-99-6	≥0.1 - <1%
1,2-benzisothiazol-3(2H)-one (BIT)	2634-33-5	≥0.025 - <0.05%
2-octyl-2H-isothiazol-3-one (OIT)	26530-20-1	≥0.0025 - <0.025%
4,5-dichloro-2-octyl-2H-isothiazol-3-one (DCOIT)	64359-81-5	≥0.0025 - <0.025%
2-methyl-l,2-benzothiazol-3(2H)-one (MBIT)	2527-66-4	≥0.0002 - <0.0015%
5-chloro-2-methyl-2H-isothiazol-3-one [EC No 247-500-7] and 2-methyl-2H-isothiazol-3-one [EC No 220-239-6] (3:1) (CMIT/MIT)	55965-84-9	≥0.0002 - <0.0015%
Talc (Mg3H2(SiO3)4)	14807-96-6	≥1 - <10%

3.2.6 Paint 6: Arkitekt

Purchased at: -
Brand: Alcro
Colour: White
Volume: 0,9 litre

Figure 6. Paint 6, Arkitekt from the Alcro brand.

Table 8. Summary of the contents of Arkitekt including substance name, CAS number and concentration. The information has been taken from the product safety data sheet.

Substance	CAS number	Concentrations
3-Iodo-2-propynyl butylcarbamate (IPBC)	55406-53-6	<1%
1,2-benzisothiazol-3(2H)-one (BIT)	2634-33-5	<0.05%
5-chloro-2-methyl-2H-isothiazol-3-one [EC No 247-500-7] and 2-methyl-2H-isothiazol-3-one [EC No 220-239-6] (3:1) (CMIT/MIT)	55965-84-9	<0.0015%

3.2.7 Paint 7: Front Akrylatfärg Max

Purchased at: -
Brand: Beckers
Colour: White
Volume: 1 litre

Figure 7. Paint 7, Front Akrylatfärg Max from the Beckers brand.

Table 9. Summary of the contents of Front Akrylatfärg Max including substance name, CAS number and concentration. The information has been taken from the product's safety data sheet.

Substance	CAS number	Concentrations
3-Iodo-2-propynyl butylcarbamate (IPBC)	55406-53-6	<1%
1,2-benzisothiazol-3(2H)-one (BIT)	2634-33-5	<0.05%
5-chloro-2-methyl-2H-isothiazol-3-one [EC No 247-500-7] and 2-methyl-2H-isothiazol-3-one [EC No 220-239-6] (3:1) (CMIT/MIT)	55965-84-9	<0.001%

3.2.8 Paint 8: Metall Plåttak

Purchased at: -
Brand: Beckers
Colour: Black
Volume: 3 litres

Figure 8. Paint 8, Metall Plåttak from the Beckers brand.

Table 10. Summary of the content of Metall Plåttak including substance name, CAS number and concentration. The information has been taken from the product safety data sheet.

Substance	CAS number	Concentrations
1,2-benzisothiazol-3(2H)-one (BIT)	2634-33-5	<0.05%
5-chloro-2-methyl-2H-isothiazol-3-one [EC No 247-500-7] and 2-methyl-2H-isothiazol-3-one [EC No 220-239-6] (3:1) (CMIT/MIT)	55965-84-9	≤0.0014%

3.2.9 Roofing felt material 1: Icopal Topsafe 3

Purchased at: -
Brand: Icopal
Colour: Black

Figure 9. Roofing felt material 1, Topsafe 3 from the brand Icopal (Beijer Byggmaterial; Ytpapp Topsafe 3º, n.d.).

3.2.10 Roofing felt material 2: Mataki Självtäck 3º

Purchased at: -
Brand: Mataki
Colour: Slate grey

Figure 10. Roofing felt material 2, Self-covering 3º from the brand Mataki (XL Bygg; Ytpapp Självtäck 3, n.d.).

3.2.11 Roofing felt material 3: Mataki Shingel Nordic

Purchased at: -
Brand: Mataki
Colour: Black

Figure 11. Roofing felt material 3, Shingel Nordic from the brand Mataki (K-Rauta; Shingel Nordic Mataki, n.d.).

3.2.12 Roofing felt material 4: Takshingel Raw

Purchased at: -
Brand: Raw
Colour: Black

Figure 12. Roofing felt material 4, Takshingel from the brand Raw (Beijer Byggmaterial; Takshingel Raw, n.d.).

4 Results

The analysis results for the material samples are presented for all eight paints and four roofing felt materials. The results are presented per material, where the results for all analysed substance groups are presented in the respective tables. In cases of measurement uncertainty, reporting limit or where an expert estimate is stated for the substance group, this is also reported in the table. All substances with "<" in front of their value were below their respective reporting limits.

For the paints, analysis results are reported for the following groups of substances:

- Metals
- Pesticides
- Isothiazolinones
- PFAS TOP
- Phthalates
- 3-iodo-2-propynylbutylcarbamate (IPBC)
- 2,4,7,9-tetramethyl-5-decyne-4,7-diol
- Benzamide, 2,2'-dithiobis[nmethyl-benzamide].

For the roofing felt materials, analytical results are reported for the same groups of substances, except for the last two individual substances.

For full results and reporting limits for each topic, see Appendix 2.

4.1 Paint 1: Träfasad V Pro

4.1.1 Metals

The results of the analyses of metals in paint 1 show that the substance with the highest concentration was titanium, followed by calcium and magnesium as shown in Table 11. Several substances were also below their respective reporting limits.

The measurement uncertainty for the analysed metals is illustrated in percent in a separate column. Values for measurement uncertainty marked with an asterisk (*) are instead reported in mg/kg DM.

Table 11. Analytical results for metals present in paint 1: Träfasad V Pro.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	6500	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	<18	40
Beryllium, Be	<0,45	35
Lead, Pb	1,7	35
Boron, B	<11	25
Phosphorus, P	580	35
Iron, Fe	460	20
Cadmium, Cd	<0,18	20
Calcium, Ca	26000	20
Potassium, K	390	35
Cobalt, Co	4,4	35
Copper, Cu	<3,6	20
Chromium, Cr	1,1	30
Lithium, Li	22	35
Magnesium, Mg	15000	20
Manganese, Mg	71	25
Molybdenum, Mo	<1,8	40
Sodium, Na	1800	20
Nickel, Ni	<1,8	30
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	<3,6	35
Sulphur, S	1100	30
Tallium, Tl	<0,18	20
Tenn, Sn	<0,45	35
Uranium, U	0,18	35
Vanadium, V	<5,4	35
Zinc, Zn	<9,0	35
Titanium, Ti	49000	5900*

4.1.2 Pesticides

The results of the analyses of pesticides in paint 1 show that the substance with the highest concentration was diuron as shown in Table 12. The remaining substances were below the reporting limit.

Table 12. Analytical results for metals present in paint 1: Träfasad V Pro.

PESTICIDES	
Substance	Result [µg/kg]
Diuron	780 000
Irgarol	<10
Isoproturon	<10
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	<10
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

4.1.3 Isothiazolinones

The results of the analyses of isothiazolinones in paint 1 show that the substance with the highest concentration was BIT, followed by OIT as shown in Table 13. Several substances were also below their respective reporting limits.

Table 13. Analytical results for isothiazolinones present in paint 1: Träfasad V Pro.

ISOTHIAZOLINONES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	2,7	0,5	± 50 %
CIT	2,3	0,1	± 50 %
BIT	25	0,1	± 50 %
OIT	19	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	<0,5	0,5	± 50 %

4.1.4 PFAS TOP

All analysed PFAS TOP substances were below the reporting limit of 5.0 µg/kg.

4.1.5 Phthalates

All phthalates analysed were below their respective reporting limits. The reporting limits for this analysis ranged from 5 mg/kg to 200 mg/kg. For the respective reporting limits of the individual substances, see Appendix 2.

4.1.6 Individual substances

The results of the analyses of the individual substances in paint 1 show that 3-Iodo-2-propynyl butylcarbamate (IPBC) was the only substance detected, see Table 14. The remaining substances were below their respective reporting limits.

Table 14. Analytical results for individual substances present in paint 1: Träfasad V Pro.

SPECIFIC SUBSTANCES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
2,4,7,9-tetramethyl-5-decyne-4,7-diol	<5	5	±50
Benzamide, 2,2'-dithiobis[nmethyl-benza	<20	20	±50
3-Iodo-2-propynyl butylcarbamate (IPBC)	1094	0,1	±50

4.2 Paint 2: Facade Paint

4.2.1 Metals

The results of the analyses of metals in paint 2 show that the substance with the highest concentration was titanium, see Table 15. Several substances were also below their respective reporting limits.
The measurement uncertainty for the analysed metals is illustrated in percent in a separate column. Values for measurement uncertainty marked with an asterisk (*) are instead reported in mg/kg DM.

Table 15. Analysis results of metals present in paint 2: Facade Paint.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	5100	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	<18	40
Beryllium, Be	<0,45	35
Lead, Pb	<0,90	35
Boron, B	<11	25
Phosphorus, P	170	35
Iron, Fe	490	20
Cadmium, Cd	<0,18	20
Calcium, Ca	7600	20
Potassium, K	180	35
Cobalt, Co	<0,45	30
Copper, Cu	<3,6	20
Chromium, Cr	<0,90	30
Lithium, Li	8,8	35
Magnesium, Mg	4400	20
Manganese, Mg	28	25
Molybdenum, Mo	<1,8	40
Sodium, Na	2000	20
Nickel, Ni	<1,8	30
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	<3,6	35
Sulphur, S	400	30
Tallium, Tl	<0,18	20
Tenn, Sn	<0,45	35
Uranium, U	<0,18	35
Vanadium, V	<5,4	35
Zinc, Zn	<9,0	35
Titanium, Ti	140000	16000*

4.2.2 Pesticides

The results of the analyses of pesticides in paint 2 show that the substance with the highest concentration was diuron, see Table 16. The remaining substances, except terbutryn, were below the reporting limit.

Table 16. Analytical results of pesticides present in paint 2: Facade Paint.

PESTICIDES	
Substance	Result [µg/kg]
Diuron	760 000
Irgarol	<10
Isoproturon	<10
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	140
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

4.2.3 Isothiazolinones

The results of the analyses of isothiazolinones in paint 2 show that the substance with the highest concentration was BIT, see Table 17. Several substances were also below their respective reporting limits.

Table 17. Analytical results of isothiazolinones present in paint 2: Facade Paint.

ISOTHIAZOLINONES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	3,3	0,5	± 50 %
CIT	1,2	0,1	± 50 %
BIT	36	0,1	± 50 %
OIT	22	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	<0,5	0,5	± 50 %

4.2.4 PFAS TOP

All analysed PFAS TOP substances were below the reporting limit of 5 µg/kg.

4.2.5 Phthalates

All phthalates analysed were below the reporting limit. The reporting limit for this analysis ranged from 5 mg/kg to 200 mg/kg. For the respective reporting limits of the individual substances, see Appendix 2.

4.2.6 Individual substances

The results of the analyses of the individual substances in paint 2 show that 3-Iodo-2-propynyl butylcarbamate (IPBC) was the only substance detected, see Table 18. The remaining substances were below their respective reporting limits.

Table 18. Analytical results of individual substances in paint 2: Facade Paint.

SPECIFIC SUBSTANCES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
2,4,7,9-tetramethyl-5-decyne-4,7-diol	<5	5	±50
Benzamide, 2,2'-dithiobis[nmethyl-benzami	<20	20	±50
3-Iodo-2-propynyl butylcarbamate (IPBC)	1099	0,1	±50

4.3 Paint 3: Murtex Siloxane

4.3.1 Metals

The results of the analyses of metals in paint 3 show that the substance with the highest concentration was titanium, followed by calcium and aluminium as shown in Table 19. Several substances were also below their respective reporting limits.

The measurement uncertainty for the analysed metals is illustrated in percent in a separate column. Values for measurement uncertainty marked with an asterisk (*) are instead reported in mg/kg DM.

Table 19. Analytical results for metals present in paint 3: Murtex Siloxane.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	7700	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	<18	40
Beryllium, Be	0,89	35
Lead, Pb	5,8	35
Boron, B	<11	25
Phosphorus, P	550	35
Iron, Fe	780	20
Cadmium, Cd	<0,18	20
Calcium, Ca	24000	20
Potassium, K	3300	35
Cobalt, Co	<0,45	30
Copper, Cu	<3,6	20
Chromium, Cr	3,9	30
Lithium, Li	28	35
Magnesium, Mg	950	20
Manganese, Mg	21	25
Molybdenum, Mo	<1,8	40
Sodium, Na	2100	20
Nickel, Ni	<1,8	30
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	7,8	35
Sulphur, S	390	30
Tallium, Tl	0,2	20
Tenn, Sn	8,5	35
Uranium, U	0,49	35
Vanadium, V	11	35
Zinc, Zn	240	20
Titanium, Ti	160000	19000*

4.3.2 Pesticides

The results of the analyses of pesticides in paint 3 show that the substance with the highest concentration was diuron, see Table 20. The remaining substances, except terbutryn, were below the reporting limits.

Table 20. Analytical results for pesticides present in paint 3: Murtex Siloxane.

PESTICIDES	
Substance	Result [µg/kg]
Diuron	210 000
Irgarol	<10
Isoproturon	<10
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	13
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

4.3.3 Isothiazolinones

The results of the analyses of isothiazolinones in paint 3 showed that all isothiazolinones were below their respective reporting limits. For CIT, BIT, OIT, DCOIT and BBIT the reporting limit was 0.1 mg/kg, and for MIT and MBIT it was 0.5 mg/kg.

4.3.4 PFAS TOP

All analysed PFAS TOP substances were below the reporting limit of 5.0 µg/kg.

4.3.5 Phthalates

All phthalates analysed were below their respective reporting limits. The reporting limits for this analysis ranged from 5 mg/kg to 200 mg/kg. For the respective reporting limits of the individual substances, see Appendix 2.

4.3.6 Individual substances

The results of the analyses of the individual substances in paint 3 showed that all individual substances were below their respective reporting limits. The reporting limit was 5 mg/kg for 2,4,7,9-tetramethyl-5-decyne-4,7-diol, 20 mg/kg for benzamide, 2,2'-dithiobis[nmethyl-benzamide] and 0,1 mg/kg for 3-iodo-2-propynylbutylcarbamate (IPBC).

4.4 Paint 4: One Super Tech

4.4.1 Metals

The results of the analyses of metals in paint 4 show that the substance with the highest concentration was titanium, see Table 21. Several substances were also below their respective reporting limits.
The measurement uncertainty for the analysed metals is illustrated in percent in a separate column. Values for measurement uncertainty marked with an asterisk (*) are instead reported in mg/kg DM.

Table 21. Analytical results of metals present in paint 4: One Super Tech.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	3100	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	<18	40
Beryllium, Be	<0,45	35
Lead, Pb	<0,90	35
Boron, B	<11	25
Phosphorus, P	200	35
Iron, Fe	390	20
Cadmium, Cd	<0,18	20
Calcium, Ca	92	20
Potassium, K	180	35
Cobalt, Co	0,6	30
Copper, Cu	<3,6	20
Chromium, Cr	83	30
Lithium, Li	4	35
Magnesium, Mg	2200	20
Manganese, Mg	4	25
Molybdenum, Mo	<1,8	40
Sodium, Na	1900	20
Nickel, Ni	14	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	<3,6	35
Sulphur, S	950	30
Tallium, Tl	<0,18	20
Tenn, Sn	3,5	35
Uranium, U	<0,18	35
Vanadium, V	<5,4	35
Zinc, Zn	<9,0	35
Titanium, Ti	150000	18000*

4.4.2 Pesticides

The results of the analyses of pesticides in paint 4 show that the substance with the highest concentration was diuron, see Table 22. The remaining substances were below the reporting limits.

Table 22. Analytical results of pesticides present in paint 4: One Super Tech.

PESTICIDES	
Substance	Result [µg/kg]
Diuron	9500
Irgarol	<10
Isoproturon	<10
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	<10
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

4.4.3 Isothiazolinones

The results of the analyses of isothiazolinones in paint 4 show that the substance with the highest concentration was BIT, see Table 23. Several substances were also below their respective reporting limits.

Table 23. Analytical results of isothiazolinones present in paint 4: One Super Tech.

ISOTHIAZOLINONES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	1,7	0,5	± 50 %
CIT	<0,1	0,1	± 50 %
BIT	62	0,1	± 50 %
OIT	<0,1	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	37	0,5	± 50 %

4.4.4 PFAS TOP

All analysed PFAS TOP substances were below the reporting limit of 25 µg/kg.

4.4.5 Phthalates

All phthalates analysed were below the reporting limits. The reporting limits for this analysis ranged from 5 mg/kg to 200 mg/kg. For the respective reporting limits of the individual substances, see Appendix 2.

4.4.6 Individual substances

The results of the analyses of the individual substances in paint 4 show that 3-Iodo-2-propynyl butylcarbamate (IPBC) was the only substance detected, see Table 24. The remaining substances were below their respective reporting limits.

Table 24. Analytical results of individual substances in paint 4: One Super Tech.

SPECIFIC SUBSTANCES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
2,4,7,9-tetramethyl-5-decyne-4,7-diol	<5	5	±50
Benzamide, 2,2'-dithiobis[nmethyl-benzami	<20	20	±50
3-Iodo-2-propynyl butylcarbamate (IPBC)	7589	0,1	±50

4.5 Paint 5: Intact Total

4.5.1 Metals

The results of the analyses of metals in paint 5 show that the substance with the highest concentration was titanium, followed by sulphur and magnesium as shown in Table 25. Several substances were also below their respective reporting limits.

The measurement uncertainty for the analysed metals is illustrated in percent in a separate column. Values for measurement uncertainty marked with an asterisk (*) are instead reported in mg/kg DM.

Table 25. Analytical results for metals present in paint 5: Intact Total.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	770	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	<18	40
Beryllium, Be	<0,45	35
Lead, Pb	1,1	35
Boron, B	<11	25
Phosphorus, P	1000	35
Iron, Fe	190	20
Cadmium, Cd	<0,18	20
Calcium, Ca	140	20
Potassium, K	210	35
Cobalt, Co	<0,45	30
Copper, Cu	8,6	20
Chromium, Cr	45	30
Lithium, Li	<3,6	35
Magnesium, Mg	1300	20
Manganese, Mg	<3,6	25
Molybdenum, Mo	<1,8	40
Sodium, Na	830	20
Nickel, Ni	9	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	<3,6	35
Sulphur, S	1500	30
Tallium, Tl	<0,18	20
Tenn, Sn	<0,45	35
Uranium, U	<0,18	35
Vanadium, V	<5,4	35
Zinc, Zn	<9,0	35
Titanium, Ti	170000	20000*

4.5.2 Pesticides

The results of the analyses of pesticides in paint 5 show that the substance with the highest concentration was terbutryn, see Table 26. The remaining substances were below the reporting limit.

Table 26. Analytical results for pesticides present in paint 5: Intact Total.

PESTICIDES	
Substance	Result [µg/kg]
Diuron	<10
Irgarol	<10
Isoproturon	<10
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	40
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

4.5.3 Isothiazolinones

The results of the analyses of isothiazolinones in paint 5 show that the substance with the highest concentration was BIT, followed by OIT as shown in Table 27. Several substances were also below their respective reporting limits.

Table 27. Analytical results for isothiazolinones present in paint 5: Intact Total.

ISOTHIAZOLINONES			
Substance	**Result [mg/kg]**	**Reporting limit [mg/kg]**	**Expert estimate [%]**
MIT	4,2	0,5	± 50 %
CIT	<0,1	0,1	± 50 %
BIT	72	0,1	± 50 %
OIT	38	0,1	± 50 %
DCOIT	0,77	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	10	0,5	± 50 %

4.5.4 PFAS TOP

All analysed PFAS TOP substances were below the reporting limit of 5.0 µg/kg.

4.5.5 Phthalates

All phthalates analysed were below their respective reporting limits. The reporting limits for this analysis ranged from 5 mg/kg to 200 mg/kg. For the respective reporting limits of the individual substances, see Appendix 2.

4.5.6 Individual substances

The results of the analyses of the individual substances in paint 5 show that 3-Iodo-2-propynyl butylcarbamate (IPBC) was the only substance detected, see Table 28. The remaining substances were below their respective reporting limits.

Table 28. Analytical results for individual substances present in paint 5: Intact Total.

SPECIFIC SUBSTANCES			
Substance	**Result [mg/kg]**	**Reporting limit [mg/kg]**	**Expert estimate [%]**
2,4,7,9-tetramethyl-5-decyne-4,7-diol	<5	5	±50
Benzamide, 2,2'-dithiobis[nmethyl-benzami	<20	20	±50
3-Iodo-2-propynyl butylcarbamate (IPBC)	4091	0,1	±50

4.6 Paint 6: Arkitekt

4.6.1 Metals

The results of the analyses of metals in paint 6 show that the substance with the highest concentration was titanium, followed by aluminium as shown in Table 29. Several substances were also below their respective reporting limits.

The measurement uncertainty for the analysed metals is illustrated in percent in a separate column. Values for measurement uncertainty marked with an asterisk (*) are instead reported in mg/kg DM.

Table 29. Analytical results of metals present in paint 6: Arkitekt.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	8300	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	93	40
Beryllium, Be	<0,45	35
Lead, Pb	15	35
Boron, B	<11	25
Phosphorus, P	190	35
Iron, Fe	700	20
Cadmium, Cd	0,35	20
Calcium, Ca	160	20
Potassium, K	340	35
Cobalt, Co	0,97	30
Copper, Cu	18	20
Chromium, Cr	110	30
Lithium, Li	<3,6	35
Magnesium, Mg	3100	20
Manganese, Mg	6,1	25
Molybdenum, Mo	<1,8	40
Sodium, Na	1400	20
Nickel, Ni	23	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	9,2	35
Sulphur, S	1400	30
Tallium, Tl	<0,18	20
Tenn, Sn	1,8	35
Uranium, U	0,42	35
Vanadium, V	<5,4	35
Zinc, Zn	<9,0	35
Titanium, Ti	150000	17000*

4.6.2 Pesticides

All analysed pesticides were below the reporting limit of 10 µg/kg.

4.6.3 Isothiazolinones

The results of the analyses of isothiazolinones in paint 6 show that the substance with the highest concentration was BIT, see Table 30. The remaining substances were below their respective reporting limits.

Table 30. Analytical results of isothiazolinones present in paint 6: Arkitekt.

ISOTHIAZOLINONES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	<0,5	0,5	± 50 %
CIT	<0,1	0,1	± 50 %
BIT	1,9	0,1	± 50 %
OIT	<0,1	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	<0,5	0,5	± 50 %

4.6.4 PFAS TOP

All analysed PFAS TOP substances were below the reporting limit of 5 µg/kg.

4.6.5 Phthalates

All phthalates analysed were below the reporting limits. The reporting limits for this analysis ranged from 5 mg/kg to 200 mg/kg. For the respective reporting limits of the individual substances, see Appendix 2.

4.6.6 Individual substances

The results of the analyses of the individual substances in paint 6 show that 3-Iodo-2-propynyl butylcarbamate (IPBC) was the only substance detected, see Table 31. The remaining substances were below their respective reporting limits.

Table 31. Analytical results of individual substances in paint 6: Arkitekt.

SPECIFIC SUBSTANCES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
2,4,7,9-tetramethyl-5-decyne-4,7-diol	<5	5	±50
Benzamide, 2,2'-dithiobis[nmethyl-benzami	<20	20	±50
3-Iodo-2-propynyl butylcarbamate (IPBC)	133	0,1	±50

4.7 Paint 7: Front Akrylatfärg Max

4.7.1 Metals

The results of the analyses of metals in paint 7 show that the substance with the highest concentration was titanium, followed by aluminium and sodium as shown in Table 32. Several substances were also below their respective reporting limits.

The measurement uncertainty for the analysed metals is illustrated in percent in a separate column. Values for measurement uncertainty marked with an asterisk (*) are instead reported in mg/kg DM.

Table 32. Analytical results for metals present in paint 7. Front Akrylatfärg Max.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	9300	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	32	40
Beryllium, Be	<0,45	35
Lead, Pb	0,99	35
Boron, B	<11	25
Phosphorus, P	160	35
Iron, Fe	510	20
Cadmium, Cd	<0,18	20
Calcium, Ca	570	20
Potassium, K	1600	35
Cobalt, Co	0,63	30
Copper, Cu	4,1	20
Chromium, Cr	69	30
Lithium, Li	<3,6	35
Magnesium, Mg	2100	20
Manganese, Mg	6,5	25
Molybdenum, Mo	<1,8	40
Sodium, Na	4100	20
Nickel, Ni	14	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	40	35
Sulphur, S	1400	30
Tallium, Tl	<0,18	20
Tenn, Sn	<0,45	35
Uranium, U	<0,18	35
Vanadium, V	<5,4	35
Zinc, Zn	<9,0	35
Titanium, Ti	140000	17000*

4.7.2 Pesticides

The results of the analyses of pesticides in paint 7 show that the substance with the highest concentration was diuron, see Table 33. The remaining substances, except isoproturon, were below the reporting limit.

Table 33. Analytical results for pesticides present in paint 7: Front Akrylatfärg Max.

PESTICIDES	
Substance	Result [µg/kg]
Diuron	12 000
Irgarol	<10
Isoproturon	19
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	<10
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

4.7.3 Isothiazolinones

The results of the analyses of isothiazolinones in paint 7 show that the substance with the highest concentration was BIT, see Table 34. Several substances were also below their respective reporting limits.

Table 34. Analytical results for isothiazolinones present in paint 7: Front Akrylatfärg Max.

ISOTHIAZOLINONES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	2,1	0,5	± 50 %
CIT	<0,1	0,1	± 50 %
BIT	26	0,1	± 50 %
OIT	<0,1	0,1	± 50 %
DCOIT	0,25	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	<0,5	0,5	± 50 %

4.7.4 PFAS TOP

All analysed PFAS TOP substances were below the reporting limit of 5.0 µg/kg.

4.7.5 Phthalates

All phthalates analysed were below their respective reporting limits. The reporting limits for this analysis ranged from 5 mg/kg to 200 mg/kg. For the respective reporting limits of the individual substances, see Appendix 2.

4.7.6 Individual substances

The results of the analyses of the individual substances in paint 7 show that 3-Iodo-2-propynyl butylcarbamate (IPBC) was the only substance detected, see Table 35. The remaining substances were below their respective reporting limits.

Table 35. Analytical results for individual substances present in paint 7: Front Akrylatfärg Max.

SPECIFIC SUBSTANCES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
2,4,7,9-tetramethyl-5-decyne-4,7-diol	<5	5	±50
Benzamide, 2,2'-dithiobis[nmethyl-benzami	<20	20	±50
3-Iodo-2-propynyl butylcarbamate (IPBC)	6865	0,1	±50

4.8 Paint 8: Metall Plåttak

4.8.1 Metals

The results of the analyses of metals in paint 8 show that the substance with the highest concentration was potassium, followed by aluminium and sulphur as shown in Table 36. Several substances were also below their respective reporting limits.

The measurement uncertainty for the analysed metals is illustrated in percent in a separate column. Values for measurement uncertainty marked with an asterisk (*) are instead reported in mg/kg DM.

Table 36. Analytical results of metals present in paint 8: Metall Plåttak.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	910	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	<18	40
Beryllium, Be	<0,45	35
Lead, Pb	2,1	35
Boron, B	<11	25
Phosphorus, P	410	35
Iron, Fe	350	20
Cadmium, Cd	<0,18	20
Calcium, Ca	<90	20
Potassium, K	1400	35
Cobalt, Co	<0,45	30
Copper, Cu	<3,6	20
Chromium, Cr	20	30
Lithium, Li	5,2	35
Magnesium, Mg	690	20
Manganese, Mg	<3,6	25
Molybdenum, Mo	<1,8	40
Sodium, Na	710	20
Nickel, Ni	4,6	30
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	<3,6	35
Sulphur, S	830	30
Tallium, Tl	<0,18	20
Tenn, Sn	2	35
Uranium, U	<0,18	35
Vanadium, V	<5,4	35
Zinc, Zn	<9,0	35
Titanium, Ti	170	36*

4.8.2 Pesticides

Paint 8 could not be analysed for pesticides due to difficult sample matrix. No results are therefore available.

4.8.3 Isothiazolinones

The results of the analyses of isothiazolinones in paint 8 show that the substance with the highest concentration was BIT, see Table 37. Several substances were also below their respective reporting limits.

Table 37. Analytical results of isothiazolinones present in paint 8: Metall Plåttak.

ISOTHIAZOLINONES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	1,7	0,5	± 50 %
CIT	<0,1	0,1	± 50 %
BIT	62	0,1	± 50 %
OIT	0,22	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	<0,5	0,5	± 50 %

4.8.4 PFAS TOP
All analysed PFAS TOP substances were below the reporting limit of 25 µg/kg.

4.8.5 Phthalates
All phthalates analysed were below the reporting limits. The reporting limits for this analysis ranged from 5 mg/kg to 200 mg/kg. For the respective reporting limits of the individual substances, see Appendix 2.

4.8.6 Individual substances
The results of the analyses of the individual substances in paint 8 show that 3-Iodo-2-propynyl butylcarbamate (IPBC) and 2,4,7,9-tetramethyl-5-decyne-4,7-diol were the only substances detected, see Table 38. The remaining substance was below the reporting limit.

Table 38. Analytical results of individual substances in paint 8: Metall Plåttak.

SPECIFIC SUBSTANCES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
2,4,7,9-tetramethyl-5-decyne-4,7-diol	1600	5	±50
Benzamide, 2,2'-dithiobis[nmethyl-benzami	<20	20	±50
3-Iodo-2-propynyl butylcarbamate (IPBC)	85	0,1	±50

4.9 Roofing felt material 1: Icopal Topsafe 3

4.9.1 Metals
The results of the analyses of metals in roofing felt material 1 show that the substance with the highest concentration was calcium, followed by aluminium and iron as shown in Table 39. Several substances were also below their respective reporting limits.

The measurement uncertainty for the analysed metals is illustrated in percent in a separate column.

Table 39. Analysis results for metals present in roofing felt material 1: Icopal Topsafe 3.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	6000	35
Antimony, Sb	10	40
Arsenic, As	<4,5	30
Barium, Ba	<18	40
Beryllium, Be	<0,45	35
Lead, Pb	2,8	35
Boron, B	120	25
Phosphorus, P	520	35
Iron, Fe	4400	20
Cadmium, Cd	<0,18	20
Calcium, Ca	49000	20
Potassium, K	1100	35
Cobalt, Co	1,5	30
Copper, Cu	6,1	20
Chromium, Cr	6,3	30
Lithium, Li	8,9	35
Magnesium, Mg	2300	20
Manganese, Mg	320	25
Molybdenum, Mo	14	40
Sodium, Na	<540	20
Nickel, Ni	7,5	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	15	35
Sulphur, S	3300	30
Tallium, Tl	<0,18	20
Tenn, Sn	0,57	35
Uranium, U	0,19	35
Vanadium, V	19	35
Zinc, Zn	150	20
Titanium, Ti	140	35

4.9.2 Pesticides

All pesticides analysed were below the reporting limit of 10 µg/kg.

4.9.3 Isothiazolinones

All isothiazolinones analysed were below their respective reporting limits. For the respective reporting limits of the individual substances, see Appendix 2.

4.9.4 PFAS TOP

All analysed PFAS TOP substances were below the reporting limit of 5.0 µg/kg.

4.9.5 Phthalates

All phthalates analysed were below their respective reporting limits. For the respective reporting limits of the individual substances, see Appendix 2.

4.9.6 Individual substances

The presence of 3-iodo-2-propynyl butylcarbamate (IPBC) was below the reporting limit of 0.1 mg/kg.

4.10 Roofing felt material 2: Mataki Självtäck 3º

4.10.1 Metals

The results of the analyses of metals in roofing felt material 2 show that the substance with the highest concentration was iron, followed by calcium as shown in Table 40. Several substances were also below their respective reporting limits.

The measurement uncertainty for the analysed metals is illustrated in percent in a separate column.

Table 40. Analysis results of metals present in roofing felt material 2: Mataki Självtäck 3º.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	7900	35
Antimony, Sb	59	40
Arsenic, As	32	30
Barium, Ba	350	40
Beryllium, Be	2,2	35
Lead, Pb	30	35
Boron, B	400	25
Phosphorus, P	240	35
Iron, Fe	78000	20
Cadmium, Cd	<0,18	20
Calcium, Ca	62000	20
Potassium, K	1800	35
Cobalt, Co	160	35
Copper, Cu	1400	20
Chromium, Cr	380	30
Lithium, Li	10	35
Magnesium, Mg	3000	20
Manganese, Mg	1100	25
Molybdenum, Mo	310	20
Sodium, Na	1400	20
Nickel, Ni	86	35
Selenium, Se	<0,90	40
Silver, Ag	0,89	40
Strontium, Sr	100	35
Sulphur, S	7700	30
Tallium, Tl	<0,18	20
Tenn, Sn	220	35
Uranium, U	1,9	35
Vanadium, V	46	35
Zinc, Zn	2300	20
Titanium, Ti	390	35

4.10.2 Pesticides

All analysed pesticides were below the reporting limit of 10 µg/kg.

4.10.3 Isothiazolinones

The results of the analyses of isothiazolinones in roofing felt material 2 show that the substance with the highest concentration was BIT, see Table 41. Several substances were also below their respective reporting limits.

Table 41. Analytical results of isothiazolinones present in roofing felt material 2: Mataki Självtäck 3º.

ISOTHIAZOLINONES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	3,2	0,5	± 50 %
CIT	0,76	0,1	± 50 %
BIT	130	0,1	± 50 %
OIT	8,1	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	<0,5	0,5	± 50 %

4.10.4 PFAS TOP

All analysed PFAS TOPs were below the reporting limit of 25 µg/kg.

4.10.5 Phthalates

All phthalates analysed were below the reporting limits. For the respective reporting limits of the individual substances, see Appendix 2.

4.10.6 Individual substances

Table 42 below shows that 3-iodo-2-propynyl butylcarbamate (IPBC) was present at 1384 mg/kg in roofing felt material 2.

Table 42. Analysis results of individual substances in roofing felt material 2: Mataki Självtäck 3º.

SPECIFIC SUBSTANCES			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
3-Iodo-2-propynyl butylcarbamate (IPBC)	1384	0,1	±50

4.11 Roofing felt material 3: Mataki Shingel Nordic

4.11.1 Metals

The results of the analyses of metals in roofing felt material 3 show that the substance with the highest concentration was calcium, followed by iron and magnesium as shown in Table 43. Several substances were also below their respective reporting limits.

The measurement uncertainty for the analysed metals is illustrated in percent in a separate column.

Table 43. Analysis results for metals present in roofing felt material 3: Mataki Shingel Nordic.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	3400	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	26	40
Beryllium, Be	<0,45	35
Lead, Pb	7,2	35
Boron, B	270	25
Phosphorus, P	57	35
Iron, Fe	63000	20
Cadmium, Cd	<0,18	20
Calcium, Ca	94000	20
Potassium, K	1100	35
Cobalt, Co	340	35
Copper, Cu	350	20
Chromium, Cr	190	30
Lithium, Li	4	35
Magnesium, Mg	10000	20
Manganese, Mg	200	25
Molybdenum, Mo	<1,8	40
Sodium, Na	580	20
Nickel, Ni	410	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	44	35
Sulphur, S	2600	30
Tallium, Tl	<0,18	20
Tenn, Sn	0,69	35
Uranium, U	0,3	35
Vanadium, V	35	35
Zinc, Zn	63	35
Titanium, Ti	140	35

4.11.2 Pesticides
All analysed pesticides were below the reporting limit of 10 µg/kg.

4.11.3 Isothiazolinones
All isothiazolinones analysed were below their respective reporting limits. For the respective reporting limits of the individual substances, see Appendix 2.

4.11.4 PFAS TOP
All analysed PFAS TOP substances were below the reporting limit of 5.0 µg/kg.

4.11.5 Phthalates
All phthalates analysed were below their respective reporting limits. For the respective reporting limits of the individual substances, see Appendix 2.

4.11.6 Individual substances
The presence of 3-iodo-2-propynyl butylcarbamate (IPBC) was below the reporting limit of 0.1 mg/kg.

4.12 Roofing felt material 4: Takshingel Raw

4.12.1 Metals

The results of the analyses of metals in roofing felt material 4 show that the substance with the highest concentration was calcium, see Table 44. Several substances were also below their respective reporting limits.

The measurement uncertainty for the analysed metals is illustrated in percent in a separate column.

Table 44. Analysis results of metals present in roofing felt material 4: Takshingel Raw.

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	3100	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	23	40
Beryllium, Be	<0,45	35
Lead, Pb	5,7	35
Boron, B	240	25
Phosphorus, P	54	35
Iron, Fe	48000	20
Cadmium, Cd	<0,18	20
Calcium, Ca	82000	20
Potassium, K	1000	35
Cobalt, Co	230	30
Copper, Cu	250	20
Chromium, Cr	160	30
Lithium, Li	3,6	35
Magnesium, Mg	7900	20
Manganese, Mg	170	25
Molybdenum, Mo	2,8	40
Sodium, Na	<540	20
Nickel, Ni	280	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	37	35
Sulphur, S	4900	30
Tallium, Tl	<0,18	20
Tenn, Sn	0,82	35
Uranium, U	0,71	35
Vanadium, V	81	35
Zinc, Zn	52	20
Titanium, Ti	220	35

4.12.2 Pesticides

All pesticides analysed were below the reporting limit of 10 µg/kg.

4.12.3 Isothiazolinones

All analysed isothiazolinones were below their respective reporting limit. For the respective reporting limits of the individual substances, see Appendix 2.

4.12.4 PFAS TOP

All analysed PFAS TOP substances were below the reporting limit of 5 µg/kg.

4.12.5 Phthalates

All phthalates analysed were below their respective reporting limits. For the respective reporting limits of the individual substances, see Appendix 2.

4.12.6 Individual substances

The presence of 3-iodo-2-propynyl butylcarbamate (IPBC) was below the reporting limit, <0.1 mg/kg.

5 Discussion

Based on the results of this project, it can be concluded that the presence of biocides and other additives varies in different types of building materials. This result is expected, since different types of building materials have different purposes and uses, which in turn means that different additives are used. Moreover, the presence of biocides and other additives has been shown to vary even within specific groups of building materials, which means that the content may vary from product to product within a product group.

Regarding roofing felt materials, biocides were detected in only one material. In that sample, a biocide was found in a relatively high concentration. For the paint samples, the results for the presence of biocides varied from paint to paint.

Although a large variation was observed in the occurrence of the majority of the analysed substance groups, a link was identified for the substance groups PFAS and phthalates and alternative plasticisers. All analysed substances within these substance groups were below the respective detection limits in all paints and roofing felt materials and were thus not detected at all in this study.

An important finding that emerged from this project was that the analytical results for the metals showed that most of the paints contained lead in concentrations. This is of particular concern as lead is not permitted to be used in paints. This discovery further highlights the importance of clear requirements and continuous follow-ups to ensure that requirements of contents are met.

Since the analyses of the paints were carried out after drying, it can be established that many of the substances analysed were still present after curing. This is an interesting observation as it highlights that various precautionary or preventive measures may need to be taken not only during use, but also after construction or installation. This also gives an indication of the environmental and health risks that may arise from the release of the substances, for example through leaching or abrasion of materials.

Analysing the content of building materials like performed within this project is an area where previous research is limited. Instead, studies are often carried out on the leaching of various substances from building materials. It is therefore complex to draw make comparisons with previous research, especially regarding the specific building materials investigated in this project.

However, some general relationships can be established, for example regarding the presence of PFAS in paint products. When compared with previous research and the results of this study, the results differ. Previous studies found that PFASs are commonly used in paint products to provide resistance to factors such as weather and abrasion. However, in this study, no PFASs were detected in any of the paints analysed.

However, it is important to note that the absence of PFAS compounds in paints does not mean that these compounds are not present in paints at all. Instead, it can be concluded from this result, as well as from previous research, that the presence of PFAS compounds in paint products is highly variable. The difference could be due to variations in use, i.e. the purpose of the paint in question as an indoor or outdoor paint. Therefore, this is something that should be considered before using this type of product. It is also important to note that the PFAS compounds analysed in this project are only a small fraction of all the PFAS compounds that exist, and the results are therefore not fully representative.

There are also cases where consistency with previous research has been demonstrated, for example in the case of the biocide diuron. According to previous research, diuron is often

detected in high concentrations. Sometimes, the concentrations are several orders of magnitude higher than other biocides analysed. This is largely consistent with the results of this project, where diuron was the biocide that occurred most frequently and in the highest concentrations.

6 Conclusion

Based on the results of this project, the following conclusions could be drawn. Biocides and other additives can be found in different types of building materials. It was found that the presence of biocides and other additives varies in different types of building materials, and that it also varies within specific groups of building materials. Based on this, it can be concluded that customisation and awareness regarding the material or product used, and the potential risks involved in each individual situation is important.

The fact that lead was detected in most of the paints, despite the fact that it is prohibited, also shows that strict and clear standards must be set, and that it is of great importance to carry out follow-ups to ensure that these are actually met.

The analyses of the dried paints revealed that harmful substances remain even after curing. It is therefore important to be aware that potential risks do not only occur during the use of the product, but also after installation or construction. This also means that preventive measures may be necessary to minimise the environmental and health impacts that can result from potential releases such as leaching or abrasion of materials.

As this area of analysing direct content in building materials is to date relatively unexplored, the amount of previous research is limited. This means that comparisons with previous studies were not possible. It also indicates that this is an area where further and more extensive research is required. In order to draw more accurate and comprehensive conclusions, further investigations should be conducted on a wider range of building materials.

This study shows that it is essential to continue to investigate larger quantities of different types of building materials in order to make informed choices in construction that favour a non-toxic and sustainable society.

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Annex 1: Substances analysed

Compound name	Abbreviation	CAS number
Phthalate esters		
Dibutyl phthalate	DBP	84-74-2
Benzyl butyl phthalate	BBP	85-68-7
Bis(2-ethylhexyl) phthalate	DEHP	117-81-7
Diisononyl phthalate	DINP	68515-48-0
Diisodecyl phthalate	DIDP	26761-40-0
Di-n-octyl phthalate	DNOP	117-84-0
Diisobutyl phthalate	DIBP	84-69-5
Bis(2-methoxyethyl) phthalate	DMEP	117-82-8
Dipentyl phthalate	PLR	131-18-0
Diisopentyl phthalate	DIPP	605-50-5
N-pentyl-isopentyl phthalate		776297-69-9
Dimethyl phthalate	DMP	131-11-3
Diethyl phthalate		84-66-2
Diisoheptyl phthalate		71888-89-6
Diisooctyl phthalate		27554-26-3
Diisoundecyl phthalates		96507-86-7
Diisododecyl phthalate		141-17-3
Diisotridecyl phthalate		27253-26-5
Bis(2-propylheptyl) phthalate		53306-54-0
Dihexyl phthalate		84-75-3
Diheptyl phthalate		3648-21-3
Dipropyl phthalate		131-16-8
Diisopropyl phthalate		605-45-8
Dibenzyl phthalate		523-31-9
Dicyclohexyl phthalate		84-61-7
Diphenyl phthalate		84-62-8
HNSUP		68515-42-4
Di-hexylphthalate, branched and linear		68515-50-4
Diisohexyl phthalate		71850-09-4
1,2-Benzenedicarboxylic acid, di-C6-10-alkyl esters		68515-51-5
Dinonyl phthalate		84-76-4
Mixed C6-C8-C10 phthalates		68648-93-1
Diallyl phthalate		131-17-9
Bis(2-ethoxyethyl) phthalate		605-54-9
Bis(1,3-dimethyl butyl) phthalate		84-63-9
Bis(2-butoxyethyl) phthalate		117-83-9
Diundecyl phthalate		3648-20-2
Didodecyl phthalate		2432-90-8
Didecyl phthalate		84-77-5
Biocides/Pesticides		
Diuron		330-54-1
Isoproturon		34123-59-6
Terbutryn		886-50-0
Cybutryn/Irgarol		28159-98-0
carbendazim		10605-21-7
Propiconazole		60207-90-1
Tebuconazole		107534-96-3
Mecoprop		16484-77-8
Iodopropynyl butylcarbamate	IPBC	55406-53-6

Isothiazolinones		
Methylisothiazolinone	MIT	2682-20-4
Methylchloroisothiazolinone	CIT	26172-55-4
Benzisothiazolinones	BIT	2634-33-5
Octylisothiazolinone	ILO	26530-20-1
Dichlorooctylisothiazolone	DCOIT	64359-81-5
Butylbenzisothiazolinone	BBIT	4299-07-4
Methylbenzothiazolone	MBIT	2527-66-4
Poly- & perfluoroalkyl substances		
Perfluorobutanoic acid	PFBA (TOP)	375-22-4
Perfluorohexanoic acid	PFHxA (TOP)	307-24-4
Perfluoroheptanoic acid	PFHpA (TOP)	375-85-9
Perfluorooctanoic acid	PFOA (TOP)	335-67-1
Perfluorononanoic acid	PFNA (TOP)	375-95-1
Perfluorodecanoic acid	PFDA (TOP)	335-76-2
Perfluorotridecanoic acid	PFTrDA (TOP)	72629-94-8
Perfluorotetradecanoic acid	PFTeDA (TOP)	376-06-7
Perfluorohexadecanoic acid	PFHxDA (TOP)	67905-19-5
Perfluorobutanesulfonic acid	PFBS (TOP)	375-73-5
Perfluorohexanesulfonic acid	PFHxS (TOP)	355-46-4
Perfluoroheptane sulfonic acid	PFHpS (TOP)	375-92-8
Perfluorooctanesulfonic acid	PFOS (TOP)	1763-23-1
Perfluorodecanesulfonic acid	PFDS (TOP)	335-77-3
Perfluorooctane sulfonamide	PFOSA (TOP)	754-91-6
6:2 fluorotelomer sulphonic acid	6:2 FTS (TPOP)	27619-97-2
8:2 fluorotelomer sulphonic acid	8:2 FTS (TOP)	39108-34-4
4:2 fluorotelomer sulphonic acid	4:2 FTS (TOP)	757124-72-4
Perfluorooctane sulfonamido acetic acid	FOSAA (TOP)	2806-24-8
N-methylperfluorooctane sulfonamidoacetic acid	Me-FOSAA (TOP)	2355-31-9
N-ethylperfluoro-1-octanesulfonamidoacetic acid	Et-FOSAA (TOP)	2991-50-6
N-methylperfluorooctane sulfonamide	Me-FOSA (TOP)	31506-32-8
N-ethylperfluorooctane sulfonamide	Et-FOSA (TOP)	4151-50-2
N-Methylperfluorooctane sulfonamidoethanol	Me-FOSE (TOP)	24448-09-7
N-Ethylperfluorooctane sulfonamidoethanol	Et-FOSE (TOP)	1691-99-2
Perfluoroundecanoic acid	PFUdA (TOP)	2058-94-8
Perfluoroundecanoic acid	PFDoA (TOP)	307-55-1
Perfluoro-3,7-dimethyloctanoic acid	P37DMOA (TOP)	172155-07-6
7H-Perfluoroheptanoic acid	HPFHpA (TOP)	1546-95-8
Perfluoropentanoic acid	PFPeA (TOP)	2706-90-3
Metals		
Lead	Pb	7439-92-1
Cadmium	CD	7440-43-9
nickel	Nine	7440-02-0
Arsenic	Axis	7440-38-2
Copper	Cu	7440-50-8
Zinc	Zn	7440-66-6
Chromium	Cr	7440-47-3
Aluminium	Al	7429-90-5
Boron	B	7440-42-8
Calcium	Ca	7440-70-2
Iron	Fairy	7439-89-6
Potassium	K	7440-09-7
Magnesium	Mg	7439-95-4
Manganese	Mn	7439-96-5
Sodium	Na	7440-23-5

Phosphorus	P	7723-14-0
Sulphur	S	7704-34-9
Molybdenum	Mo	7439-98-7
Antimony	Sb	7440-36-0
Cobalt	Co	7440-48-4
Tin	Sn	7440-31-5
Silver	Ag	7440-22-4
Selenium	See	7782-49-2
Barium	Ba	7440-39-3
Lithium	Li	7439-93-2
Strontium	Sr	7440-24-6
Titanium	Ti	7440-32-6
Vanadium	V	7440-62-2
Beryllium	Be	7440-41-7
Thallium	Tl	7440-28-0
Uranium	U	7440-61-1

Other

2,4,7,9-tetramethyldec-5-yn-4,7-diol	126-86-3
Benzamide, 2,2'-dithiobis[nmethyl-benzamide]	2527-58-4

Annex 2: Analysis results

See separate Excel file attached for the analysis results.

Patrol 1, T/Sibanda's Pre Billoma

Sample number:
Unknown

Methods	
Lower limit	Mean(Log10 Reg Mfu)
Ayebare, Ab	4.08
Ayebare, Ab	3.97
Bensch, Ba	3.96
Bensch, Ba	4.11
Ayebare, Ab	3.77
Bensch, B	3.82
Ayebare, Ab	3.96
Pelt, Lm	3.96
Sahoo, Ks	3.98
Sahoo, Ks	3.97
Sahoo, Ks	3.97
Ayebare, Ab	3.97
Ayebare, Ab	3.97
Ayebare, Ab

Molybdenum, Mo	<1,8	40
Sodium, Na	2100	20
Nickel, Ni	<1,8	30
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	7,8	35
Sulphur, S	390	30
Tallium, T	0,2	20
Tenn, Sn	8,5	35
Uranium, U	0,49	35
Vanadium, V	11	35
Zinc, Zn	240	20
Titanium, Ti	160000	19000*

* mg/kg DM

PFHpS (Perfluoroheptane sulphonic acid) (TOP)	<5,0	±36
PFHxA (Perfluorohexanoic acid) (TOP)	<5,0	±36
PFHxDA (Perfluorohexadecanoic acid) (TOP)	<5,0	±36
PFHxS (Perfluorohexanesulfonic acid) (TOP)	<5,0	±36
PFNA (Perfluorononanoic acid) (TOP)	<5,0	±36
PFOA (Perfluorooctanoic acid) (TOP)	<5,0	±36
PFOS (Perfluorooctane sulfonic acid) (TOP)	<5,0	±36
PFOSA (Perfluorooctane sulfonamide) (TOP)	<5,0	±36
PFPeA (Perfluoropentanoic acid) (TOP)	<5,0	±36
PFTeDA (Perfluorotetradecanoic acid) (TOP)	<5,0	±36
PFTrDA (Perfluorotridecanoic acid) (TOP)	<5,0	±36
PFUdA (Perfluorundecanoic acid) (TOP)	<5,0	±36
Total PFAS (TOP) incl. ½ LOQ	<80	-

diisopentyl phthalate (C)	<20	20	± 30 %	
n-pentylisopentyl phthalate (D)	<20	20		± 50 %
diisoheptyl phthalate (C)	<100	100	± 30 %	
diisooctyl phthalate (C)	<100	100	± 30 %	
Diisoundecyl phthalate (D)	<100	100		± 50 %
Diisododecyl phthalate (D)	<100	100		± 50 %
Diisotridecyl phthalate (C)	<100	100	± 30 %	
bis(2-propylheptyl) phthalate (C)	<50	50	± 30 %	
Di-n-hexyl phthalate (C)	<20	20	± 30 %	
Di-n-heptyl phthalate (C)	<50	50	± 30 %	
Di-n-propyl phthalate (C)	<20	20	± 30 %	
Diisopropyl phthalate (C)	<20	20	± 30 %	
Dibenzyl phthalate (C)	<20	20	± 51 %	
dicyclohexylphthalate (C)	<50	50	± 30 %	
Diphenylphthalate (C)	<20	20	± 40 %	
HNSUP (D)	<200	200		± 50 %
di-hexylphthalate, branched and linear (D)	<100	100		± 50 %
diisohexyl phthalate (C)	<100	100	± 30 %	
1,2-Benzenedicarboxylic acid, di-C6-10-alkyl esters (D)	<200	200		± 50 %
Dinonyl phthalate (D)	<20	20		± 50 %
mixed C6-C8-C10 phthalate (D)	<200	200		± 50 %

Paint 4, One Super Tech Nordsjö

Sample number:
12040669

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	3100	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	<18	40
Beryllium, Be	<0,45	35
Lead, Pb	<0,90	35
Boron, B	<11	25
Phosphorus, P	200	35
Iron, Fe	390	20
Cadmium, Cd	<0,18	20
Calcium, Ca	92	20
Potassium, K	180	35
Cobalt, Co	0,6	30
Copper, Cu	<3,6	20
Chromium, Cr	83	30
Lithium, Li	4	35
Magnesium, Mg	2200	20
Manganese, Mg	4	25
Molybdenum, Mo	<1,8	40
Sodium, Na	1900	20
Nickel, Ni	14	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	<3,6	35
Sulphur, S	950	30
Tallium, T	<0,18	20
Tenn, Sn	3,5	35
Uranium, U	<0,18	35
Vanadium, V	<5,4	35
Zinc, Zn	<9,0	35
Titanium, Ti	150000	18000*

* mg/kg DM

PESTICIDES	
Substance	Result [µg/kg]
Diuron	9500
Irgarol	<10
Isoproturon	<10
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	<10
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

PFAS TOP		
Substance	Result [µg/kg]	Measurement uncertainty [%]
4:2 FTS (Fluorotelomer sulphonate) (TOP)	<25	±36
6:2 FTS (fluorotelomer sulfonate) (TOP)	<25	±36
8:2 FTS (fluorotelomer sulfonate) (TOP)	<25	±36
EtFOSA (N-ethylperfluorooctane sulfonamide) (TOP)	<25	±36
EtFOSAA(N-ethylperfluorooctane sulfonamide-HAc) (TOP)	<25	±36
EtFOSE(N-ethylperfluorooctane sulfonamide-EtOH) (TOP)	<25	±36
FOSAA (Perfluorooctane sulphonamide acetic acid) (TOP)	<25	±36
HPFHpA (7H-Perfluorheptanoic acid) (TOP)	<25	±36
MeFOSA(N-methylperfluorooctane sulfonamide)(TOP)	<25	±36
MeFOSAA(N-methylperfluorooctane sulfonamide-Hac) (TOP)	<25	±36
MeFOSE(N-methylperfluorooctanesulfonamide-EtOH) (TOP)	<25	±36
P37DMOA (Perfluoro-3,7-dimethyloctanoic acid) (TOP)	<25	±36
PFBA (Perfluorobutanoic acid) (TOP)	<25	±36
PFBS (Perfluorobutanesulfonic acid) (TOP)	<25	±36
PFDA (Perfluorodecanoic acid) (TOP)	<25	±36
PFDoA (Perfluorododecanoic acid) (TOP)	<25	±36
PFDS (Perfluorodecanesulfonic acid) (TOP)	<25	±36
PFHpA (Perfluorheptanoic acid) (TOP)	<25	±36
PFHpS (Perfluoroheptane sulphonic acid) (TOP)	<25	±36
PFHxA (Perfluorohexanoic acid) (TOP)	<25	±36
PFHxDA (Perfluorohexadecanoic acid) (TOP)	<25	±36
PFHxS (Perfluorohexanesulfonic acid) (TOP)	<25	±36
PFNA (Perfluorononanoic acid) (TOP)	<25	±36
PFOA (Perfluorooctanoic acid) (TOP)	<25	±36
PFOS (Perfluorooctane sulfonic acid) (TOP)	<25	±36
PFOSA (Perfluorooctane sulfonamide) (TOP)	<25	±36
PFPeA (Perfluoropentanoic acid) (TOP)	<25	±36
PFTeDA (Perfluorotetradecanoic acid) (TOP)	<25	±36
PFTrDA (Perfluorotridecanoic acid) (TOP)	<25	±36
PFUdA (Perfluorundecanoic acid) (TOP)	<25	±36
Total PFAS (TOP) incl. ½ LOQ	<380	-

SPECIFIC SUBSTANCE!			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
2,4,7,9-tetramethyl-5-decyne-4,7-diol	<5	5	±50
Benzamide, 2,2'-dithiobis[nmethyl-benzamide]	<20	20	±50
3-Iodo-2-propynyl butylcarbamate (IPBC)	7589	0,1	±50

ISOTHIAZOLINONE!			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	1,7	0,5	± 50 %
CIT	<0,1	0,1	± 50 %
BIT	62	0,1	± 50 %
OIT	<0,1	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	37	0,5	± 50 %

PHTHALATES				
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Measurement uncertainty [%]	Expert estimate [%]
bis(2-ethoxyethyl) phthalate (C)	<20	20	± 40 %	
Bis(1,3-dimethylbutyl) phthalate (C)	<20	20	± 30 %	
2-Butoxyethyl phthalate (C)	<10	10	± 40 %	
Di-n-decyl phthalate (C)	<50	50	± 30 %	
diallyl phthalate (C)	<20	20	± 30 %	
Diundecyl phthalate (C)	<100	100	± 30 %	
Didodecyl phthalate (C)	<100	100	± 30 %	
dimethyl phthalate (C)	<5	5	± 30 %	
diethyl phthalate (C)	<5	5	± 30 %	
diisobutyl phthalate (C)	<20	20	± 30 %	
dibutyl phthalate (C)	<20	20	± 30 %	
butyl benzyl phthalate (C)	<20	20	± 30 %	
DEHP (C)	<50	50	± 30 %	
di-n-octyl phthalate (C)	<20	20	± 50 %	
diisononyl phthalate (C)	<100	100	± 30 %	
diisodecyl phthalate (C)	<100	100	± 30 %	
bis(2-methoxyethyl) phthalate (C)	<20	20	± 30 %	
di-n-pentyl phthalate (C)	<20	20	± 30 %	
diisopentyl phthalate (C)	<20	20	± 30 %	
n-pentylisopentyl phthalate (D)	<20	20		± 50 %
diisoheptyl phthalate (C)	<100	100	± 30 %	
diisooctyl phthalate (C)	<100	100	± 30 %	
Diisoundecyl phthalate (D)	<100	100		± 50 %
Diisododecyl phthalate (D)	<100	100		± 50 %
Diisotridecyl phthalate (C)	<100	100	± 30 %	
bis(2-propylheptyl) phthalate (C)	<50	50	± 30 %	
Di-n-hexyl phthalate (C)	<20	20	± 30 %	
Di-n-heptyl phthalate (C)	<50	50	± 30 %	
Di-n-propyl phthalate (C)	<20	20	± 30 %	
Diisopropyl phthalate (C)	<20	20	± 30 %	
Dibenzyl phthalate (C)	<20	20	± 51 %	
dicyclohexylphthalate (C)	<50	50	± 30 %	
Diphenylphthalate (C)	<20	20	± 40 %	
HNSUP (D)	<200	200		± 50 %
di-hexylphthalate, branched and linear (D)	<100	100		± 50 %
diisohexyl phthalate (C)	<100	100	± 30 %	
1,2-Benzenedicarboxylic acid, di-C6-10-alkyl esters (D)	<200	200		± 50 %
Dinonyl phthalate (D)	<20	20		± 50 %
mixed C6-C8-C10 phthalate (D)	<200	200		± 50 %

Paint 5, Intact Total Caparol

Sample number:
12040670

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	770	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	<18	40
Beryllium, Be	<0,45	35
Lead, Pb	1,1	35
Boron, B	<11	25
Phosphorus, P	1000	35
Iron, Fe	190	20
Cadmium, Cd	<0,18	20
Calcium, Ca	140	20
Potassium, K	210	35
Cobalt, Co	<0,45	30
Copper, Cu	8,6	20
Chromium, Cr	45	30
Lithium, Li	<3,6	35
Magnesium, Mg	1300	20
Manganese, Mg	<3,6	25
Molybdenum, Mo	<1,8	40
Sodium, Na	830	20
Nickel, Ni	9	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	<3,6	35
Sulphur, S	1500	30
Tallium, T	<0,18	20
Tenn, Sn	<0,45	35
Uranium, U	<0,18	35
Vanadium, V	<5,4	35
Zinc, Zn	<9,0	35
Titanium, Ti	170000	20000*

* mg/kg DM

PESTICIDES	
Substance	Result [µg/kg]
Diuron	<10
Irgarol	<10
Isoproturon	<10
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	40
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

PFAS TOP		
Substance	Result [µg/kg]	Measurement uncertainty [%]
4:2 FTS (Fluorotelomer sulphonate) (TOP)	<5,0	±36
6:2 FTS (fluorotelomer sulfonate) (TOP)	<5,0	±36
8:2 FTS (fluorotelomer sulfonate) (TOP)	<5,0	±36
EtFOSA (N-ethylperfluorooctane sulfonamide) (TOP)	<5,0	±36
EtFOSAA(N-ethylperfluorooctane sulfonamide-HAc) (TOP)	<5,0	±36
EtFOSE(N-ethylperfluorooctane sulfonamide-EtOH) (TOP)	<5,0	±36
FOSAA (Perfluorooctane sulphonamide acetic acid) (TOP)	<5,0	±36
HPFHpA (7H-Perfluorheptanoic acid) (TOP)	<5,0	±36
MeFOSA(N-methylperfluorooctane sulfonamide)(TOP)	<5,0	±36
MeFOSAA(N-methylperfluorooctane sulfonamide-Hac) (TOP)	<5,0	±36
MeFOSE(N-methylperfluorooctanesulfonamide-EtOH) (TOP)	<5,0	±36
P37DMOA (Perfluoro-3,7-dimethyloctanoic acid) (TOP)	<5,0	±36
PFBA (Perfluorobutanoic acid) (TOP)	<5,0	±36
PFBS (Perfluorobutanesulfonic acid) (TOP)	<5,0	±36
PFDA (Perfluorodecanoic acid) (TOP)	<5,0	±36
PFDoA (Perfluorododecanoic acid) (TOP)	<5,0	±36
PFDS (Perfluorodecanesulfonic acid) (TOP)	<5,0	±36
PFHpA (Perfluorheptanoic acid) (TOP)	<5,0	±36
PFHpS (Perfluoroheptane sulphonic acid) (TOP)	<5,0	±36
PFHxA (Perfluorohexanoic acid) (TOP)	<5,0	±36
PFHxDA (Perfluorohexadecanoic acid) (TOP)	<5,0	±36
PFHxS (Perfluorohexanesulfonic acid) (TOP)	<5,0	±36
PFNA (Perfluorononanoic acid) (TOP)	<5,0	±36
PFOA (Perfluorooctanoic acid) (TOP)	<5,0	±36
PFOS (Perfluorooctane sulfonic acid) (TOP)	<5,0	±36
PFOSA (Perfluorooctane sulfonamide) (TOP)	<5,0	±36
PFPeA (Perfluoropentanoic acid) (TOP)	<5,0	±36
PFTeDA (Perfluorotetradecanoic acid) (TOP)	<5,0	±36
PFTrDA (Perfluorotridecanoic acid) (TOP)	<5,0	±36
PFUdA (Perfluorundecanoic acid) (TOP)	<5,0	±36
Total PFAS (TOP) incl. ½ LOQ	<80	-

SPECIFIC SUBSTANCE!			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
2,4,7,9-tetramethyl-5-decyne-4,7-diol	<5	5	±50
Benzamide, 2,2'-dithiobis[nmethyl-benzamide]	<20	20	±50
3-Iodo-2-propynyl butylcarbamate (IPBC)	4091	0,1	±50

ISOTHIAZOLINONE!			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	4,2	0,5	± 50 %
CIT	<0,1	0,1	± 50 %
BIT	72	0,1	± 50 %
OIT	38	0,1	± 50 %
DCOIT	0,77	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	10	0,5	± 50 %

PHTHALATES				
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Measurement uncertainty [%]	Expert estimate [%]
bis(2-ethoxyethyl) phthalate (C)	<20	20	± 40 %	
Bis(1,3-dimethylbutyl) phthalate (C)	<20	20	± 30 %	
2-Butoxyethyl phthalate (C)	<10	10	± 40 %	
Di-n-decyl phthalate (C)	<50	50	± 30 %	
diallyl phthalate (C)	<20	20	± 30 %	
Diundecyl phthalate (C)	<100	100	± 30 %	
Didodecyl phthalate (C)	<100	100	± 30 %	
dimethyl phthalate (C)	<5	5	± 30 %	
diethyl phthalate (C)	<5	5	± 30 %	
diisobutyl phthalate (C)	<20	20	± 30 %	
dibutyl phthalate (C)	<20	20	± 30 %	
butyl benzyl phthalate (C)	<20	20	± 30 %	
DEHP (C)	<50	50	± 30 %	
di-n-octyl phthalate (C)	<20	20	± 50 %	
diisononyl phthalate (C)	<100	100	± 30 %	
diisodecyl phthalate (C)	<100	100	± 30 %	
bis(2-methoxyethyl) phthalate (C)	<20	20	± 30 %	
di-n-pentyl phthalate (C)	<20	20	± 30 %	
diisopentyl phthalate (C)	<20	20	± 30 %	
n-pentylisopentyl phthalate (D)	<20	20		± 50 %
diisoheptyl phthalate (C)	<100	100	± 30 %	
diisooctyl phthalate (C)	<100	100	± 30 %	
Diisoundecyl phthalate (D)	<100	100		± 50 %
Diisododecyl phthalate (D)	<100	100		± 50 %
Diisotridecyl phthalate (C)	<100	100	± 30 %	
bis(2-propylheptyl) phthalate (C)	<50	50	± 30 %	
Di-n-hexyl phthalate (C)	<20	20	± 30 %	
Di-n-heptyl phthalate (C)	<50	50	± 30 %	
Di-n-propyl phthalate (C)	<20	20	± 30 %	
Diisopropyl phthalate (C)	<20	20	± 30 %	
Dibenzyl phthalate (C)	<20	20	± 51 %	
dicyclohexylphthalate (C)	<50	50	± 30 %	
Diphenylphthalate (C)	<20	20	± 40 %	
HNSUP (D)	<200	200		± 50 %
di-hexylphthalate, branched and linear (D)	<100	100		± 50 %
diisohexyl phthalate (C)	<100	100	± 30 %	
1,2-Benzenedicarboxylic acid, di-C6-10-alkyl esters (D)	<200	200		± 50 %
Dinonyl phthalate (D)	<20	20		± 50 %
mixed C6-C8-C10 phthalate (D)	<200	200		± 50 %

Paint 6, Arkitekt Alcro

Sample number:
12040671

METALS

PESTICIDES

PFAS TOP

SPECIFIC SUBSTANCE!

ISOTHIAZOLINONE!

PHTHALATES

Subdivision	Amount (mg/kg) RWA	Measurement Uncertainty (mg)
Administrative Unit	4.56	0.5
Administrative Unit	4.56	0.5
Alternate Site	4.56	0.5
Alternate Site	4.56	0.5
Alternate Site

Sulphur, S	830	30
Tallium, T	<0,18	20
Tenn, Sn	2	35
Uranium, U	<0,18	35
Vanadium, V	<5,4	35
Zinc, Zn	<9,0	35
Titanium, Ti	170	36*

* mg/kg DM

PFOS (Perfluorooctane sulfonic acid) (TOP)	<25	±36
PFOSA (Perfluorooctane sulfonamide) (TOP)	<25	±36
PFPeA (Perfluoropentanoic acid) (TOP)	<25	±36
PFTeDA (Perfluorotetradecanoic acid) (TOP)	<25	±36
PFTrDA (Perfluorotridecanoic acid) (TOP)	<25	±36
PFUdA (Perfluorundecanoic acid) (TOP)	<25	±36
Total PFAS (TOP) incl. ½ LOQ	<380	-

Diisotridecyl phthalate (C)	<100	100	± 30 %	
bis(2-propylheptyl) phthalate (C)	<50	50	± 30 %	
Di-n-hexyl phthalate (C)	<20	20	± 30 %	
Di-n-heptyl phthalate (C)	<50	50	± 30 %	
Di-n-propyl phthalate (C)	<20	20	± 30 %	
Diisopropyl phthalate (C)	<20	20	± 30 %	
Dibenzyl phthalate (C)	<20	20	± 51 %	
dicyclohexylphthalate (C)	<50	50	± 30 %	
Diphenylphthalate (C)	<20	20	± 40 %	
HNSUP (D)	<200	200		± 50 %
di-hexylphthalate, branched and linear (D)	<100	100		± 50 %
diisohexyl phthalate (C)	<100	100	± 30 %	
1,2-Benzenedicarboxylic acid, di-C6-10-alkyl esters (D)	<200	200		± 50 %
Dinonyl phthalate (D)	<20	20		± 50 %
mixed C6-C8-C10 phthalate (D)	<200	200		± 50 %

Roofing felt 1, Icopal TopSafe 3

Sample number:
12040697

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	6000	35
Antimony, Sb	10	40
Arsenic, As	<4,5	30
Barium, Ba	<18	40
Beryllium, Be	<0,45	35
Lead, Pb	2,8	35
Boron, B	120	25
Phosphorus, P	520	35
Iron, Fe	4400	20
Cadmium, Cd	<0,18	20
Calcium, Ca	49000	20
Potassium, K	1100	35
Cobalt, Co	1,5	30
Copper, Cu	6,1	20
Chromium, Cr	6,3	30
Lithium, Li	8,9	35
Magnesium, Mg	2300	20
Manganese, Mg	320	25
Molybdenum, Mo	14	40
Sodium, Na	<540	20
Nickel, Ni	7,5	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	15	35
Sulphur, S	3300	30
Tallium, T	<0,18	20
Tenn, Sn	0,57	35
Uranium, U	0,19	35
Vanadium, V	19	35
Zinc, Zn	150	20
Titanium, Ti	140	35

PESTICIDES	
Substance	Result [µg/kg]
Diuron	<10
Irgarol	<10
Isoproturon	<10
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	<10
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

PFAS TOP		
Substance	Result [µg/kg]	Measurement uncertainty [%]
4:2 FTS (Fluorotelomer sulphonate) (TOP)	<5,0	±36
6:2 FTS (fluorotelomer sulfonate) (TOP)	<5,0	±36
8:2 FTS (fluorotelomer sulfonate) (TOP)	<5,0	±36
EtFOSA (N-ethylperfluorooctane sulfonamide) (TOP)	<5,0	±36
EtFOSAA(N-ethylperfluorooctane sulfonamide-HAc) (TOP)	<5,0	±36
EtFOSE(N-ethylperfluorooctane sulfonamide-EtOH) (TOP)	<5,0	±36
FOSAA (Perfluorooctane sulphonamide acetic acid) (TOP)	<5,0	±36
HPFHpA (7H-Perfluorheptanoic acid) (TOP)	<5,0	±36
MeFOSA(N-methylperfluorooctane sulfonamide)(TOP)	<5,0	±36
MeFOSAA(N-methylperfluorooctane sulfonamide-Hac) (TOP)	<5,0	±36
MeFOSE(N-methylperfluorooctanesulfonamide-EtOH) (TOP)	<5,0	±36
P37DMOA (Perfluoro-3,7-dimethyloctanoic acid) (TOP)	<5,0	±36
PFBA (Perfluorobutanoic acid) (TOP)	<5,0	±36
PFBS (Perfluorobutanesulfonic acid) (TOP)	<5,0	±36
PFDA (Perfluorodecanoic acid) (TOP)	<5,0	±36
PFDoA (Perfluorododecanoic acid) (TOP)	<5,0	±36
PFDS (Perfluorodecanesulfonic acid) (TOP)	<5,0	±36
PFHpA (Perfluorheptanoic acid) (TOP)	<5,0	±36
PFHpS (Perfluoroheptane sulphonic acid) (TOP)	<5,0	±36
PFHxA (Perfluorohexanoic acid) (TOP)	<5,0	±36
PFHxDA (Perfluorohexadecanoic acid) (TOP)	<5,0	±36
PFHxS (Perfluorohexanesulfonic acid) (TOP)	<5,0	±36
PFNA (Perfluorononanoic acid) (TOP)	<5,0	±36
PFOA (Perfluorooctanoic acid) (TOP)	<5,0	±36
PFOS (Perfluorooctane sulfonic acid) (TOP)	<5,0	±36
PFOSA (Perfluorooctane sulfonamide) (TOP)	<5,0	±36
PFPeA (Perfluoropentanoic acid) (TOP)	<5,0	±36
PFTeDA (Perfluorotetradecanoic acid) (TOP)	<5,0	±36
PFTrDA (Perfluorotridecanoic acid) (TOP)	<5,0	±36
PFUdA (Perfluorundecanoic acid) (TOP)	<5,0	±36
Total PFAS (TOP) incl. ½ LOQ	<80	-

SPECIFIC SUBSTANCES		
Substance	Result [mg/kg]	Reporting limit [mg/kg]
3-Iodo-2-propynyl butylcarbamate (IPBC)	<0,1	0,1

ISOTHIAZOLINONE!			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	<0,5	0,5	± 50 %
CIT	<0,1	0,1	± 50 %
BIT	<0,1	0,1	± 50 %
OIT	<0,1	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	<0,5	0,5	± 50 %

PHTHALATES				
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Measurement uncertainty [%]	Expert estimate [%]
bis(2-ethoxyethyl) phthalate (C)	<20	20	± 40 %	
Bis(1,3-dimethylbutyl) phthalate (C)	<20	20	± 30 %	
2-Butoxyethyl phthalate (C)	<10	10	± 40 %	
Di-n-decyl phthalate (C)	<50	50	± 30 %	
diallyl phthalate (C)	<20	20	± 30 %	
Diundecyl phthalate (C)	<100	100	± 30 %	
Didodecyl phthalate (C)	<100	100	± 30 %	
dimethyl phthalate (C)	<5	5	± 30 %	
diethyl phthalate (C)	<5	5	± 30 %	
diisobutyl phthalate (C)	<20	20	± 30 %	
dibutyl phthalate (C)	<20	20	± 30 %	
butyl benzyl phthalate (C)	<20	20	± 30 %	
DEHP (C)	<50	50	± 30 %	
di-n-octyl phthalate (C)	<20	20	± 50 %	
diisononyl phthalate (C)	<100	100	± 30 %	
diisodecyl phthalate (C)	<100	100	± 30 %	
bis(2-methoxyethyl) phthalate (C)	<20	20	± 30 %	
di-n-pentyl phthalate (C)	<20	20	± 30 %	
diisopentyl phthalate (C)	<20	20	± 30 %	
n-pentylisopentyl phthalate (D)	<20	20		± 50 %
diisoheptyl phthalate (C)	<100	100	± 30 %	
diisooctyl phthalate (C)	<100	100	± 30 %	
Diisoundecyl phthalate (D)	<100	100		± 50 %
Diisododecyl phthalate (D)	<100	100		± 50 %
Diisotridecyl phthalate (C)	<100	100	± 30 %	
bis(2-propylheptyl) phthalate (C)	<50	50	± 30 %	
Di-n-hexyl phthalate (C)	<20	20	± 30 %	
Di-n-heptyl phthalate (C)	<50	50	± 30 %	
Di-n-propyl phthalate (C)	<20	20	± 30 %	
Diisopropyl phthalate (C)	<20	20	± 30 %	
Dibenzyl phthalate (C)	<20	20	± 51 %	
dicyclohexylphthalate (C)	<50	50	± 30 %	
Diphenylphthalate (C)	<20	20	± 40 %	
HNSUP (D)	<200	200		± 50 %
di-hexylphthalate, branched and linear (D)	<100	100		± 50 %
diisohexyl phthalate (C)	<100	100	± 30 %	
1,2-Benzenedicarboxylic acid, di-C6-10-alkyl esters (D)	<200	200		± 50 %
Dinonyl phthalate (D)	<20	20		± 50 %
mixed C6-C8-C10 phthalate (D)	<200	200		± 50 %

Roofing felt 2, MATAKI Självtävk 3 skiffergrå 3

Sample number:
12040698

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	7900	35
Antimony, Sb	59	40
Arsenic, As	32	30
Barium, Ba	350	40
Beryllium, Be	2,2	35
Lead, Pb	30	35
Boron, B	400	25
Phosphorus, P	240	35
Iron, Fe	78000	20
Cadmium, Cd	<0,18	20
Calcium, Ca	62000	20
Potassium, K	1800	35
Cobalt, Co	160	35
Copper, Cu	1400	20
Chromium, Cr	380	30
Lithium, Li	10	35
Magnesium, Mg	3000	20
Manganese, Mg	1100	25
Molybdenum, Mo	310	20
Sodium, Na	1400	20
Nickel, Ni	86	35
Selenium, Se	<0,90	40
Silver, Ag	0,89	40
Strontium, Sr	100	35
Sulphur, S	7700	30
Tallium, T	<0,18	20
Tenn, Sn	220	35
Uranium, U	1,9	35
Vanadium, V	46	35
Zinc, Zn	2300	20
Titanium, Ti	390	35

PESTICIDES	
Substance	Result [µg/kg]
Diuron	<10
Irgarol	<10
Isoproturon	<10
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	<10
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

PFAS TOP		
Substance	Result [µg/kg]	Measurement uncertainty [%]
4:2 FTS (Fluorotelomer sulphonate) (TOP)	<25	±36
6:2 FTS (fluorotelomer sulfonate) (TOP)	<25	±36
8:2 FTS (fluorotelomer sulfonate) (TOP)	<25	±36
EtFOSA (N-ethylperfluorooctane sulfonamide) (TOP)	<25	±36
EtFOSAA(N-ethylperfluorooctane sulfonamide-HAc) (TOP)	<25	±36
EtFOSE(N-ethylperfluorooctane sulfonamide-EtOH) (TOP)	<25	±36
FOSAA (Perfluorooctane sulphonamide acetic acid) (TOP)	<25	±36
HPFHpA (7H-Perfluorheptanoic acid) (TOP)	<25	±36
MeFOSA(N-methylperfluorooctane sulfonamide)(TOP)	<25	±36
MeFOSAA(N-methylperfluorooctane sulfonamide-Hac) (TOP)	<25	±36
MeFOSE(N-methylperfluorooctanesulfonamide-EtOH) (TOP)	<25	±36
P37DMOA (Perfluoro-3,7-dimethyloctanoic acid) (TOP)	<25	±36
PFBA (Perfluorobutanoic acid) (TOP)	<25	±36
PFBS (Perfluorobutanesulfonic acid) (TOP)	<25	±36
PFDA (Perfluorodecanoic acid) (TOP)	<25	±36
PFDoA (Perfluorododecanoic acid) (TOP)	<25	±36
PFDS (Perfluorodecanesulfonic acid) (TOP)	<25	±36
PFHpA (Perfluorheptanoic acid) (TOP)	<25	±36
PFHpS (Perfluoroheptane sulphonic acid) (TOP)	<25	±36
PFHxA (Perfluorohexanoic acid) (TOP)	<25	±36
PFHxDA (Perfluorohexadecanoic acid) (TOP)	<25	±36
PFHxS (Perfluorohexanesulfonic acid) (TOP)	<25	±36
PFNA (Perfluorononanoic acid) (TOP)	<25	±36
PFOA (Perfluorooctanoic acid) (TOP)	<25	±36
PFOS (Perfluorooctane sulfonic acid) (TOP)	<25	±36
PFOSA (Perfluorooctane sulfonamide) (TOP)	<25	±36
PFPeA (Perfluoropentanoic acid) (TOP)	<25	±36
PFTeDA (Perfluorotetradecanoic acid) (TOP)	<25	±36
PFTrDA (Perfluorotridecanoic acid) (TOP)	<25	±36
PFUdA (Perfluorundecanoic acid) (TOP)	<25	±36
Total PFAS (TOP) incl. ½ LOQ	<380	-

SPECIFIC SUBSTANCE!			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
3-Iodo-2-propynyl butylcarbamate (IPBC)	1384	0,1	±50

ISOTHIAZOLINONE!			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	3,2	0,5	± 50 %
CIT	0,76	0,1	± 50 %
BIT	130	0,1	± 50 %
OIT	8,1	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	<0,5	0,5	± 50 %

PHTHALATES				
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Measurement uncertainty [%]	Expert estimate [%]
bis(2-ethoxyethyl) phthalate (C)	<20	20	± 40 %	
Bis(1,3-dimethylbutyl) phthalate (C)	<20	20	± 30 %	
2-Butoxyethyl phthalate (C)	<10	10	± 40 %	
Di-n-decyl phthalate (C)	<50	50	± 30 %	
diallyl phthalate (C)	<20	20	± 30 %	
Diundecyl phthalate (C)	<100	100	± 30 %	
Didodecyl phthalate (C)	<100	100	± 30 %	
dimethyl phthalate (C)	<5	5	± 30 %	
diethyl phthalate (C)	<5	5	± 30 %	
diisobutyl phthalate (C)	<20	20	± 30 %	
dibutyl phthalate (C)	<20	20	± 30 %	
butyl benzyl phthalate (C)	<20	20	± 30 %	
DEHP (C)	<50	50	± 30 %	
di-n-octyl phthalate (C)	<20	20	± 50 %	
diisononyl phthalate (C)	<100	100	± 30 %	
diisodecyl phthalate (C)	<100	100	± 30 %	
bis(2-methoxyethyl) phthalate (C)	<20	20	± 30 %	
di-n-pentyl phthalate (C)	<20	20	± 30 %	
diisopentyl phthalate (C)	<20	20	± 30 %	
n-pentylisopentyl phthalate (D)	<20	20		± 50 %
diisoheptyl phthalate (C)	<100	100	± 30 %	
diisooctyl phthalate (C)	<100	100	± 30 %	
Diisoundecyl phthalate (D)	<100	100		± 50 %
Diisododecyl phthalate (D)	<100	100		± 50 %
Diisotridecyl phthalate (C)	<100	100	± 30 %	
bis(2-propylheptyl) phthalate (C)	<50	50	± 30 %	
Di-n-hexyl phthalate (C)	<20	20	± 30 %	
Di-n-heptyl phthalate (C)	<50	50	± 30 %	
Di-n-propyl phthalate (C)	<20	20	± 30 %	
Diisopropyl phthalate (C)	<20	20	± 30 %	
Dibenzyl phthalate (C)	<20	20	± 51 %	
dicyclohexylphthalate (C)	<50	50	± 30 %	
Diphenylphthalate (C)	<20	20	± 40 %	
HNSUP (D)	<200	200		± 50 %
di-hexylphthalate, branched and linear (D)	<100	100		± 50 %
diisohexyl phthalate (C)	<100	100	± 30 %	
1,2-Benzenedicarboxylic acid, di-C6-10-alkyl esters (D)	<200	200		± 50 %
Dinonyl phthalate (D)	<20	20		± 50 %
mixed C6-C8-C10 phthalate (D)	<200	200		± 50 %

Roofing felt 3, MATAKI Shingel Nordic

Sample number:
12040699

METALS		
Substance	Result [mg/kg DM]	Measurement uncertainty [%]
Aluminium, Al	3400	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30

PESTICIDES	
Substance	Result [µg/kg]
Diuron	<10
Irgarol	<10
Isoproturon	<10

PFAS TOP		
Substance	Result [µg/kg]	Measurement uncertainty [%]
4:2 FTS (Fluorotelomer sulphonate) (TOP)	<5,0	±36
6:2 FTS (fluorotelomer sulfonate) (TOP)	<5,0	±36
8:2 FTS (fluorotelomer sulfonate) (TOP)	<5,0	±36

SPECIFIC SUBSTANCES		
Substance	Result [mg/kg]	Reporting limit [mg/kg]
3-Iodo-2-propynyl butylcarbamate (IPBC)	<0,1	0,1

ISOTHIAZOLINONE!			
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Expert estimate [%]
MIT	<0,5	0,5	± 50 %
CIT	<0,1	0,1	± 50 %
BIT	<0,1	0,1	± 50 %

PHTHALATES				
Substance	Result [mg/kg]	Reporting limit [mg/kg]	Measurement uncertainty [%]	Expert estimate [%]
bis(2-ethoxyethyl) phthalate (C)	<20	20	± 40 %	
Bis(1,3-dimethylbutyl) phthalate (C)	<20	20	± 30 %	
2-Butoxyethyl phthalate (C)	<10	10	± 40 %	

Barium, Ba	26	40
Beryllium, Be	<0,45	35
Lead, Pb	7,2	35
Boron, B	270	25
Phosphorus, P	57	35
Iron, Fe	63000	20
Cadmium, Cd	<0,18	20
Calcium, Ca	94000	20
Potassium, K	1100	35
Cobalt, Co	340	35
Copper, Cu	350	20
Chromium, Cr	190	30
Lithium, Li	4	35
Magnesium, Mg	10000	20
Manganese, Mg	200	25
Molybdenum, Mo	<1,8	40
Sodium, Na	580	20
Nickel, Ni	410	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	44	35
Sulphur, S	2600	30
Tallium, T	<0,18	20
Tenn, Sn	0,69	35
Uranium, U	0,3	35
Vanadium, V	35	35
Zinc, Zn	63	35
Titanium, Ti	140	35

propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	<10
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

EtFOSA (N-ethylperfluorooctane sulfonamide) (TOP)	<5,0	±36
EtFOSAA(N-ethylperfluorooctane sulfonamide-HAc) (TOP)	<5,0	±36
EtFOSE(N-ethylperfluorooctane sulfonamide-EtOH) (TOP)	<5,0	±36
FOSAA (Perfluorooctane sulphonamide acetic acid) (TOP)	<5,0	±36
HPFHpA (7H-Perfluorheptanoic acid) (TOP)	<5,0	±36
MeFOSA(N-methylperfluorooctane sulfonamide)(TOP)	<5,0	±36
MeFOSAA(N-methylperfluorooctane sulfonamide-Hac) (TOP)	<5,0	±36
MeFOSE(N-methylperfluorooctanesulfonamide-EtOH) (TOP)	<5,0	±36
P37DMOA (Perfluoro-3,7-dimethyloctanoic acid) (TOP)	<5,0	±36
PFBA (Perfluorobutanoic acid) (TOP)	<5,0	±36
PFBS (Perfluorobutanesulfonic acid) (TOP)	<5,0	±36
PFDA (Perfluorodecanoic acid) (TOP)	<5,0	±36
PFDoA (Perfluorododecanoic acid) (TOP)	<5,0	±36
PFDS (Perfluorodecanesulfonic acid) (TOP)	<5,0	±36
PFHpA (Perfluorheptanoic acid) (TOP)	<5,0	±36
PFHpS (Perfluoroheptane sulphonic acid) (TOP)	<5,0	±36
PFHxA (Perfluorohexanoic acid) (TOP)	<5,0	±36
PFHxDA (Perfluorohexadecanoic acid) (TOP)	<5,0	±36
PFHxS (Perfluorohexanesulfonic acid) (TOP)	<5,0	±36
PFNA (Perfluorononanoic acid) (TOP)	<5,0	±36
PFOA (Perfluorooctanoic acid) (TOP)	<5,0	±36
PFOS (Perfluorooctane sulfonic acid) (TOP)	<5,0	±36
PFOSA (Perfluorooctane sulfonamide) (TOP)	<5,0	±36
PFPeA (Perfluoropentanoic acid) (TOP)	<5,0	±36
PFTeDA (Perfluorotetradecanoic acid) (TOP)	<5,0	±36
PFTrDA (Perfluorotridecanoic acid) (TOP)	<5,0	±36
PFUdA (Perfluorundecanoic acid) (TOP)	<5,0	±36
Total PFAS (TOP) incl. ½ LOQ	<80	-

OIT	<0,1	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	<0,5	0,5	± 50 %

Di-n-decyl phthalate (C)	<50	50	± 30 %	
diallyl phthalate (C)	<20	20	± 30 %	
Diundecyl phthalate (C)	<100	100	± 30 %	
Didodecyl phthalate (C)	<100	100	± 30 %	
dimethyl phthalate (C)	<5	5	± 30 %	
diethyl phthalate (C)	<5	5	± 30 %	
diisobutyl phthalate (C)	<20	20	± 30 %	
dibutyl phthalate (C)	<20	20	± 30 %	
butyl benzyl phthalate (C)	<20	20	± 30 %	
DEHP (C)	<50	50	± 30 %	
di-n-octyl phthalate (C)	<20	20	± 50 %	
diisononyl phthalate (C)	<100	100	± 30 %	
diisodecyl phthalate (C)	<100	100	± 30 %	
bis(2-methoxyethyl) phthalate (C)	<20	20	± 30 %	
di-n-pentyl phthalate (C)	<20	20	± 30 %	
diisopentyl phthalate (C)	<20	20	± 30 %	
n-pentylisopentyl phthalate (D)	<20	20		± 50 %
diisoheptyl phthalate (C)	<100	100	± 30 %	
diisooctyl phthalate (C)	<100	100	± 30 %	
Diisoundecyl phthalate (D)	<100	100		± 50 %
Diisododecyl phthalate (D)	<100	100		± 50 %
Diisotridecyl phthalate (C)	<100	100	± 30 %	
bis(2-propylheptyl) phthalate (C)	<50	50	± 30 %	
Di-n-hexyl phthalate (C)	<20	20	± 30 %	
Di-n-heptyl phthalate (C)	<50	50	± 30 %	
Di-n-propyl phthalate (C)	<20	20	± 30 %	
Diisopropyl phthalate (C)	<20	20	± 30 %	
Dibenzyl phthalate (C)	<20	20	± 51 %	
dicyclohexylphthalate (C)	<50	50	± 30 %	
Diphenylphthalate (C)	<20	20	± 40 %	
HNSUP (D)	<200	200		± 50 %
di-hexylphthalate, branched and linear (D)	<100	100		± 50 %
diisohexyl phthalate (C)	<100	100	± 30 %	
1,2-Benzenedicarboxylic acid, di-C6-10-alkyl esters (D)	<200	200		± 50 %
Dinonyl phthalate (D)	<20	20		± 50 %
mixed C6-C8-C10 phthalate (D)	<200	200		± 50 %

Roofing felt 4, TAKSHINGEL RAW SVART

Sample number:
12040700

METALS		
Substance	**Result [mg/kg DM]**	**Measurement uncertainty [%]**
Aluminium, Al	3100	35
Antimony, Sb	<1,8	40
Arsenic, As	<4,5	30
Barium, Ba	23	40
Beryllium, Be	<0,45	35
Lead, Pb	5,7	35
Boron, B	240	25
Phosphorus, P	54	35
Iron, Fe	48000	20
Cadmium, Cd	<0,18	20
Calcium, Ca	82000	20
Potassium, K	1000	35
Cobalt, Co	230	30
Copper, Cu	250	20
Chromium, Cr	160	30
Lithium, Li	3,6	35
Magnesium, Mg	7900	20
Manganese, Mg	170	25
Molybdenum, Mo	2,8	40
Sodium, Na	<540	20
Nickel, Ni	280	35
Selenium, Se	<0,90	40
Silver, Ag	<0,45	40
Strontium, Sr	37	35
Sulphur, S	4900	30
Tallium, T	<0,18	20
Tenn, Sn	0,82	35
Uranium, U	0,71	35
Vanadium, V	81	35
Zinc, Zn	52	20
Titanium, Ti	220	35

PESTICIDES	
Substance	**Result [µg/kg]**
Diuron	<10
Irgarol	<10
Isoproturon	<10
propiconazole	<10
Thiabendazole	<10
Tebuconazole	<10
Terbutryn	<10
Penconazole	<10
Mecoprop	<10
Carbendazim	<10

PFAS TOP		
Substance	**Result [µg/kg]**	**Measurement uncertainty [%]**
4:2 FTS (Fluorotelomer sulphonate) (TOP)	<5,0	±36
6:2 FTS (fluorotelomer sulfonate) (TOP)	<5,0	±36
8:2 FTS (fluorotelomer sulfonate) (TOP)	<5,0	±36
EtFOSA (N-ethylperfluorooctane sulfonamide) (TOP)	<5,0	±36
EtFOSAA(N-ethylperfluorooctane sulfonamide-HAc) (TOP)	<5,0	±36
EtFOSE(N-ethylperfluorooctane sulfonamide-EtOH) (TOP)	<5,0	±36
FOSAA (Perfluorooctane sulphonamide acetic acid) (TOP)	<5,0	±36
HPFHpA (7H-Perfluorheptanoic acid) (TOP)	<5,0	±36
MeFOSA(N-methylperfluorooctane sulfonamide)(TOP)	<5,0	±36
MeFOSAA(N-methylperfluorooctane sulfonamide-Hac) (TOP)	<5,0	±36
MeFOSE(N-methylperfluorooctanesulfonamide-EtOH) (TOP)	<5,0	±36
P37DMOA (Perfluoro-3,7-dimethyloctanoic acid) (TOP)	<5,0	±36
PFBA (Perfluorobutanoic acid) (TOP)	<5,0	±36
PFBS (Perfluorobutanesulfonic acid) (TOP)	<5,0	±36
PFDA (Perfluorodecanoic acid) (TOP)	<5,0	±36
PFDoA (Perfluorododecanoic acid) (TOP)	<5,0	±36
PFDS (Perfluorodecanesulfonic acid) (TOP)	<5,0	±36
PFHpA (Perfluorheptanoic acid) (TOP)	<5,0	±36
PFHpS (Perfluoroheptane sulphonic acid) (TOP)	<5,0	±36
PFHxA (Perfluorohexanoic acid) (TOP)	<5,0	±36
PFHxDA (Perfluorohexadecanoic acid) (TOP)	<5,0	±36
PFHxS (Perfluorohexanesulfonic acid) (TOP)	<5,0	±36
PFNA (Perfluorononanoic acid) (TOP)	<5,0	±36
PFOA (Perfluorooctanoic acid) (TOP)	<5,0	±36
PFOS (Perfluorooctane sulfonic acid) (TOP)	<5,0	±36
PFOSA (Perfluorooctane sulfonamide) (TOP)	<5,0	±36
PFPeA (Perfluoropentanoic acid) (TOP)	<5,0	±36
PFTeDA (Perfluorotetradecanoic acid) (TOP)	<5,0	±36
PFTrDA (Perfluorotridecanoic acid) (TOP)	<5,0	±36
PFUdA (Perfluorundecanoic acid) (TOP)	<5,0	±36
Total PFAS (TOP) incl. ½ LOQ	<80	-

SPECIFIC SUBSTANCES		
Substance	**Result [mg/kg]**	**Reporting limit [mg/kg]**
3-Iodo-2-propynyl butylcarbamate (IPBC)	<0,1	0,1

ISOTHIAZOLINONE!			
Substance	**Result [mg/kg]**	**Reporting limit [mg/kg]**	**Expert estimate [%]**
MIT	<0,5	0,5	± 50 %
CIT	<0,1	0,1	± 50 %
BIT	<0,1	0,1	± 50 %
OIT	<0,1	0,1	± 50 %
DCOIT	<0,1	0,1	± 50 %
BBIT	<0,1	0,1	± 50 %
MBIT	<0,5	0,5	± 50 %

PHTHALATES				
Substance	**Result [mg/kg]**	**Reporting limit [mg/kg]**	**Measurement uncertainty [%]**	**Expert estimate [%]**
bis(2-ethoxyethyl) phthalate (C)	<20	20	± 40 %	
Bis(1,3-dimethylbutyl) phthalate (C)	<20	20	± 30 %	
2-Butoxyethyl phthalate (C)	<10	10	± 40 %	
Di-n-decyl phthalate (C)	<50	50	± 30 %	
diallyl phthalate (C)	<20	20	± 30 %	
Diundecyl phthalate (C)	<100	100	± 30 %	
Didodecyl phthalate (C)	<100	100	± 30 %	
dimethyl phthalate (C)	<5	5	± 30 %	
diethyl phthalate (C)	<5	5	± 30 %	
diisobutyl phthalate (C)	<20	20	± 30 %	
dibutyl phthalate (C)	<20	20	± 30 %	
butyl benzyl phthalate (C)	<20	20	± 30 %	
DEHP (C)	<50	50	± 30 %	
di-n-octyl phthalate (C)	<20	20	± 50 %	
diisononyl phthalate (C)	<100	100	± 30 %	
diisodecyl phthalate (C)	<100	100	± 30 %	
bis(2-methoxyethyl) phthalate (C)	<20	20	± 30 %	
di-n-pentyl phthalate (C)	<20	20	± 30 %	
diisopentyl phthalate (C)	<20	20	± 30 %	
n-pentylisopentyl phthalate (D)	<20	20		± 50 %
diisoheptyl phthalate (C)	<100	100	± 30 %	
diisooctyl phthalate (C)	<100	100	± 30 %	
Diisoundecyl phthalate (D)	<100	100		± 50 %
Diisododecyl phthalate (D)	<100	100		± 50 %
Diisotridecyl phthalate (C)	<100	100	± 30 %	
bis(2-propylheptyl) phthalate (C)	<50	50	± 30 %	
Di-n-hexyl phthalate (C)	<20	20	± 30 %	
Di-n-heptyl phthalate (C)	<50	50	± 30 %	
Di-n-propyl phthalate (C)	<20	20	± 30 %	
Diisopropyl phthalate (C)	<20	20	± 30 %	
Dibenzyl phthalate (C)	<20	20	± 51 %	
dicyclohexylphthalate (C)	<50	50	± 30 %	
Diphenylphthalate (C)	<20	20	± 40 %	
HNSUP (D)	<200	200		± 50 %
di-hexylphthalate, branched and linear (D)	<100	100		± 50 %
diisohexyl phthalate (C)	<100	100	± 30 %	
1,2-Benzenedicarboxylic acid, di-C6-10-alkyl esters (D)	<200	200		± 50 %
Dinonyl phthalate (D)	<20	20		± 50 %
mixed C6-C8-C10 phthalate (D)	<200	200		± 50 %

Appendix 5E.

Tunnel sheet investigation

Amanda Öhman & Ali Al Husseinat

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Interreg Baltic Sea Region
Co-funded by the European Union
SUSTAINABLE WATERS
NonHazCity 3
goodpoint
Part of the Semcon Group

Summary

This investigation explored the safety of using PVC cloth in tunnel construction, aiming to understand the risks associated with leaching harmful chemicals. Specifically, the study focused on Protan 554 supplied by Protan AB. Results revealed varying amounts of phthalates in the PVC cloth, with DiNP and DiDP being the most prevalent. Despite their presence, leaching into water was minimal, especially at lower temperatures. Organophosphate esters and bisphenols were also detected but at extremely low levels, posing minimal risk. Notably, no PFAS, a harmful substance, were found, eliminating concerns regarding their presence. While some hazardous chemicals were identified in the PVC cloth, their leaching into water was limited. This suggests that the material's impact on the environment and human health might be low. Continued monitoring and evaluation are recommended to ensure safety in tunnel construction projects. It is also important to keep in mind the amount of material that is used for tunnelling, as it in this case is used across many kilometres of tunnel. This in turn affects the concentrations of substances leached, and the extent of dispersion.

Glossary

LOD	Limit of detection
SVOA	Stockholm Vatten och Avfall, Stockholm Water and Waste

Table of contents

1 Introduction

The work towards a non-toxic and sustainable society includes a variety of different areas of concern. The focus of this study is the evaluation of PVC sheets used in tunnels and their potential risks, and environmental and health impacts.

This study is carried out by the City of Stockholm in co-operation with Stockholm Water and Waste, SVOA. SVOA is currently in the process of developing Stockholm's future wastewater treatment to make it functioning in a growing city, and at the same time meet increased environmental requirements. The new technologies that are introduced will also allow for treatment of more wastewater, while at the same time making it cleaner before it is discharged into the Baltic Sea. Included in this work is the construction of a new sewer tunnel, about 30-90 meters underground, to lead wastewater from the west of Stockholm to the Henriksdal treatment plant for treatment (Stockholm Vatten och Avfall, n.d.).

The tunnelling during this construction process also means that large amounts of PVC cloth is used to protect technical equipment and such against water in the tunnels. For this study, the focus is one specific PVC cloth that is being used extensively in SVOA's tunnelling.

This report is intended for stakeholders for issues related to chemical exposure and the environmental and health impacts of the materials used in the construction. Specifically focusing on the risks associated with the PVC cloth in the tunnel construction. For example, this report can be used as a basis for evaluation of the safety and suitability of PVC cloth in the project. Also guiding decisions on material selection and risk mitigation strategies related to chemical exposure.

1.1 Objective

The aim of this study was to investigate the potential dangers using PVC cloth in tunnel construction, specifically focusing on the leachate of dangerous chemicals and their environmental and health impacts.

The specific product that was researched in this study was Protan 554 from the supplier Protan AB.

The questions to be answered in this study were the following:

- What potentially harmful substances are found in the tunnel sheet?
- What potentially harmful substances are leached from the tunnel sheet?
- Is it possible to determine whether the amounts leached pose potential risks to health and the environment?

2 Background

To promote further understanding on this topic, the following background information has been produced regarding PVC in general, and the specific products that has been used in this case.

2.1 PVC

Polyvinyl chloride is a synthetic plastic polymer. PVC is known for its durability, flexibility, and resistance to environmental degradation. Its properties make the material suitable for a wide range of applications, such as construction, medical devices, and consumer goods. In construction, PVC is used for pipes, window frames and flooring because it is waterproof and the strength of the material. PVC also has a long lifespan in addition to being cheap making it popular in the construction industry. The flexibility of PVC can be improved by introducing plasticizers in the material, making it ideal for items such as cables and cloths. Depending on the plasticizers, different properties can be introduced into the material such as fire resistance (The European Council of Vinyl Manufacturers, n.d.).

2.2 Protan 554 – PVC cloth

Protan 554 is a stretched, exposed, and waterproof fabric that conducts different types of moisture and drips from roofs and walls to a suitable drainage system. The fabric is designed for waterproofing tunnels and other types of rock installations. The cloth is used to protect technical equipment and such, against water in the tunnels. Water exposure can occur through for example condensation and groundwater penetration. During installation, the product is joined together with hot air to create strong, long-lasting, and waterproof joints. The tunnel fabric is polyester-reinforced, waterproof, and thermoplastic. Protan 554 is also fire-stabilised to meet the fire resistance requirements of tunnels and underground facilities (Byggvarubedömningen, n.d.).

Protan 554 contains the substance Diisononyl phthalate (DiNP) which is used as a plasticizer. DiNP makes up 24% of the material and it is listed under EDC-SIN, EDC-CAT2, and SIN, indicating the presence of endocrine-disrupting chemicals (EDCs) and substances identified as potentially harmful. These classifications warrant the need for careful evaluation due to the possible health and environmental risks associated with this substance. Protan 554 also contains antimony trioxide which used as a flame retardant. It makes up around 6% of the material and has the SIN classification (Byggvarubedömningen, n.d.).

3 Methodology

The piece of PVC cloth that was analysed was collected from one of the tunnels of the ongoing construction project. It was then sent from SVOA to the City of Stockholm, and then further to IVL for analysis.

The substance groups that were analysed in this study were the following, for both the material analysis and the leachate experiment:

- Phthalates and alternative plasticizers
- Organophosphate esters
- Bisphenol A and its analogues
- Per- and polyfluoroalkyl substances (PFAS)

3.1 Material analysis

The methods for analysis of the different substance groups are presented under their respective chapters. All descriptions of the methods for analysis are written by IVL, see Appendix 1 for their report.

3.1.1 Phthalates and alternative plasticizers

Material samples (approx. 0.1 g each) were spiked with 200 ng deuterated internal standard (IS) mix for the phthalate and alternative plasticizers, consisting of DMP-d4, DnBP-d4 and DEHP-d4. The samples were extracted with organic solvent (with 2*10 mL of acetone: n-hexane, 2:1 and 1:1, v/v) and ultrasonication (30 min at 40 °C) with in-between vortex (1min) every 10 min. The samples were concentrated by applying a gentle nitrogen (N2) stream to approx. 1 mL, filtrate at 0.45µm with PTFE filters and then 100 ng biphenyl was added as volumetric pre-injection standard. The analyses were carried out, with a gas chromatography tandem mass spectrometry GC/MS/MS system (Agilent 7000; Agilent Technologies, Inc., Santa Clara, CA, USA) in electron impact ionization mode (EI) with DB-5 30 m, 0.25 mm, 0.25 µm column. The instrument was equipped with an auto injector (Agilent 7683B) and the injection was in pulsed splitless mode. Integration was made with MassHunter software version B.04.00 for quantitative analysis (Agilent Technologies, Inc. 2008).

3.1.2 Organophosphate esters

Material samples (approx. 0.1 g each) were spiked with 200 ng deuterated internal standard (IS) mix for the organophosphate esters, consisting of DMP-d4, DnBP-d4 and DEHP-d4. The samples were extracted with organic solvent (with 2*10 mL of acetone: n-hexane, 2:1 and 1:1, v/v) and ultrasonication (30 min at 40 °C) with in-between vortex (1min) every 10 min. The samples were concentrated by applying a gentle nitrogen stream to approx. 1 mL, filtrate at 0.45µm with PTFE filters and then 100 ng biphenyl was added as volumetric pre-injection standard. The analyses were carried out, with a gas chromatography tandem mass spectrometry GC/MS/MS system (Agilent 7000; Agilent Technologies, Inc., Santa Clara, CA, USA) in electron impact ionization mode (EI) with DB-5 30 m, 0.25 mm, 0.25 µm column. The instrument was equipped with an auto injector (Agilent 7683B) and the injection was in pulsed splitless mode. Integration was made with MassHunter software version B.04.00 for quantitative analysis (Agilent Technologies, Inc. 2008).

3.1.3 Bisphenol A and its analogues

Material samples (approx. 0.1 g each) were spiked with 200 ng deuterated IS BPA-d16. The samples were extracted with organic solvent (with 2*10 mL of acetone: n-hexane, 2:1 and 1:1, v/v) and ultrasonication (30 min at 40 °C) with in-between vortex (1min) every 10 min.

The samples were concentrated by applying a gentle nitrogen stream to approx. 1 mL, filtrate at 0.45µm with PTFE filters, derivatized with N-Methyl-N-trimethylsilyltrifluoroacetamide (MSTFA) and then 100 ng biphenyl was added as volumetric pre-injection standard. The analyses were carried out, with a gas chromatography tandem mass spectrometry GC/MS/MS system (Agilent 7000; Agilent Technologies, Inc., Santa Clara, CA, USA) in electron impact ionization mode (EI) with DB-5 30 m, 0.25 mm, 0.25 µm column. The instrument was equipped with an auto injector (Agilent 7683B) and the injection was in pulsed splitless mode. Integration was made with MassHunter software version B.04.00 for quantitative analysis (Agilent Technologies, Inc. 2008).

3.1.4 Per- and polyfluoroalkyl substances (PFAS)

Material samples (approx. 0.5 g each) were spiked with 10 ng carbon and oxygen labelled internal standard (IS) mix for PFAS, consisting of 18O2-PFHxS, 13C4-PFOS, 13C4-PFBA,13C4-PFPeA, 13C2-PFHxA, 13C4-PFOA, 13C5-PFNA, 13C2-PFDA. The samples were extracted with organic solvent (with 2*5 mL of methanol) and ultrasonication (10 min). The samples were concentrated by applying a gentle nitrogen stream to approx. 1 mL and then 50 ng of 3.5 BTPA was added as volumetric pre-injection standard. The analyses were carried out, with an UPLC instrument Shimadzu 8060NX coupled to Shimadzu UPLC system was used for analysis of PFAS in fish samples from 2022, where the LC operated at flow rate 0.36 to 0.4 mL/min using mobile phase (A) 100% water containing 2 mM ammonium acetate, (B) 100% MeOH containing 2 mM ammonium acetate under gradient from 95:5 to 5:95 for 9 min followed by 2 min equilibration. The LC column Shim-pack GIST-HP (C18-AQ; 1.9 µm; 50x2.1), was maintained at 40°C. The Shimadzu 8060NX triple quadrupole mass spectrometer was equipped with an electrospray ionization source operating under negative mode. The interface temperature 300°C, heating gas flow 15L/min, DL temperature 150, and heat block temperature 350°C. Ion source temperature 600 °C and the interface voltage was set at -1.0 kV. The quantification of studied PFAS was done by using LabSolutions Insghit (LCMS) by dilution of internal standard approach using a 9- point linear calibration curve with 1/x weighting ranging from 0.02 to 20 ng/mL (linear). For quality control and evaluation of accuracy and precision, three procedural blanks each consisting of an empty 13 PP-tube were extracted with every batch for monitoring laboratory background contamination. The limit of detection (LOD) for the analysed PFAS was determined as three times the standard deviation of the blank signals.

3.2 Leachate experiment

A leachate experiment L/S 10 (1 g material in 10 mL water) at 6 °C and 21 °C was prepared for each targeted group of chemicals. Each sample was sieved at 10 mm and shaken with deionized Milli-Q water in one step: at L/S 10 for 72 hours. After filtering, the water phase was separated from the material and transferred to a solid phase extraction (SPE) cartridge.

For the phthalates and alternative plasticizers, organophosphate esters, bisphenol A and its analogues water extraction procedure. Briefly, prior to extraction, sample was fortified with IS mix, Isolute C18 cartridges (Biotage; 500 mg, 6 mL) were conditioned (2*6 mL MeOH), then the sample loaded and extracted by 2 drops per sec. Cartridges were eluted (once with 6 mL MTBE and once with 6 mL MTBE : n-hexane 1:1 v/v). The extract was reduced to 1mL under a gentle nitrogen stream and analysed by GC/MS/MS.

For the PFAS water extraction procedure, a SPE was used according to an established method with some modifications. Briefly, prior to extraction, sample was fortified with internal labelled PFAS standard 10 ng each (50 µL of 200 ng/mL) see table S1. Oasis WAX cartridges (Waters; 150 mg, 6 mL) were conditioned (4 mL 0.1% NH4OH in MeOH, 4 mL MeOH, 4 mL Milli-Q water), then the sample loaded at _2 drops per sec. Cartridges were

rinsed (4 mL pH 4 aqueous ammonium acetate, 4 mL Milli-Q water), the sample was eluted (4mL MeOH, 4 mL 0.1% NH4OH in MeOH). The extract was reduced to 1mL under a gentle nitrogen stream and analysed by UPLC/MS/MS.

4 Results

The results of the analysis are presented below for both the material analysis and the leachate experiment. The results are presented according to substance group and method for analysis. For the complete results, see IVL's report in Appendix 1.

The result tables are based on IVL's report in Appendix 1.

4.1 Phthalates and alternative plasticizers

4.1.1 In material

The results show that all analysed phthalates except two are under 1% of the PVC cloth material. The phthalates above 1% was Diisononyl and Diisodecyl phthalate, they were measured at 35.4% and 9.14% respectively of the total material. The PVC cloth was measured to be comprised of 45% phthalates.

Table 1. Phthalates and alternative plasticizers in material (µg/g). The sample weight was 120 g.

Substance	Abbreviation	LOD	PVC	% in material
Dimethyl phthalate	DMP	0.0011	0.31	<1
Diethyl phthalate	DEP	0.0120	0.95	<1
Diisobutyl phthalate	DiBP	0.0034	0.47	<1
Di-n-butyl phthalate	DnBP	0.0281	0.47	<1
Acetyl tributyl citrate	ATBC	0.0011	0.19	<1
Butyl benzyl phthalate	BBzP	0.0002	22.3	<1
Bis(2-etylhexyl) adipate	DEHA	0.0008	0.14	<1
Diethyl hexyl phthalate	DEHP	0.0027	1.51	<1
Diisononyl cyclohexan-1,2-dicarboxylate	DINCH	0.0069	317	<1
Dioctyl terephthalate	DEHT	0.0010	14.7	<1
Diisononyl phthalate	DiNP	0.7470	353 677	35.4
Diisodecyl phthalate	DiDP	0.0656	91 725	9.17
Di-2-propyl heptyl phthalate	DPHP	0.0006	3 006	<1
Tris (2-ethylhexyl) trimellitate	TOTM	0.0031	0.02	<1
Sum phthalates and alternative plasticizers			448 766	45%

4.1.2 In water leachate

The sample which water leachate was performed at a lower temperature yielded a higher content of phthalates and alternative plasticizers.

Table 2. Phthalates and alternative plasticizers in water leachate, measured in ng/L. The conditions for sample 1 were (L/S 10, 21°C) and 0.997 g / 10.022 mL. The conditions for sample 2 were (L/S 10, 6°C) and 1.017 g / 10.028 mL

Substance	Abbreviation	LOD	Sample 1	Sample 2
Dimethyl phthalate	DMP	0.15	5200	5300
Diethyl phthalate	DEP	0.92	120400	56 600
Diisobutyl phthalate	DiBP	0.81	<LOD	<LOD
Di-n-butyl phthalate	DnBP	5.5	<LOD	<LOD
Acetyl tributyl citrate	ATBC	0.61	<LOD	<LOD
Butyl benzyl phthalate	BzBP	0.04	66	11
Bis(2-etylhexyl) adipate	DEHA	2.2	<LOD	<LOD
Diethyl hexyl phthalate	DEHP	4.9	<LOD	<LOD
Diisononyl cyclohexan-1,2-dicarboxylate	DINCH	1.1	12 300	1 260
Dioctyl terephthalate	DEHT	0.58	533	230
Diisononyl phthalate	DiNP	12.6	24 227 500	656 200
Diisodecyl phthalate	DiDP	2.0	2 834 300	69 600
Di-2-propyl heptyl phthalate	DPHP	0.66	<LOD	<LOD
Tris (2-ethylhexyl) trimellitate	TOTM	0.09	<LOD	<LOD
Sum phthalates and alternative plasticizers			27 200 µg/L	789 µg/L

4.2 Organophosphate esters

4.2.1 In material

There was no substance that was more than 1% of the material and the sum of all the organophosphates was 0.0001%.

Table 3. Organophosphate esters in material (µg/g). The sample weight was 120 g.

Substance	Abbreviation	LOD	PVC	% in material
Tris(ethyl) phosphate	TEP	0.0004	0.001	<1
Tris(iso-butyl) phosphate	TiBP	0.0002	0.007	<1
Tributyl phosphate	TnBP	0.000005	0.014	<1
Tris(2-chloroethyl) phosphate	TCEP	0.014	0.255	<1
Tris(2-chloro-iso-propyl) phosphate	TCPP	0.002	0.152	<1
Tris(1,3-dikloro-iso-propyl phosphate	TDCP	0.0004	0.027	<1
Tributoxy ethyl phosphate	TBEP	0.012	0.016	<1
Tris(2-ethylhexyl) phosphate	TEHP	0.001	0.133	<1
Triphenyl phosphate	TPhP	0.002	0.103	<1
2-Etylhexyl-di-phenyl phosphate	EHDPP	0.002	0.011	<1
Tris(o-cresol) phosphate	ToCrP	0.002	0.09	<1
Tricresyl phosphate (mix of isomers)	TCrP-mix	0.008	0.720	<1
Sum organophosphates			1.45	0.0001%

4.2.2 In water leachate

The sum of organophosphates in both samples was almost identical at 0.75 and 0.77 ng for sample 1 and sample 2 respectively.

Table 4. Organophosphate esters in in water leachate, measured in ng/L. The conditions for sample 1 were (L/S 10, 21°C) and 0.997 g / 10.022 mL. The conditions for sample 2 were (L/S 10, 6°C) and 1.017 g / 10.028 mL

Substance	Abbreviation	LOD	Sample 1	Sample 2
Tris(ethyl) phosphate	TEP	83	<LOD	<LOD
Tris(iso-butyl) phosphate	TiBP	0.001	1	1
Tributyl phosphate	TnBP	0.0003	0.3	1
Tris(2-chloroethyl) phosphate	TCEP	0.15	27	21
Tris(2-chloro-iso-propyl) phosphate	TCPP	0.01	46	53
Tris(1,3-dikloro-iso-propyl phosphate	TDCP	0.011	<LOD	<LOD
Tributoxy ethyl phosphate	TBEP	0.07	<LOD	<LOD
Tris(2-ethylhexyl) phosphate	TEHP	0.0004	<LOD	<LOD
Triphenyl phosphate	TPhP	0.01	<LOD	<LOD
2-Etylhexyl-di-phenyl phosphate	EHDPP	0.008	2	1
Tris(o-cresol) phosphate	ToCrP	0.003	<LOD	<LOD
Tricresyl phosphate (mix of isomers)	TCrP-mix	0.06	<LOD	<LOD
Sum organophosphates			76.3 ng/L	77 ng/L

4.3 Bisphenol A and its analogues

4.3.1 In material

Only the bisphenol A, S and F contents were high enough to be over the limit of detection.

Table 5. Bisphenol and its analogues in material (µg/g). The sample weight was 120 g.

Substance	Abbreviation	LOD	PVC	% in material
Bisphenol A	BPA	0.003	0.037	<1
Bisphenol S	BPS	0.004	0.153	<1
Bisphenol F	BPF	0.0002	0.0004	<1
Bisphenol AF	BPAF	0.008	<LOD	<1
Tetrabromobisphenol A	TBBPA	0.003	<LOD	<1
Sum BPA and its analogues			0.19	0.0002%

4.3.2 In water leachate

None of the analysed bisphenol substances were detected in the water leachate samples.

Table 6. Bisphenol A and its analogues in water leachate, measured in ng/L. The conditions for sample 1 were (L/S 10, 21°C) and 0.997 g / 10.022 mL. The conditions for sample 2 were (L/S 10, 6°C) and 1.017 g / 10.028 mL

Substance	Abbreviation	LOD	Sample 1	Sample 2
Bisphenol A	BPA	0.43	<LOD	<LOD
Bisphenol S	BPS	0.94	<LOD	<LOD
Bisphenol F	BPF	0.14	<LOD	<LOD
Bisphenol AF	BPAF	0.49	<LOD	<LOD
Tetrabromobisphenol A	TBBPA	0.27	<LOD	<LOD

4.4 PFAS

4.4.1 In material

None of the listed PFAS could be detected in the PVC cloth.

Table 7. PFAS in material (ng/g). The sample weight was 637 g.

Substance	Abbreviation	LOD	PVC
Perfluoropropanoic acid	PFPrA	0.07	<LOD
Perfluorobutanoic acid	PFBA	0.07	<LOD
Perfluoropentanoic acid	PFPeA	0.06	<LOD
Perfluorohexanoic aci	PFHxA	0.05	<LOD
Perfluoroheptanoic acid	PFHpA	0.05	<LOD
Perfluorooctanoic acid	PFOA	0.05	<LOD
Perfluorononanoic acid	PFNA	0.05	<LOD
Perfluorodecanoic acid	PFDA	0.05	<LOD
Perfluoroundecanoic acid	PFUnDA	0.05	<LOD
Perfluorododecanoic acid	PFDoDA	0.05	<LOD
Perfluorotridecanoic acid	PFTrDA	0.07	<LOD
Perfluorotetradecanoic acid	PFTeDA	0.07	<LOD
Perfluorohexadecanoic acid	PFHxDA	0.07	<LOD
Perfluorooctadecanoic acid	PFODA	0.07	<LOD
Perfluoropropane sulfonic acid	PFPrS	0.07	<LOD
Perfluorobutane sulfonic acid	PFBS	0.05	<LOD
Perfluoropentane sulfonic acid	PFPeS	0.05	<LOD
Perfluorohexane sulfonic acid	PFHxS	0.05	<LOD
Perfluoroheptane sulfonic acid	PFHpS	0.05	<LOD
Perfluorooctane sulfonic acid	PFOS	0.05	<LOD
Perfluorononane sulfonic acid	PFNS	0.05	<LOD
Perfluorodecane sulfonic acid	PFDS	0.05	<LOD
Perfluoroundecane sulfonic acid	PFUnDS	0.07	<LOD

Perfluorododecane sulfonic acid	PFDoDS	0.07	<LOD
Perfluorotridecane sulfonic acid	PFTrDS	0.07	<LOD
3:3 Fluorotelomer carboxylic acid	FPrPA	0.0.7	<LOD
5:3 Fluorotelomer carboxylic acid	FPePA	0.05	<LOD
7:3 Fluorotelomer carboxylic acid	FHpPA	0.05	<LOD
Perfluoro-2-propoxypropanoic acid	Gen-X	0.07	<LOD
Dodecafluoro-3H-4,8,-dioxanonanoic acid	ADONA	0.05	<LOD
6:2 Fluorotelomer unsaturated carboxylic acid	6:2 FTUA	0.07	<LOD
8:2 Fluorotelomer unsaturated carboxylic acid	8:2 FTUA	0.07	<LOD
10:2 Fluorotelomer unsaturated carboxylic acid	10:2 FTUA	0.07	<LOD
6:2 fluorotelomer sulfonic acid	6:2 FTS	0.05	<LOD
8:2 fluorotelomer sulfonic acid	8:2 FTS	0.05	<LOD
Perfluorooctane sulfonamide	PFOSA	0.07	<LOD
Perfluorooctane sulfonamido acetate	FOSAA	0.07	<LOD
N-methyl perfluorooctane sulfonamidoacetic acid	Me-FOSAA	0.07	<LOD
N-ethyl perfluorooctane sulfonamidoacetic acid	Et-FOSAA	0.07	<LOD
6:2 Fluorotelomer phosphate monoester	6:2PAP	0.57	<LOD
8:2 Fluorotelomer phosphate monoester	8:2PAP	0.07	<LOD
6:2 Fluorotelomer phosphate diester	6:2diPAP	0.07	<LOD
6:2/8:2 Fluorotelomer phosphate diester	6:2/8:2 diPAP	0.07	<LOD
8:2 Fluorotelomer phosphate diester	8:2 diPAP	0.07	<LOD
6:6 Bis(perfluorohexyl)phosphinic acid	6:6 PFPi	0.07	<LOD
6:8 Bis(perfluorohexyl)phosphinic acid	6:8 PFPi	0.07	<LOD
8:8 Bis(perfluorohexyl)phosphinic acid	8:8 PFPi	0.07	<LOD
N-ethyl perfluorooctane sulfonamide ethanol-based phosphate diester	diSAmPAP	0.07	<LOD
(trifluoromethoxy)-1,3-dioxolan-4- yl]oxy}acetic acid	C6O4	0.20	<LOD

8-chloroperfluoro-1-octanesulfonate	8Cl-PFOS	0.07	<LOD
6:2 Fluorotelomer acid	6:2 FTA	0.07	<LOD
8:2 Fluorotelomer acid	8:2 FTA	0.07	<LOD
10:2 Fluorotelomer acid	10:2 FTA	0.07	<LOD
N-methyl Perfluorooctane sulfonamide	Me-FOSA	0.07	<LOD
N-ethyl Perfluorooctane sulfonamide	Et-FOSA	0.07	<LOD
Perfluoro-4-oxapentanoic acid	PF4OPeA	0.07	<LOD
perfluoro(2-ethoxyethane)sulfonate	PFEESA	0.07	<LOD

4.4.2 In water leachate

None of the analysed PFAS were detected in the water leachate samples.

Table 8. PFAS in water leachate, measured in ng/L. The conditions for sample 1 were (L/S 10, 21°C) and 0.999 g / 10.012 mL. The conditions for sample 2 were (L/S 10, 6°C) and 1.009 g / 10.012 mL

Substance	Abbreviation	LOD	Sample 1	Sample 2
Perfluoropropanoic acid	PFPrA	0.07	<LOD	<LOD
Perfluorobutanoic acid	PFBA	0.07	<LOD	<LOD
Perfluoropentanoic acid	PFPeA	0.06	<LOD	<LOD
Perfluorohexanoic aci	PFHxA	0.05	<LOD	<LOD
Perfluoroheptanoic acid	PFHpA	0.05	<LOD	<LOD
Perfluorooctanoic acid	PFOA	0.05	<LOD	<LOD
Perfluorononanoic acid	PFNA	0.05	<LOD	<LOD
Perfluorodecanoic acid	PFDA	0.05	<LOD	<LOD
Perfluoroundecanoic acid	PFUnDA	0.05	<LOD	<LOD
Perfluorododecanoic acid	PFDoDA	0.05	<LOD	<LOD
Perfluorotridecanoic acid	PFTrDA	0.07	<LOD	<LOD
Perfluorotetradecanoic acid	PFTeDA	0.07	<LOD	<LOD
Perfluorohexadecanoic acid	PFHxDA	0.07	<LOD	<LOD
Perfluorooctadecanoic acid	PFODA	0.07	<LOD	<LOD
Perfluoropropane sulfonic acid	PFPrS	0.07	<LOD	<LOD
Perfluorobutane sulfonic acid	PFBS	0.05	<LOD	<LOD
Perfluoropentane sulfonic acid	PFPeS	0.05	<LOD	<LOD
Perfluorohexane sulfonic acid	PFHxS	0.05	<LOD	<LOD
Perfluoroheptane sulfonic acid	PFHpS	0.05	<LOD	<LOD
Perfluorooctane sulfonic acid	PFOS	0.05	<LOD	<LOD
Perfluorononane sulfonic acid	PFNS	0.05	<LOD	<LOD
Perfluorodecane sulfonic acid	PFDS	0.05	<LOD	<LOD
Perfluoroundecane sulfonic acid	PFUnDS	0.07	<LOD	<LOD
Perfluorododecane sulfonic acid	PFDoDS	0.07	<LOD	<LOD
Perfluorotridecane sulfonic acid	PFTrDS	0.07	<LOD	<LOD
3:3 Fluorotelomer carboxylic acid	FPrPA	0.0.7	<LOD	<LOD
5:3 Fluorotelomer carboxylic acid	FPePA	0.05	<LOD	<LOD

7:3 Fluorotelomer carboxylic acid	FHpPA	0.05	<LOD	<LOD
Perfluoro-2-propoxypropanoic acid	Gen-X	0.07	<LOD	<LOD
Dodecafluoro-3H-4,8,-dioxanonanoic acid	ADONA	0.05	<LOD	<LOD
6:2 Fluorotelomer unsaturated carboxylic acid	6:2 FTUA	0.07	<LOD	<LOD
8:2 Fluorotelomer unsaturated carboxylic acid	8:2 FTUA	0.07	<LOD	<LOD
10:2 Fluorotelomer unsaturated carboxylic acid	10:2 FTUA	0.07	<LOD	<LOD
6:2 fluorotelomer sulfonic acid	6:2 FTS	0.05	<LOD	<LOD
8:2 fluorotelomer sulfonic acid	8:2 FTS	0.05	<LOD	<LOD
Perfluorooctane sulfonamide	PFOSA	0.07	<LOD	<LOD
Perfluorooctane sulfonamido acetate	FOSAA	0.07	<LOD	<LOD
N-methyl perfluorooctane sulfonamidoacetic acid	Me-FOSAA	0.07	<LOD	<LOD
N-ethyl perfluorooctane sulfonamidoacetic acid	Et-FOSAA	0.07	<LOD	<LOD
6:2 Fluorotelomer phosphate monoester	6:2PAP	0.57	<LOD	<LOD
8:2 Fluorotelomer phosphate monoester	8:2PAP	0.07	<LOD	<LOD
6:2 Fluorotelomer phosphate diester	6:2diPAP	0.07	<LOD	<LOD
6:2/8:2 Fluorotelomer phosphate diester	6:2/8:2 diPAP	0.07	<LOD	<LOD
8:2 Fluorotelomer phosphate diester	8:2 diPAP	0.07	<LOD	<LOD
6:6 Bis(perfluorohexyl)phosphinic acid	6:6 PFPi	0.07	<LOD	<LOD
6:8 Bis(perfluorohexyl)phosphinic acid	6:8 PFPi	0.07	<LOD	<LOD
8:8 Bis(perfluorohexyl)phosphinic acid	8:8 PFPi	0.07	<LOD	<LOD
N-ethyl perfluorooctane sulfonamide ethanol-based phosphate diester	diSAmPAP	0.07	<LOD	<LOD

5 Discussion and conclusions

Based on the results from this study, the following discussions and conclusions have been established.

5.1 Phthalates and alternative plasticizers

The results from the analysis shows that there are varying amounts of phthalates in the material and the water leachate. Most notably of the analysed phthalates are Diisononyl (DiNP) and Diisodecyl (DiDP) phthalate which together comprise 45% of the total material. The sum of the remaining phthalates is less than 1% of the material. The results of the leachate experiment shows that DiNP and DiDP are the two phthalates that have the highest concentration in the water after leaching. When leaching was performed at 21°C, the sum of the phthalate leachate was 27 200 µg/L. When the temperature was lowered to 6°C the sum of the phthalate leachate lowered to 789 µg/L. All phthalate substances showed a decrease in leachate when the temperature was lowered, except for one outlier: Dimethyl phthalate (DMP), which increased from 5200 ng/L to 5300 ng/L. However, this is a very low increase. All the other phthalates of those that could be measured, resulted in a big decrease when temperature was lowered.

According to the classification provided by some companies to ECHA, DiDP is very toxic to aquatic life with long lasting effects and is very toxic to aquatic life. However, this is not a harmonised classification by ECHA. Meaning that there is no consensus on the dangers of DiDP but there is a risk. Most companies did not register any hazards associated with DiNP, but around 5% of the companies registered the hazard code H361FD, which stands for “Suspected of damaging fertility. Suspected of damaging the unborn child” (European Chemicals Agency, n.d.).

5.2 Organophosphates esters

Organophosphates were detected in the material. Together, they comprised 0.0001% of the material and a sum of 1.45 µg/g of sample. The most detected substance was Tricresyl phosphate (mix of isomers) (TCrP-mix) at 0.72 ng/g. Some substances leach from the PVC cloth more readily than others. This can be seen in the results showing that no detectable amounts of TCrP-mix were in the water after the leachate test even though it was the most abundant of the organophosphate. The difference between the two leachate temperatures was negligent. The sum of organophosphates in the water after the experiment was 76.3 ng/L and 77 ng/L for sample 1 and sample 2 respectively. The two substances that leached the most from the PVC cloth were Tris(2-chloro-iso-propyl) phosphate (TCPP) and Tris(2-chloroethyl) phosphate (TCEP).

According to the classification provided by companies to ECHA, TCPP is harmful if swallowed, is harmful to aquatic life with long lasting effects and is suspected of damaging fertility or the unborn child. According ECHA, this substance may damage fertility, is toxic to aquatic life with long lasting effects, is harmful if swallowed and is suspected of causing cancer (European Chemicals Agency, n.d.).

5.3 Bisphenol and its analogues

The results of the analysis of the material shows that there is a very low amount of Bisphenol and its analogues. The sum of bisphenols in the material is 0.0002%. The bisphenol with the highest content was bisphenol S at 0.153 ng in a 120g sample. Consequently, the results from the water leachate tests show that leachate occurs at such a low level that none of the bisphenols could be detected.

The hazard code H360FD is registered for bisphenol S, which stands for “May damage fertility. May damage the unborn child”. The substances bisphenol A and F have more hazards connected to them. Common between these two bisphenols is that they are toxic to aquatic life, causes serious eye damage, causes respiratory irritation, and causes an allergic skin reaction. Also, bisphenol A may damage fertility (European Chemicals Agency, n.d.).

5.4 PFAS

No amount of PFAS was detected in either the PVC cloth or the water leachate tests. Meaning no precautions need to be taken regarding PFAS contamination or PFAS related health and environmental risks for this material.

5.5 Comparison with previous studies

When comparing the results of this study with previously performed studies, a good comparison can be made with Muller et al. 2023, where releases of micropollutants from building surface materials into rainwater and snowmelt induced runoff was studied. In this study, the results for phthalates showed that they were detected in runoff despite their known hydrophobicity, and no decreasing trends were observed during the five-year study period (Muller et al., 2023). For DiNP specifically, the event specific concentrations were between circa 500 000 to 2 000 000 ng/L depending on when the sampling was performed. These concentrations are comparable to the results for DiNP for both samples in this study. Muller et al. 2023 also concluded that the materials tested in their study may contribute to the degradation of runoff quality for a significant period of their life span (Muller et al., 2023). With the likeness and comparison of these two studies in mind, it can be assumed that the PVC material in this study likely may also contribute to quality degradation of runoff water for a significant part of its lifespan.

5.6 Conclusions

This study showed that the PVC cloth contained varying amounts of phthalates, with DiNP and DiDP being the most abundant. These phthalates also had the highest concentration in water leachate tests. Lower temperatures resulted in significantly reduced leachate amounts, except for a slight increase in DMP. Despite the presence of organophosphate esters and bisphenols in the material, their leachate levels were very low, posing minimal risk. Notably, no PFAS were detected, indicating no major concerns regarding these harmful substances in this case.

Overall, while some hazardous chemicals were found present in the PVC cloth, the effects of their leaching into runoff water remains complex to specify. Though the majority of substances may have concentrations that are considered on the lower side, it is difficult to identify the material’s impact on environmental and human health. Continued monitoring and evaluation are recommended moving forward to ensure safety. It is also important to keep in mind the amount of material that is used for tunnelling, as it in this case is used across many kilometers of tunnel. This in turn affects the concentrations of substances leached, and the extent of dispersion.

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Annex 1: Results report from IVL

See separate PDF-file for the compete result report from IVL.

Analys för PVC material från Stockholm Vatten och Avfall (SVOA)

IVL Swedish Environmental Research Institute, 100 31 Stockholm, Sweden
Raam Ibrahim, Raed Awad, Georgios Giovanoulis
Project Number: 218549
Order of Assignment: Goodpoint AB
Sample received date: 2024-04-15
Analyses date: 2024-05-10 (material), 2024-05-13 (water leachate)

The scope of the assignment

Goodpoint AB ordered the analysis of the PVC cloth sheet from Stockholm Vatten och Avfall (SVOA). Phthalates and alternative plasticizers, organophosphate esters, bisphenol A and its analogues, and Per- and polyfluoroalkyl substances (PFAS) should be quantified in the material and its water leachate.

Methods

Phthalates and alternative plasticizers in material

Material samples (approx. 0.1 g each) were spiked with 200 ng deuterated internal standard (IS) mix for the phthalate and alternative plasticizers, consisting of DMP-d_4, DnBP-d_4 and DEHP-d_4. The samples were extracted with organic solvent (with 2*10 mL of acetone: n-hexane, 2:1 and 1:1, v/v) and ultrasonication (30 min at 40 °C) with in-between vortex (1min) every 10 min. The samples were concentrated by applying a gentle nitrogen (N_2) stream to approx. 1 mL, filtrate at 0.45µm with PTFE filters and then 100 ng biphenyl was added as volumetric pre-injection standard. The analyses were carried out, with a gas chromatography tandem mass spectrometry GC/MS/MS system (Agilent 7000; Agilent Technologies, Inc., Santa Clara, CA, USA) in electron impact ionization mode (EI) with DB-5 30 m, 0.25 mm, 0.25 µm column. The instrument was equipped with an auto injector (Agilent 7683B) and the injection was in pulsed splitless mode. Integration was made with MassHunter software version B.04.00 for quantitative analysis (Agilent Technologies, Inc. 2008).

Organophosphate esters in material

Material samples (approx. 0.1 g each) were spiked with 200 ng deuterated internal standard (IS) mix for the organophosphate esters, consisting of DMP-d4, DnBP-d4 and DEHP-d4. The samples were extracted with organic solvent (with 2*10 mL of acetone: n-hexane, 2:1 and 1:1, v/v) and ultrasonication (30 min at 40 °C) with in-between vortex (1min) every 10 min. The samples were concentrated by applying a gentle nitrogen stream to approx. 1 mL, filtrate at 0.45µm with PTFE filters and then 100 ng biphenyl was added as volumetric pre-injection standard. The analyses were carried out, with a gas chromatography tandem mass spectrometry GC/MS/MS system (Agilent 7000; Agilent Technologies, Inc., Santa Clara, CA, USA) in electron impact ionization mode (EI) with DB-5 30 m, 0.25 mm, 0.25 µm column. The instrument was equipped with an auto injector (Agilent 7683B) and the injection was in pulsed splitless mode. Integration was made with MassHunter software version B.04.00 for quantitative analysis (Agilent Technologies, Inc. 2008).

Bisphenol A and its analogues in material

Material samples (approx. 0.1 g each) were spiked with 200 ng deuterated IS BPA-d_{16}. The samples were extracted with organic solvent (with 2*10 mL of acetone: n-hexane, 2:1 and 1:1, v/v) and ultrasonication (30 min at 40 °C) with in-

between vortex (1min) every 10 min. The samples were concentrated by applying a gentle nitrogen stream to approx. 1 mL, filtrate at 0.45µm with PTFE filters, derivatized with N-Methyl-N-trimethylsilyltrifluoroacetamide (MSTFA) and then 100 ng biphenyl was added as volumetric pre-injection standard. The analyses were carried out, with a gas chromatography tandem mass spectrometry GC/MS/MS system (Agilent 7000; Agilent Technologies, Inc., Santa Clara, CA, USA) in electron impact ionization mode (EI) with DB-5 30 m, 0.25 mm, 0.25 µm column. The instrument was equipped with an auto injector (Agilent 7683B) and the injection was in pulsed splitless mode. Integration was made with MassHunter software version B.04.00 for quantitative analysis (Agilent Technologies, Inc. 2008).

Per- and polyfluoroalkyl substances (PFAS) in material

Material samples (approx. 0.5 g each) were spiked with 10 ng carbon and oxygen labelled internal standard (IS) mix for PFAS, consisting of ^{18}O2-PFHxS, $^{13}C_4$-PFOS, $^{13}C_4$-PFBA,$^{13}C_4$-PFPeA, $^{13}C_2$-PFHxA, $^{13}C_4$-PFOA, $^{13}C_5$-PFNA, $^{13}C_2$-PFDA. The samples were extracted with organic solvent (with 2*5 mL of methanol) and ultrasonication (10 min). The samples were concentrated by applying a gentle nitrogen stream to approx. 1 mL and then 50 ng of 3.5 BTPA was added as volumetric pre-injection standard. The analyses were carried out, with an UPLC instrument Shimadzu 8060NX coupled to Shimadzu UPLC system was used for analysis of PFAS in fish samples from 2022, where the LC operated at flow rate 0.36 to 0.4 mL/min using mobile phase (A) 100% water containing 2 mM ammonium acetate, (B) 100% MeOH containing 2 mM ammonium acetate under gradient from 95:5 to 5:95 for 9 min followed by 2 min equilibration. The LC column Shim-pack GIST-HP (C18-AQ; 1.9 µm; 50x2.1), was maintained at 40°C. The Shimadzu 8060NX triple quadrupole mass spectrometer was equipped with an electrospray ionization source operating under negative mode. The interface temperature 300°C, heating gas flow 15L/min, DL temperature 150, and heat block temperature 350°C. Ion source temperature 600 °C and the interface voltage was set at -1.0 kV. The quantification of studied PFAS was done by using LabSolutions Insghit (LCMS) by dilution of internal standard approach using a 9- point linear calibration curve with 1/x weighting ranging from 0.02 to 20 ng/mL (linear). For quality control and evaluation of accuracy and precision, three procedural blanks each consisting of an empty 13 PP-tube were extracted with every batch for monitoring laboratory background contamination. The limit of detection (LOD) for the analyzed PFAS was determined as three times the standard deviation of the blank signals.

Leachate experiment

A leachate experiment L/S 10 (1 g material in 10 mL water) at 6 °C and 21 °C was prepared for each targeted group of chemicals. Each sample was sieved at 10 mm and shaken with deionized Milli-Q water in one step: at L/S 10 for 72 hours. After filtering, the water phase was separated from the material and transferred to a solid phase extraction (SPE) cartridge.

For the phthalates and alternative plasticizers, organophosphate esters, bisphenol A and its analogues water extraction procedure. Briefly, prior to extraction, sample was fortified with IS mix, Isolute C18 cartridges (Biotage; 500 mg, 6 mL) were conditioned (2*6 mL MeOH), then the sample loaded and extracted by 2 drops per sec. Cartridges were eluted (once with 6 mL MTBE and once with 6 mL MTBE : n-hexane 1:1 v/v). The extract was reduced to 1mL under a gentle nitrogen stream and analyzed by GC/MS/MS.

For the PFAS water extraction procedure, a SPE was used according to an established method with some modifications. Briefly, prior to extraction, sample was fortified with internal labelled PFAS standard 10 ng each (50 µL of 200 ng/mL) see table S1. Oasis WAX cartridges (Waters; 150 mg, 6 mL) were conditioned (4 mL 0.1% NH4OH in MeOH, 4 mL MeOH, 4 mL Milli-Q water), then the sample loaded at _2 drops per sec. Cartridges were rinsed (4 mL pH 4 aqueous ammonium acetate, 4 mL Milli-Q water), the sample was eluted (4mL MeOH, 4 mL 0.1% NH4OH in MeOH). The extract was reduced to 1mL under a gentle nitrogen stream and analyzed by UPLC/MS/MS.

Results

Table 1. Phthalates and alternative plasticizers in material (µg/g)

	Abbreviation	LOD	PVC	% in material
	Sample weight (g) ----->		0,120 g	
Phthalate esters				
Dimethyl phthalate	DMP	0.0011	0.31	<1
Diethyl phthalate	DEP	0.0120	0.95	<1
Diisobutyl phthalate	DiBP	0.0034	0.47	<1
Di-n-butyl phthalate	DnBP	0.0281	0.47	<1
Butyl benzyl phthalate	BBzP	0.0002	22.3	<1
Diethyl hexyl phthalate	DEHP	0.0027	1.51	<1
Diisononyl phthalate	DiNP	0.7470	353 677	35.4
Diisodecyl phthalate	DiDP	0.0656	91 725	9.17
Di-2-propyl heptyl phthalate	DPHP	0.0006	3 006	<1
Alternative plasticizers				<1
Acetyl tributyl citrate	ATBC	0.0011	0.19	<1
Bis(2-etylhexyl) adipate	DEHA	0.0008	0.14	<1
Dioctyl terephthalate	DEHT	0.0010	14.7	<1
Diisononyl cyclohexan-1,2-dicarboxylate	DINCH	0.0069	317	<1
Tris (2-ethylhexyl) trimellitate	TOTM	0.0031	0.02	<1
Sum phthalates and alternative plasticizers			448 766	
Sum in % in material			45%	

Table 2. Organophosphate esters in material (µg/g)

	Abbreviation	LOD	PVC
	Sample weight (g) ---------->		0.120 g
Tris(ethyl) phosphate	TEP	0.0004	0.001
Tris(iso-butyl) phosphate	TiBP	0.0002	0.007
Tributyl phosphate	TnBP	0.000005	0.014
Tris(2-chloroethyl) phosphate	TCEP	0.014	0.255
Tris(2-chloro-iso-propyl) phosphate	TCPP	0.002	0.152
Tris(1,3-dikloro-iso-propyl phosphate	TDCP	0.0004	0.027
Tributoxy ethyl phosphate	TBEP	0.012	0.016
Tris(2-ethylhexyl) phosphate	TEHP	0.001	0.133
Triphenyl phosphate	TPhP	0.002	0.103
2-Etylhexyl-di-phenyl phosphate	EHDPP	0.002	0.011
Tris(o-cresol) phosphate	ToCrP	0.002	0.009
Tricresyl phosphate (mix of isomers)	TCrP-mix	0.008	0.720
Sum organophosphates			1.45
Sum in % in material			0.0001%

Table 3. Bisphenol A and its analogues in material (µg/g)

	Abbreviation	LOD	PVC
	Sample weight (g) ---------->		0.120 g
Bisphenol A	BPA	0.003	0.037
Bisphenol S	BPS	0.004	0.153
Bisphenol F	BPF	0.0002	0.0004
Bisphenol AF	BPAF	0.008	<LOD
Tetrabromobisphenol A	TBBPA	0.003	<LOD
Sum BPA and its analogues			0.19
Sum in % in material			0.00002%

Table 4. PFAS in material (ng/g)

	Abbreviation	LOD	PVC
	Sample weight (g) ---->		0.637
Perfluoropropanoic acid	PFPrA	0.07	<LOD
Perfluorobutanoic acid	PFBA	0.07	<LOD
Perfluoropentanoic acid	PFPeA	0.06	<LOD
Perfluorohexanoic acid	PFHxA	0.05	<LOD
Perfluoroheptanoic acid	PFHpA	0.05	<LOD
Perfluorooctanoic acid	PFOA	0.05	<LOD
Perfluorononanoic acid	PFNA	0.05	<LOD
Perfluorodecanoic acid	PFDA	0.05	<LOD
Perfluoroundecanoic acid	PFUnDA	0.05	<LOD
Perfluorododecanoic acid	PFDoDA	0.05	<LOD
Perfluorotridecanoic acid	PFTrDA	0.07	<LOD
Perfluorotetradecanoic acid	PFTeDA	0.07	<LOD
Perfluorohexadecanoic acid	PFHxDA	0.07	<LOD
Perfluorooctadecanoic acid	PFODA	0.07	<LOD
Perfluoropropane sulfonic acid	PFPrS	0.07	<LOD
Perfluorobutane sulfonic acid	PFBS	0.05	<LOD
Perfluoropentane sulfonic acid	PFPeS	0.05	<LOD
Perfluorohexane sulfonic acid	PFHxS	0.05	<LOD
Perfluoroheptane sulfonic acid	PFHpS	0.05	<LOD
Perfluorooctane sulfonic acid	PFOS	0.05	<LOD
Perfluorononane sulfonic acid	PFNS	0.05	<LOD
Perfluorodecane sulfonic acid	PFDS	0.05	<LOD
Perfluoroundecane sulfonic acid	PFUnDS	0.07	<LOD
Perfluorododecane sulfonic acid	PFDoDS	0.07	<LOD
Perfluorotridecane sulfonic acid	PFTrDS	0.07	<LOD
3:3 Fluorotelomer carboxylic acid	FPrPA	0.07	<LOD
5:3 Fluorotelomer carboxylic acid	FPePA	0.05	<LOD
7:3 Fluorotelomer carboxylic acid	FHpPA	0.05	<LOD
Perfluoro-2-propoxypropanoic acid	Gen-X	0.07	<LOD
Dodecafluoro-3H-4,8,-dioxanonanoic acid	ADONA	0.05	<LOD

6:2 Fluorotelomer unsaturated carboxylic acid	6:2 FTUA	0.07	<LOD
8:2 Fluorotelomer unsaturated carboxylic acid	8:2 FTUA	0.07	<LOD
10:2 Fluorotelomer unsaturated carboxylic acid	10:2 FTUA	0.07	<LOD
6:2 fluorotelomer sulfonic acid	6:2 FTS	0.05	<LOD
8:2 fluorotelomer sulfonic acid	8:2 FTS	0.05	<LOD
Perfluorooctane sulfonamide	PFOSA	0.07	<LOD
Perfluorooctane sulfonamido acetate	FOSAA	0.07	<LOD
N-methyl perfluorooctane sulfonamidoacetic acid	Me-FOSAA	0.07	<LOD
N-ethyl perfluorooctane sulfonamidoacetic acid	Et-FOSAA	0.07	<LOD
6:2 Fluorotelomer phosphate monoester	6:2PAP	0.57	<LOD
8:2 Fluorotelomer phosphate monoester	8:2PAP	0.07	<LOD
6:2 Fluorotelomer phosphate diester	6:2diPAP	0.07	<LOD
6:2/8:2 Fluorotelomer phosphate diester	6:2/8:2 diPAP	0.07	<LOD
8:2 Fluorotelomer phosphate diester	8:2 diPAP	0.07	<LOD
6:6 Bis(perfluorohexyl)phosphinic acid	6:6 PFPi	0.07	<LOD
6:8 Bis(perfluorohexyl)phosphinic acid	6:8 PFPi	0.07	<LOD
8:8 Bis(perfluorohexyl)phosphinic acid	8:8 PFPi	0.07	<LOD
N-ethyl perfluorooctane sulfonamide ethanol-based phosphate diester	diSAmPAP	0.07	<LOD
difluoro{[2,2,4,5-tetrafluoro-5-(trifluoromethoxy)-1,3-dioxolan-4-yl]oxy}acetic acid	C6O4	0.20	<LOD
8-chloroperfluoro-1-octanesulfonate	8Cl-PFOS	0.07	<LOD
6:2 Fluorotelomer acid	6:2 FTA	0.07	<LOD
8:2 Fluorotelomer acid	8:2 FTA	0.07	<LOD
10:2 Fluorotelomer acid	10:2 FTA	0.07	<LOD
N-methyl Perfluorooctane sulfonamide	Me-FOSA	0.07	<LOD
N-ethyl Perfluorooctane sulfonamide	Et-FOSA	0.07	<LOD
Perfluoro-4-oxapentanoic acid	PF4OPeA	0.07	<LOD
perfluoro(2-ethoxyethane)sulfonate	PFEESA	0.07	<LOD
Sum of PFAS			<LOD

Table 5. Phthalates and alternative plasticizers in water leachate (ng/leachate test)

	Abbreviation	LOD	Water leachate (L/S 10, 21°C)		Water leachate (L/S 10, 6°C)	
	Sample weight (L) --------->		0.997 g / 10.022 mL	ng/L *	1.017 g / 10.028 mL	ng/L *
Phthalate esters						
Dimethyl phthalate	DMP	0.15	52	5 200	53	5 300
Diethyl phthalate	DEP	0.92	1 204	120 400	566	56 600
Diisobutyl phthalate	DiBP	0.81	<LOD	<LOD	<LOD	<LOD
Di-n-butyl phthalate	DnBP	5.5	<LOD	<LOD	<LOD	<LOD
Butyl benzyl phthalate	BBzP	0.04	0.66	66	0.11	11
Diethyl hexyl phthalate	DEHP	4.9	<LOD	<LOD	<LOD	<LOD
Diisononyl phthalate	DiNP	12.6	242 275	24 227 500	6 562	656 200
Diisodecyl phthalate	DiDP	2.0	28 343	2 834 300	696	69 600
Di-2-propyl heptyl phthalate	DPHP	0.66	<LOD	<LOD	<LOD	<LOD
Alternative plasticizers						
Acetyl tributyl citrate	ATBC	0.61	<LOD	<LOD	<LOD	<LOD
Bis(2-etylhexyl) adipate	DEHA	2.2	<LOD	<LOD	<LOD	<LOD
Dioctyl terephthalate	DEHT	0.58	5.3	533	2.3	230
Diisononyl cyclohexan-1,2-dicarboxylate	DINCH	1.1	123	12 300	12.6	1 260
Tris (2-ethylhexyl) trimellitate	TOTM	0.09	<LOD	<LOD	<LOD	<LOD
Sum phthalates and alternative plasticizers			272 µg	27 200 µg/L	7.892 µg	789 µg/L

* This concentration applies to the L/S 10 test conditions

Table 6. Organophosphate esters in in water leachate (ng/leachate test)

	Abbreviation	LOD	Water leachate (L/S 10, 6°C)		Water leachate (L/S 10, 21°C)	
	Sample weight (L) ------->		0.997 g / 10.022 mL	ng/L *	1.017 g / 10.028 mL	ng/L *
Tris(ethyl) phosphate	TEP	83	<LOD	<LOD	<LOD	<LOD
Tris(iso-butyl) phosphate	TiBP	0.001	0.01	1	0.01	1
Tributyl phosphate	TnBP	0.0003	0.003	0.3	0.01	1
Tris(2-chloroethyl) phosphate	TCEP	0.15	0.27	27	0.21	21
Tris(2-chloro-iso-propyl) phosphate	TCPP	0.01	0.46	46	0.53	53
Tris(1,3-dikloro-iso-propyl phosphate	TDCP	0.011	<LOD	<LOD	<LOD	<LOD
Tributoxy ethyl phosphate	TBEP	0.07	<LOD	<LOD	<LOD	<LOD
Tris(2-ethylhexyl) phosphate	TEHP	0.0004	<LOD	<LOD	<LOD	<LOD
Triphenyl phosphate	TPhP	0.01	<LOD	<LOD	<LOD	<LOD
2-Etylhexyl-di-phenyl phosphate	EHDPP	0.008	0.02	2	0.01	1
Tris(o-cresol) phosphate	ToCrP	0.003	<LOD	<LOD	<LOD	<LOD
Tricresyl phosphate (mix of isomers)	TCrP-mix	0.06	<LOD	<LOD	<LOD	<LOD
Sum organophosphates			0.763	76.3	0.77	77

* This concentration applies to the L/S 10 test conditions

Table 7. Bisphenol A and its analogues in water leachate (ng/leachate test)

	Abbreviation	LOD	Water leachate (L/S 10, 21°C)		Water leachate (L/S 10, 6°C)	
	Sample weight (L) ---------->		0.997 g / 10.022 mL	ng/L *	1.017 g / 10.028 mL	ng/L *
Bisphenol A	BPA	0.43	<LOD	<LOD	<LOD	<LOD
Bisphenol S	BPS	0.94	<LOD	<LOD	<LOD	<LOD
Bisphenol F	BPF	0.14	<LOD	<LOD	<LOD	<LOD
Bisphenol AF	BPAF	0.49	<LOD	<LOD	<LOD	<LOD
Tetrabromobisphenol A	TBBPA	0.27	<LOD	<LOD	<LOD	<LOD

* This concentration applies to the L/S 10 test conditions

Table 8. PFAS in in water leachate (ng/leachate test)

	Abbreviation	LOD	Water leachate (L/S 10, 21°C)		Water leachate (L/S 10, 6°C)	
	Sample weight (L) ------>		0.999 g / 10.012 mL	ng/L *	1.009 g / 10.012 mL	ng/L *
Perfluoropropanoic acid	PFPrA	0.07	<LOD	<LOD	<LOD	<LOD
Perfluorobutanoic acid	PFBA	0.07	<LOD	<LOD	<LOD	<LOD
Perfluoropentanoic acid	PFPeA	0.06	<LOD	<LOD	<LOD	<LOD
Perfluorohexanoic acid	PFHxA	0.05	<LOD	<LOD	<LOD	<LOD
Perfluoroheptanoic acid	PFHpA	0.05	<LOD	<LOD	<LOD	<LOD
Perfluorooctanoic acid	PFOA	0.05	<LOD	<LOD	<LOD	<LOD
Perfluorononanoic acid	PFNA	0.05	<LOD	<LOD	<LOD	<LOD
Perfluorodecanoic acid	PFDA	0.05	<LOD	<LOD	<LOD	<LOD
Perfluoroundecanoic acid	PFUnDA	0.05	<LOD	<LOD	<LOD	<LOD
Perfluorododecanoic acid	PFDoDA	0.05	<LOD	<LOD	<LOD	<LOD
Perfluorotridecanoic acid	PFTrDA	0.07	<LOD	<LOD	<LOD	<LOD
Perfluorotetradecanoic acid	PFTeDA	0.07	<LOD	<LOD	<LOD	<LOD
Perfluorohexadecanoic acid	PFHxDA	0.07	<LOD	<LOD	<LOD	<LOD
Perfluorooctadecanoic acid	PFODA	0.07	<LOD	<LOD	<LOD	<LOD
Perfluoropropane sulfonic acid	PFPrS	0.07	<LOD	<LOD	<LOD	<LOD
Perfluorobutane sulfonic acid	PFBS	0.05	<LOD	<LOD	<LOD	<LOD
Perfluoropentane sulfonic acid	PFPeS	0.05	<LOD	<LOD	<LOD	<LOD
Perfluorohexane sulfonic acid	PFHxS	0.05	<LOD	<LOD	<LOD	<LOD
Perfluoroheptane sulfonic acid	PFHpS	0.05	<LOD	<LOD	<LOD	<LOD
Perfluorooctane sulfonic acid	PFOS	0.05	<LOD	<LOD	<LOD	<LOD
Perfluorononane sulfonic acid	PFNS	0.05	<LOD	<LOD	<LOD	<LOD
Perfluorodecane sulfonic acid	PFDS	0.05	<LOD	<LOD	<LOD	<LOD
Perfluoroundecane sulfonic acid	PFUnDS	0.07	<LOD	<LOD	<LOD	<LOD
Perfluorododecane sulfonic acid	PFDoDS	0.07	<LOD	<LOD	<LOD	<LOD
Perfluorotridecane sulfonic acid	PFTrDS	0.07	<LOD	<LOD	<LOD	<LOD

3:3 Fluorotelomer carboxylic acid	FPrPA	0.07	<LOD	<LOD	<LOD	<LOD
5:3 Fluorotelomer carboxylic acid	FPePA	0.05	<LOD	<LOD	<LOD	<LOD
7:3 Fluorotelomer carboxylic acid	FHpPA	0.05	<LOD	<LOD	<LOD	<LOD
Perfluoro-2-propoxypropanoic acid	Gen-X	0.07	<LOD	<LOD	<LOD	<LOD
Dodecafluoro-3H-4,8,-dioxanonanoic acid	ADONA	0.05	<LOD	<LOD	<LOD	<LOD
6:2 Fluorotelomer unsaturated carboxylic acid	6:2 FTUA	0.07	<LOD	<LOD	<LOD	<LOD
8:2 Fluorotelomer unsaturated carboxylic acid	8:2 FTUA	0.07	<LOD	<LOD	<LOD	<LOD
10:2 Fluorotelomer unsaturated carboxylic acid	10:2 FTUA	0.07	<LOD	<LOD	<LOD	<LOD
6:2 fluorotelomer sulfonic acid	6:2 FTS	0.05	<LOD	<LOD	<LOD	<LOD
8:2 fluorotelomer sulfonic acid	8:2 FTS	0.05	<LOD	<LOD	<LOD	<LOD
Perfluorooctane sulfonamide	PFOSA	0.07	<LOD	<LOD	<LOD	<LOD
Perfluorooctane sulfonamido acetate	FOSAA	0.07	<LOD	<LOD	<LOD	<LOD
N-methyl perfluorooctane sulfonamidoacetic acid	Me-FOSAA	0.07	<LOD	<LOD	<LOD	<LOD
N-ethyl perfluorooctane sulfonamidoacetic acid	Et-FOSAA	0.07	<LOD	<LOD	<LOD	<LOD
6:2 Fluorotelomer phosphate monoester	6:2PAP	0.57	<LOD	<LOD	<LOD	<LOD
8:2 Fluorotelomer phosphate monoester	8:2PAP	0.07	<LOD	<LOD	<LOD	<LOD
6:2 Fluorotelomer phosphate diester	6:2diPAP	0.07	<LOD	<LOD	<LOD	<LOD
6:2/8:2 Fluorotelomer phosphate diester	6:2/8:2 diPAP	0.07	<LOD	<LOD	<LOD	<LOD
8:2 Fluorotelomer phosphate diester	8:2 diPAP	0.07	<LOD	<LOD	<LOD	<LOD
6:6 Bis(perfluorohexyl)phosphinic acid	6:6 PFPi	0.07	<LOD	<LOD	<LOD	<LOD
6:8 Bis(perfluorohexyl)phosphinic acid	6:8 PFPi	0.07	<LOD	<LOD	<LOD	<LOD
8:8 Bis(perfluorohexyl)phosphinic acid	8:8 PFPi	0.07	<LOD	<LOD	<LOD	<LOD
N-ethyl perfluorooctane sulfonamide ethanol-based phosphate diester	diSAmPAP	0.07	<LOD	<LOD	<LOD	<LOD

* This concentration applies to the L/S 10 test conditions

Appendix 5F.

Evaluation of the effect of floor treatments on the chemical load in schools

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Co-funded by the European Union
SUSTAINABLE WATERS
NonHazCity 3
goodpoint
Part of the Semcon Group

Summary

This study has involved the investigation of potentially harmful substances at a school, mainly in dust, but also in materials. The study was carried out to evaluate the effect of floor treatments on the chemical load in this school's indoor environment. This was done by sampling before and after the application of the floor treatment. The aim was to assess whether the investigated floor treatments contributed to a reduction of potentially harmful substances and thereby can support the City of Stockholm's work towards a more toxic-free school environment. To answer these questions, measurements of chemical concentrations in dust were done before and after the floor treatments. These measurements were analyzed to identify any changes in the levels of potentially harmful substances. The study also aimed to assess the overall environmental friendliness and suitability of the selected products for use in school environments, with a particular focus on their contribution to a healthier indoor environment for children.

Based on the results of the study, a clear change in the levels of potentially harmful substances can be observed before and after the floor treatment. Most of the analyzed substances have decreased in measured concentration after the treatment. Based on this, an assumption can be made that floor treatments can probably be an effective alternative that can help the City of Stockholm’s schools to move towards a more toxic-free environment. The floor treatment is not as extensive as, for example, a complete replacement of the floors that are already in place. However, it is not possible based on this study to establish any long-term risks associated with floor treatments. It is therefore important to continue with caution on measures related to chemical safety, especially for children. This can be achieved by remaining up to date on current research, as well as continuing continuous evaluation through environmental toxicity monitoring.

Glossary

LOD	Limit of detection

Table of Contents

1 Introduction

Children are a very vulnerable group in society, which means they are a high priority when working towards a toxic-free and sustainable society. For this small study, the focus is on chemical safety in the indoor environment of schools. Continuously monitoring chemical safety in this environment and investigating the potentially harmful substances children are exposed to is important.

This study has included investigation of potentially harmful substances at a school, mainly in dust, but also materials. The investigation was carried out to evaluate the effect of floor treatments on the chemical load in this school's indoor environment. This has been done by taking samples before and after floor treatment. The choice to analyze dust is because dust itself is a good indicator of chemical exposure in the indoor environment. In addition to inhalation of dust as a route of exposure to chemicals, absorption can also occur through the skin via direct contact with materials. For this reason, a material sample has also been investigated in this study.

The City of Stockholm's Environmental Administration has conducted several follow-up studies of the indoor environment regarding exposure to potentially harmful substances. Previous studies included analyses of air, dust, building and construction materials and furnishing materials and goods. In this study, investigations and chemical analysis have been performed on dust samples collected indoors in selected preschools and single material samples on PVC floors.

This report is aimed at stakeholders on issues related to chemical exposure and quality aspects linked to chemical exposure in the indoor environment. The report can be used as a basis for evaluation and present examples of measures to reduce unwanted chemical exposure in schools or equivalent indoor environments.

1.1 Objective

To investigate the extent to which substances with potentially negative health effects are present in the schools of the City of Stockholm, the City of Stockholm conducts periodic investigations of children's indoor environments and the materials that children encounter. This objective of this study was to evaluate the effects of floor treatments with Bona Pure Colour and Bona Pure Matt on the chemical load in a school's indoor environment. The aim was to assess whether these specific products contribute to a reduction of potentially harmful substances and thereby support the City of Stockholm's work towards a more toxic-free school environment.

The questions to be answered in this study were the following:

- Have the levels of potentially harmful substances changed before and after the floor treatment?
- Is it possible to conclude from this study that these types of floor treatments could help the City of Stockholm’s schools move towards a more toxic-free environment?

To answer these questions, measurements of chemical levels in dust were carried out both before and after the application of BONA PURE COLOUR and BONA PURE MATT. The results of these measurements were analyzed to identify any changes in the levels of potentially harmful substances. The study also aimed to assess the overall environmental friendliness and suitability of the selected products for use in school environments, with a particular focus on their contribution to a healthier indoor environment for children.

2 Background

Health-related monitoring of indoor environmental toxins is important because people spend most of their time indoors. The monitoring of children's indoor environments is of particular importance as they are exposed more and in a different way than adults. The difference in exposure is mainly because children generally have a higher level of physical activity, which leads to increased breathing rates and higher exposure to dust particles in the air. Children also engage in more hand-to-mouth behaviors, which can also lead to increased exposure. The increased level of exposure contributes to children, who do not yet have a fully developed nervous, hormonal and immune system, being exposed to more serious health risks compared to adult individuals (Giovanoulis et al., 2019). As a result, the issue of increased chemical exposure and children's exposure to hazardous chemicals needs to become a higher priority for society and more efforts are needed to identify appropriate measures.

Sources of chemicals harmful to health in the indoor environment can be substances ranging from building materials, consumer goods and products to air, dust and dirt entering from the outdoor environment. Depending on their physiochemical properties, the substances are distributed between the gas phase, bound to particles suspended in air, and in solid form on surfaces and in dust.

In the City of Stockholm's chemicals plan, children's everyday lives are a priority area of action, and groups of substances with a particular focus are included in the plan (City of Stockholm, 2020). These groups of substances have also been the starting point for this study.

2.1 Floor treatment

Floor treatments have multiple purposes ranging from protecting the floor and extending its lifetime to improving the aesthetic appearance of the floor. Treatments can protect floors from damage caused by, for example, moisture, dirt, abrasion and chemicals. Protecting the surface of the floor with treatments increases the life of the floor, reducing the need for repairs. A treated surface can be easier to clean and maintain, leading to it retaining its appearance for a longer time. Floor treatments can also prevent dust and allergens from sticking to the surface, which can contribute to a better indoor environment.

Both Bona Pure Color and Bona Pure Matt used as floor treatments in this study are water-based paints that contain very low levels of volatile organic compounds. This means that they do not emit vapors that can negatively affect indoor air, which is important for maintaining a healthy indoor environment. As both products are water-based, this also means a lower environmental impact compared to solvent-based alternatives. This applies to both production and application. Bona Pure Matt contains less than 0.0005% of the substance 2-methyl-3-isothiazolone, which is a substance that can cause allergic reactions on skin contact (Byggvarubedömningen, n.d.).

3 Method

This study included analyzing dust and material samples from a school in Stockholm. Dust sampling was performed on two occasions, one before floor treatment and one after floor treatment.

3.1 Dust samples

Dust was collected from surfaces such as cabinets, shelves, and windowsills. The collection was done on filters using a vacuum cleaner with a specially adapted nozzle. Dust samples were collected from surfaces at least 0.5 meters above the floor and up to 2.5 meters above the floor. Collection of dust from floors was excluded to avoid the risk of contamination. Notes were made on the height at which the sample was collected, the type of material or substrate, and other factors of interest.

Where vacuum cleaner nozzles needed to be reused for further sampling, they were thoroughly cleaned by rinsing with copious amounts of water between each sampling session. The nozzles were then allowed to air dry to avoid contamination from paper or textile.

Blank samples were also collected on both sampling occasions. When collecting the blank samples, the vacuum cleaner nozzle was pointed straight into the air and the vacuum cleaner was turned on for a few seconds before being turned off again. The analytical results for the blank samples are presented with the other results in Annex 2.

3.2 Material samples

Samples of material were collected from the floor in a secluded part of the room by carefully removing a narrow piece of carpet with a knife. The material was collected in places where it would not be visible, for example from folded flooring at skirting boards. Each sample collected was approximately 0.5 g.

3.3 Analysed substance groups

The two dust samples and the two blank samples were analyzed for the substance groups phthalates and alternative plasticizers, bisphenols and PFAS substances. The dust samples taken on the first sampling occasion, before the floor treatment, were also analyzed for metals and chlorinated paraffins. The material sample was analyzed for the substance groups phthalates and alternative plasticizers, bisphenols and PFAS substances. See Appendix 1 for a description of all substances included in the various substance groups.

All chemical analyses of dust and material samples were carried out by IVL Swedish Environmental Research Institute.

4 Results

The analytical results are presented below for the two dust samples, before and after treatment. The results are presented per substance group. All tables show the measured concentrations of the different substances before and after treatment. For complete results, detection limits and results for the material sample, see Appendix 2.

4.1 Phthalates and alternative plasticizers

The analytical results for phthalates and alternative plasticizers in the dust samples are presented in Table 1. All phthalates and alternative plasticizers have decreased after treatment, except TOTM which increased from 0.014 µg/g to 0.8 µg/g.

Table 1: Measured levels of phthalates and alternative plasticizers in dust, measured in µg/g, before and after treatment.

Substance	Before treatment (µg/g)	After treatment (µg/g)
DMP	0,22	0,03
DEP	1,24	0,86
DiBP	1,18	0,29
DnBP	4,63	0,79
ATBC	11,83	8,44
BzBP	7,11	0,91
DEHA	6,58	3,06
DEHP	291,47	51,75
DINCH	117,44	42,95
DEHT	78,19	36,79
DiNP	225,28	11,57
DiDP	27,47	9,31
DPHP	13,13	1,60
TOTM	0,02	0,80

4.2 Bisphenols

Table 2 shows the results of bisphenols analyses in the dust samples. A decrease has been observed for all analyzed bisphenols after the treatment, except for TBBPA whose concentration has increased almost four times.

Table 1. Measured levels of bisphenols in dust, measured in ng/g, before and after treatment.

Substance	Before treatment (ng/g)	After treatment (ng/g)
BPAF	101,09	0,53
BPF	9,50	0,64
BPA	1294,76	14,19
BPS	193,54	3,04
TBBPA	58,98	243,41

4.3 Polyfluoroalkyl substances (PFAS)

The analytical results for polyfluoroalkyl substances (PFAS) in the dust samples are presented in Table 3. In the analysis of PFAS substances before and after treatment, different numbers of substances were included for analysis. Therefore, only substances common to both sampling events are presented in Table 3 below. For results for all analyzed PFAS substances, see Annex 2. It should also be noted that the detection limits were different for the two analysis occasions.

11 of the 25 jointly analyzed PFAS substances have decreased in concentration after treatment. This means that about half of the PFAS substances have increased in concentration after treatment, for example 6 PAP which increased from 1120.41 ng/g to 1826.31 ng/g. For some of the substances, however, it is not entirely possible to determine whether they have increased or decreased, as they were below the detection limits on both occasions of analysis, for example FPrPA and N-Me-FOSAA.

Table 3: Measured concentrations of PFAS substances in dust, measured in ng/g, before and after treatment. All substances marked with a "<" in front of their value in the table were below the respective detection limits.

Substance	Before treatment (ng/g)	After treatment (ng/g)
PFBA	12,62	<0,09
PFPeA	8,11	<0,05
PFHxA	20,90	14,31
PFHpA	5,04	3,98
PFOA	17,82	6,28
PFNA	2,46	1,35
PFDA	<0,05	2,59
PFUnDA	<0,05	<0,25
PFDoDA	<0,05	0,80
PFBS	3,54	0,18
PFHxS	<0,11	<0,272
PFOS	22,39	1,44
PFDS	3,55	3,37
PFOSA	<0,05	<0,05
6:2 FTS	0,86	1,29
6:2 PAP	1120,41	1826,31
8:2 PAP	30,44	<14,3
6:2/8:2 diPAP	6,91	4,29
8:2 diPAP	<0,05	2,70
N-Me-FOSAA	<0,05	<0,56
N-Et-FOSAA	<0,05	0,80
8:2 FTS	1,55	2,24
FPrPA	<0,05	<0,09
FPePA	<0,05	<0,07
FHpPA	<0,05	<0,85

4.4 Metals

Only one dust sample, the one collected before treatment, was analyzed for metals. The results of this analysis are presented in Table 4, so there are no results from after treatment

to compare with. Of the metals analyzed, zinc was present in the highest measured concentration before treatment.

Table 4: Measured concentrations of metals in dust, measured in µg/g, before treatment. This group of substances was not analyzed after treatment.

Substance	Before treatment (µg/g)	After treatment (µg/g)
Vanadium (V)	2,9	-
Chromium (Cr)	14	-
Manganese (Mn)	26	-
Cobalt (Co)	0,7	-
Nickel (Ni)	7,1	-
Copper (Cu)	31	-
Zinc (Zn)	170	-
Arsenic (As)	0,42	-
Cadmium (Cd)	0,12	-
Lead (Pb)	4,1	-

4.5 Chlorinated paraffins

Only one dust sample, collected before treatment, was analyzed for chlorinated paraffins. The results of this analysis are presented in Table 5, so there are no post-treatment results to compare with. Of the chlorinated paraffins analyzed, medium-chain chlorinated paraffins were present at the highest levels measured before treatment.

Table 5: Measured concentrations of chlorinated paraffins in dust, measured in µg/g, before treatment. This group of substances was not analyzed after treatment.

Substance	Before treatment (µg/g)	After treatment (µg/g)
∑SCCPs (C10-C13)	5,46	-
∑MCCPs (C14-C17)	45,2	-
∑LCCPs (C18-C21)	11,2	-

5 Discussion and conclusions

Based on the results of this study, a clear change in the levels of potentially harmful substances can be observed before and after the floor treatment. The majority of the analyzed substances have decreased in measured concentration after the treatment.

Based on this, an assumption can be made that floor treatments can probably be an effective alternative that can help the City of Stockholm's schools to move towards a more toxic-free environment. It is also not as extensive a task as, for example, completely replacing the floors already in place. However, it is not possible based on this study to establish any long-term risks associated with floor treatments. It is therefore important to continue with caution on measures related to chemical safety, especially for children. This can be achieved by remaining up to date on current research, as well as continuing continuous evaluation through environmental toxicity monitoring.

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Appendix 1: Analysed substances

Compound name	Abbreviation	CAS number
Phthalate esters		
Dimethyl phthalate	DMP	131-11-3
Diethyl phthalate	DEP	84-66-2
Diisobutyl phthalate	DiBP	84-69-5
Di-n-butylphthalate	DnBP	84-74-2
Benzyl butyl phthalate	BzBP	85-68-7
Di(2-ethylhexyl)phthalate	DEHP	117-81-7
Diisononyl phthalate	DINP	28553-12-0
Diisodecyl phthalate	DIDP	26761-40-0
Di(2-propylheptyl)phthalate	DPHP	53306-54-0
Alternative plasticizers		
Acetyltributylcitrate	ATBC	77-90-7
Di(2-ethylhexyl)adipate	DEHA	103-23-1
Di(2-ethylhexyl)terephthalate	DEHT	6422-86-2
1,2-Cyclohexane dicarboxylic acid diisononyl ester	DINCH	166412-78-8
Trioctyl trimellitate	TOTM	3319-31-1
Bisphenols		
Bisphenol A	BPA	80-05-7
Bisphenol F	BPF	620-92-8
Bisphenol AF	BPAF	1478-61-1
Bisphenol S	BPS	80-09-1
Tetrabromobisphenol A	TBBPA	79-94-7
Poly- & perfluoroalkyl substances		
Perfluorobutanoic acid	PFBA	375-22-4
Perfluoropentanoic acid	PFPeA	2706-90-3
Perfluorohexanoic acid	PFHxA	307-24-4
Perfluoroheptanoic acid	PFHpA	375-85-9
Perfluorooctanoic acid	PFOA	335-67-1
Perfluorononanoic acid	PFNA	375-95-1
Perfluorodecanoic acid	PFDA	335-76-2
Perfluoroundecanoic acid	PFUnDA	2058-94-8
Perfluorododecanoic acid	PFDoDA	307-55-1
Perfluorobutanesulfonic acid	PFBS	375-73-5
Perfluoropentane sulfonic acid	PFPeS	2706-91-4
Perfluorohexanesulfonic acid	PFHxS	355-46-4
Perfluorooctanesulfonic acid	PFOS	1763-23-1
Perfluorodecanesulfonic acid	PFDS	335-77-3
Perfluorooctane sulfonamide	PFOSA	754-91-6
6:2 fluorotelomer sulfonic acid	6:2 FTS	27619-97-2
8:2 fluorotelomer sulfonic acid	8:2 FTS	39108-34-4
Pentafluoropropionic acid	FPrPA FPePA FHpPA	422-64-0
Perfluorooctane sulfonamido acetic acid	FOSAA	2806-24-8
Mono[2-(perfluorohexyl)ethyl] phosphate	6:2 PAP	57678-01-0
Mono[2-(perfluorooctyl)ethyl] phosphate	8:2 PAP	57678-03-2
Bis[2-(perfluorohexyl)ethyl] phosphate	6:2 diPAP 6:2/8:2 diPAP	57677-95-9
Bis[2-(perfluorooctyl)ethyl] phosphate	8:2 diPAP	678-41-1

N-methylperfluorooctane sulfonamidoacetic acid	N-Me-FOSAA	2355-31-9
N-ethylperfluoro-1-octanesulfonamidoacetic acid	N-Et-FOSAA	2991-50-6
	10:2 FTOH	

Metals

Lead	Pb	7439-92-1
Cadmium	Cd	7440-43-9
Nickel	Ni	7440-02-0
Arsenic	As	7440-38-2
Copper	Cu	7440-50-8
Zinc	Zn	7440-66-6
Chromium	Cr	7440-47-3
Vanadium	V	7440-62-2
Cobalt	Co	7440-48-4
Manganese	Mn	7439-96-5

Chlorinated paraffins

Short Chained Chlorinated Paraffins (C10-C13)	∑SCCPs (C10-C13)
Medium Chained Chlorinated Paraffins (C14-C17)	∑MCCPs (C14-C17)
Long Chained Chlorinated Paraffins (C18-C21)	∑LCCPs (C18-C21)

Appendix 2: Analysis results

See separate excel-file for analysis results.

			Type of test	Dust sample				Material sample
			Year	Blanc 1 2023	Sample 1 2023	Blanc 2 2023	Sample 2 2023	2023
			Clarification	***Before*** *treatment*	***Before*** *treatment*	***After*** *treatment*	***After*** *treatment*	***Before*** *treatment*
Substance	**before treatment**	**after treatment**						
Phthalates	**LOD (2023)**	**LOD (2023)**						
Unit	*µg/g*	*µg/g*		*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*
DMP	0,00103	0,00310		<0,00103	0,216	0,009	0,028	0,156
DEP	0,00668	0,04941		<0,00668	1,238	<0,0494	0,856	2,667
DiBP	0,00766	0,03362		<0,00766	1,175	<0,0336	0,292	4,167
DnBP	0,03693	0,19454		<0,03693	4,625	<0,195	0,786	18,839
ATBC	0,00499	0,00292		0,007	11,828	<0,00292	8,440	25,529
BzBP	0,00522	0,00736		<0,00522	7,110	<0,00736	0,906	940,846
DEHA	0,00893	0,06728		<0,00893	6,576	<0,0673	3,064	17045,712
DEHP	0,01950	0,14462		<0,0195	291,471	<0,145	51,750	2680,759
DINCH	0,13768	0,01326		<0,13768	117,435	0,035	42,951	1068,966
DEHT	0,01359	0,00686		<0,01359	78,190	0,015	36,793	126,935
DiNP	0,00873	0,00675		<0,00873	225,283	0,017	11,572	3531,598
DiDP	0,01602	0,06335		<0,01602	27,474	<0,0633	9,307	7887,115
DPHP	0,02580	0,00080		<0,02580	13,127	0,003	1,596	<0,02580
TOTM	0,00209	0,00125		<0,00209	0,014	<0,00125	0,800	0,176
Bisphenols								
Unit	*ng/g*	*ng/g*		*ng/g*	*ng/g*	*ng/g*	*ng/g*	*ng/g*
BPAF	0,50	0,50		<0,50	101,090	<0,50	0,529	1,918
BPF	0,50	0,50		<0,50	9,501	<0,50	0,643	<0,05
BPA	0,50	0,50		<0,50	1294,763	<0,50	14,192	2675,302
BPS	0,50	0,50		0,688	193,529	<0,50	3,035	<0,50
TBBPA	1,00	1,00		<1,00	58,980	<1,00	243,408	<1,00
PFAS								
Unit	*ng/g*	*ng/g*		*ng/g*	*ng/g*	*ng/g*	*ng/g*	*ng/g*
PFBA	0,05	0,0879		<0,05	12,617	<0,09	<0,09	<0,05
PFPeA	0,05	0,05		<0,05	8,107	<0,05	<0,05	6,624
PFHxA	0,05	0,1121		<0,05	20,901	<0,112	14,310	12,598
PFHpA	0,05	0,1137		0,064	5,039	<0,114	3,977	0,838
PFOA	0,09	0,0755		0,549	17,817	0,303	6,275	<0,09
PFNA	0,05	0,05		<0,05	2,463	<0,05	1,346	<0,05
PFDA	0,05	0,1693		<0,05	<0,05	<0,169	2,590	<0,05
PFUnDA	0,05	0,2485		<0,05	<0,05	<0,248	<0,248	<0,05
PFDoDA	0,05	0,1720		<0,05	<0,05	<0,172	0,796	<0,05
PFBS	0,05	0,09		0,346	3,538	<0,09	0,184	<0,05
PFHxS	0,11	0,2724		<0,11	<0,11	<0,272	<0,272	<0,11
PFOS	0,05	0,05		1,343	22,387	0,068	1,441	<0,05
PFDS	0,05	0,05		<0,05	3,546	<0,05	3,368	1,024
PFOSA	0,05	0,05		<0,05	<0,05	0,276	<0,05	<0,05
6:2 FTS	0,05	0,05		<0,05	0,857	<0,05	1,288	<0,05
6:2 PAP	0,20	3,6927		<0,20	1120,408	<3,69	1826,307	10,697
8:2 PAP	0,12	14,2873		<0,12	30,436	<14,3	<14,3	<0,12
6:2 diPAP	0,05	-		<0,05	971,472	-	-	12,876
6:2/8:2 diPAP	0,05	0,1273		<0,05	6,905	<0,127	4,289	1,271
8:2 diPAP	0,05	0,2788		<0,05	<0,05	<0,279	2,7	0,323
N-Me-FOSAA	0,05	0,5581		<0,05	<0,05	<0,558	<0,558	<0,05
N-Et-FOSAA	0,05	0,6389		<0,05	<0,05	<0,639	0,799	0,338
8:2 FTS	0,05	0,05		<0,05	1,552	<0,05	2,241	<0,05
FPrPA	0,05	0,09		<0,05	<0,05	<0,09	<0,09	<0,05
FPePA	0,11	0,07		<0,05	<0,05	<0,07	<0,07	<0,05
FHpPA	0,05	0,8531		<0,05	<0,05	<0,853	<0,853	<0,05
10:2 FTOH	0,05	-		<0,50	<0,50	-	-	<0,50
PFPrA		0,09				<0,187	5,430	
PFTrDA		0,07				<0,07	<0,07	
PFTeDA		0,8303				<0,83	<0,83	
PFHxDA		0,07				<0,07	<0,07	
PFODA		0,1466				<0,147	<0,147	
PFPrS		0,09				<0,09	<0,09	
PFPeS		0,0749				<0,075	<0,075	
PFHpS		0,0636				<0,064	<0,064	
PFNS		0,05				<0,07	<0,07	
PFUnDS		0,07				<0,07	<0,07	
PFDoDS		0,07				<0,07	<0,07	
PFTrDS		0,07				<0,07	<0,07	
Gen-X		0,09				<0,09	<0,09	
ADONA		0,05				<0,05	<0,05	
6:2 FTUA		0,05				<0,05	<0,05	
8:2 FTUA		0,1972				<0,197	<0,197	
10:2 FTUA		0,5636				<0,564	<0,564	
FOSAA		0,8886				<0,889	<0,889	
FPrPA+AO37:AU37		0,1333				0,303	2993,859	
6:6 PFPi		0,1290				<0,129	<0,129	
6:8 PFPi		0,09				<0,09	<0,09	
8:8 PFPi		0,09				<0,09	<0,09	
diSAmPAP		0,1325				<0,133	<0,133	
Metals								
Unit	*µg/g*			*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*
Vanadium (V)	0,003				2,9			
Chromium (Cr)	0,020				14			
Manganese (Mn)	0,010				26			
Cobalt (Co)	0,002				0,7			
Nickel (Ni)	0,030				7,1			
Copper (Cu)	0,050				31			
Zinc (Zn)	0,300				170			
Arsenic (As)	0,010				0,42			
Cadmium (Cd)	0,002				0,12			
Lead (Pb)	0,010				4,1			
Chlorinated paraffins								
Unit	*µg/g*			*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*
∑SCCPs (C10-C13)	0,25				5,46			
∑MCCPs (C14-C17)	0,25				45,2			
∑LCCPs (C18-C21)	0,5				11,2			