Roadmap for advanced effluent treatment pilot investments

Gdańsk – Szczecin – Kaunas

EMPEREST – ELIMINATING MICRO-POLLUTANTS FROM EFFLUENTS FOR REUSE STRATEGIES

Gdańsk Water Utilities, 2023

Imprint

This publication has been developed within the project **EMPEREST – Eliminating Micro-Pollutants from Effluents for Reuse Strategies,** co-financed by the Interreg Baltic Sea Region Programme 2021–2027, and helping to drive the transition to a green and resilient Baltic Sea region.

EMPEREST consortium: Union of the Baltic Cities Sustainable Cities Commission c/o City of Turku (FI), Baltic Marine Environment Protection Commission – Helsinki Commission (HELCOM) (FI), University of Tartu (EE), Berlin University of Technology (DE), Turku University of Applied Sciences (TUAS) (FI), Gdańsk Water Utilities (PL), Water and Sewage Company Ltd of Szczecin (PL), Tartu Waterworks Ltd (EE), Tallinn Water Ltd (EE), "Kaunas water" Ltd (LT), Turku Region Wastewater Treatment Plant (FI), DWA German Association for Water, Wastewater and Waste DWA Regional group North-East (DE), Environmental Centre for Administration and Technology (LT), City of Riga (LV).

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Authors: Marek Swinarski, Gdańsk Water Utilities; Taavo Tenno and Siiri Velling, University of Tartu; Markus Raudkivi, Baltic Marine Environment Protection Commission - Helsinki Commission (HELCOM); Monika Piotrowska-Szypryt, Gdańsk Water Utilities.

Contributors: Indrek Hiiemäe, Ornella Mundi and Kaido Põhako, Tartu Waterworks Ltd; Ivar Ruubel and Jelena Valtin, Tallinn Water Ltd; Jarkko Laanti, Turku Regional Wastewater Treatment Plant; Piia Leskinen and Riikka Vainio, Turku University of Applied Sciences; Mariia Andreeva, Agnieszka Ilola and Lotta Lehti, Union of the Baltic Cities Sustainable Cities Commission.

Layout: Laura Sarlin, City of Turku

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Project note

The EMPEREST project supports local authorities, service providers and policy-making community in finding ways to reduce PFAS (Per- and polyfluoroalkyl substances) and other organic micropollutants from the water cycle. The project has four activity strands to fulfil its aims. First, in close cooperation with HELCOM EMPEREST prepares methodological recommendations to monitor PFAS group in the aquatic environment. Second, local authorities address the subject on the city level by developing a PFAS risk assessment framework to identify and assess PFAS-related risks and propose relevant risk mitigation strategies. Third, EMPEREST supports water utilities in making informed decisions about cost-effective treatment strategies and investments for removing micropollutants from wastewater. Finally, capacity building takes place for both local authorities and public service providers to inform them about the recent developments in the field and train them with tailored materials and tools.

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1. Introduction

The Baltic Sea, given its delicate nature and the substantial economic activities within its vicinity, demands an elevated level of environmental consideration. At present, wastewater treatment plants, integral to the preservation of the Baltic Sea's ecological balance, face a noteworthy challenge in the removal of micropollutants and persistent organic pollutants (POPs), including per- and polyfluoroalkyl substances (PFAS). The EMPEREST project is designed to tackle the complexities linked to advanced wastewater treatment in the delicate Baltic Sea estuary. The implementation of more effective measures to control POPs pollution, to assure chemically and ecologically sustainable water quality of the bodies of water is aimed at Directive 2000/60/EC [1].

Current wastewater treatment plants are insufficient in removing certain chemicals originated from modern lifestyles, some of which are essential. The EMPEREST project bridges this gap by designing, constructing, and operating two pilot-scale mobile plants dedicated to the advanced treatment of water, specifically focusing on the removal of micropollutants and PFASs. These mobile pilot plants will serve as testing grounds for diverse removal technologies, providing a comprehensive assessment of their efficacy. The mobile plant described in the roadmap will be operated on three or optionally four different wastewater streams, employing diverse removal technologies to assess their effectiveness. Both inflow and outflow at of the pilot plant will be analysed under different operational conditions. The insights gained from this piloting processes will be invaluable for wastewater treatment plants (WWTPs), enabling them to make informed decisions regarding the most suitable technologies for enhanced wastewater treatment.

The data acquired from the pilot plants' operation is not merely an academic exercise. Collaboration and knowledge-sharing among stakeholders will facilitate the broader adoption of effective water treatment practices. It forms the foundation for implementing more effective pollution control measures, particularly concerning the removal of persistent organic pollutants (POP) and PFAS, on a larger scale.

For the degradation of hardly degradable organic substances, the pilot plants are equipped with various filtration technologies (pile cloth, activated carbon, ion change resin, sand filter), ozone treatment tank of wastewater, as well analysers, sensors, and automatic control system. To study the reuse potential of the pilot plant effluent, a disinfection unit is incorporated into the technical design, to be optionally utilized as needed.

This document describes the structure and tendering process of the pilot plant built in Gdańsk, Poland. After a testing phase at the WWTP in Gdańsk, the plant will be first transferred to the WWTP of Szczecin and then to the one in Kaunas, Lithuania. Further use after these three WWTPs will be decided later (see section 4 below).

2. Specific technological details and parameters of the investment

General technological scheme of the mobile pilot is depicted in Annex 1.

The pilot station is supplied with biologically treated wastewater using a main pump (P.1) with a capacity of 3-15 m^3/h. Although the effluent complies with current standards concerning suspended solids, a preliminary filtration step is implemented before the inflow reaches the ozonation unit, i.e. ozone contact tank (CT). This initial filtration is carried out through a drum cloth filter (DF). The additional filtration is deemed essential to ensure an exceptionally low concentration of suspended particles in the ozone contact tank, where the degradation of organic micropollutants takes place. Ozone generator is fed with oxygen produced in oxygen concentrator (PSA) that utilizes pressure swing adsorption technology. The contact time in the ozone tank can be adjusted within the range of 5-30 minutes as needed, depending on the inflow rate from 1.0 to 3.1 m^3/h) and CT volume (100-800 liters)

Next, the water to be treated passes filtration stage consisting of two granular activated carbon (GAC) filters (F.1 and F.2) or one GAC filter and one ion exchange resin (IER) filter. The flow through the filters is 0.2-0.8 m^3/h and depends on the required empty bed contact time.

Final effluent of the pilot plant can be disinfected using a low pressure ultraviolet (UV) lamp. The purpose of UV treatment is primarily to disinfect and inactivate microorganisms present in water. UV treatment utilizes ultraviolet light, specifically UV-C light, to destroy DNA or RNA of bacteria, viruses, and other pathogens, rendering them unable to reproduce. It's important to note that while UV treatment is highly effective against microorganisms, it does not remove other contaminants like chemicals, heavy metals, or any particles from the water. Therefore, it is used in conjunction with other water treatment processes for comprehensive water purification. The disinfection step is considered optional, and its implementation adds potential for reusing the final effluent from the mobile pilot plant.

3. Prepared overall tender documentation for the purchase and installation of the investment

The investment is performed by Gdansk Water Utilities (Gdańska Infrastruktura Wodociągowo-Kanalizacyjna Sp. z o.o.). The description of the subject of the order can be found in the document Annex 2. Here, we briefly outline the equipment and services to be procured, as well as the timeline.

The subject of the order is the construction and delivery of a complete pilot wastewater treatment system in a shipping container housing, designed for testing the removal of organic micropollutants from municipal wastewater. The basic components of the pilot technological system include a drum filter, an ozone oxidation system, activated carbon adsorption, and UV disinfection. The technological diagram of the pilot plant is presented in Annex 1.

The Contractor is obliged to thoroughly verify the correctness of the requirements specified in the description of the subject of the order, including adopted technical and technological solutions, in order to ensure the proper functioning of all elements of the pilot plant. Any proposals for changes to the adopted solutions require the approval of the Contracting authority.

Before commencing the construction of the pilot plant, the Contractor is obliged to submit a detailed design concept of the plant, which shall include, among other things:

- arrangement of devices in the container
- routing of pipelines
- dimensions of tanks
- technical parameters of devices, pipes and connectors.

In May 2023 procurement process was conducted for selecting the contractor of the mobile pilot plant. The tender was awarded in June and the contract with the contractor was signed on July 3rd 2023.

According to the provisions of the contract the pilot plant construction process includes the following stages:

- Stage I - development of the conceptual design of the pilot station and its approval with Gdańsk Water Utilities
- Stage II – Construction of the pilot plant and its start-up
- Stage III – Commissioning of the pilot plant and training in its operation.

The conceptual design has been completed and accepted by Gdańsk Water Utilities. The contractor is currently assembling all the equipment specified in the conceptual design and develops detailed technical solutions for the installation works inside the container.

Commissioning of the pilot plant is scheduled by the end of March 2024.

4. General timetable of the piloting activities

The first pilot test is going to be conducted at the Wschód WWTP in Gdańsk. It is scheduled for early April 2024. Subsequently, the pilot station will be transported to Water and Sewage Company in Szczecin (Poland) where further pilot testing will be conducted, and then to Kaunas Water (Lithuania). It is planned that the duration of the pilot tests at each location will be approximately 5 months:

- In Gdańsk from April to August 2024
- In Szczecin from September 2024 to January 2025
- In Kaunas from February to June 2025.

Each 5-month testing period includes transport of the pilot plant, installation of the plant on-site, start-up, testing and deinstallation of the plant.

The last project period P6 gives opportunity to conduct the pilot test also in Riga (Latvia) (PP14). In the pilot studies schedule, the use of both pilot stations is marked for period P6, however, the decision on which plant will be used for the study will be made during the pilot test in Kaunas at the latest (project period P5).

Table 1. Timeline of piloting of mobile pilot plant in Gdańsk Water Utilities (PP06), Water and Sewage Company in Szczecin (PP07), Kaunas Water (PP10) and City of Riga (PP14).

	Period	**P2: 7–12/2023**	**P3: 1–6/2024**	**P4: 7–12/2024**	**P5: 1–6/2025**	**P6: 7-12/2025**
Activity	**Partner**					
Design and construction	PP06	7/23 – 2/24				
Commissioning and startup	PP06		3/24			
Piloting period 1	PP06		4/24 – 8/24			
Piloting period 2	PP07			9/24 –	1/25	
Piloting period 3	PP10				2/25 – 6/25	
Piloting period 4	PP14					7/25 – 11/25

5. Preliminary laboratory analysis plan with main analytes and analysis points

Laboratory analysis of wastewater samples taken from the pilot plants as well as on-line measurements of wastewater quality are crucial for assessing the efficiency of wastewater treatment processes and successful pilot tests.

In general, all pilot activities Gdańsk Water Utilities (PP06), Water and Sewage Company in Szczecin (PP07) and "Kaunas water" Ltd (PP10) will share their monitoring methods and goals.

There are three levels of monitoring the pilot plants' performance:

I – Automation: online sensors.

II – Laboratory measurements of conventional parameters

III – Laboratory measurements of specific emerging pollutants with the focus to PFAS

Monitoring level I – Automation

The pilot plants are fully automatised and essential parameters are measured on-line.

The list of measuring instruments installed at the pilot plant of Gdansk Water Utilities is as follows:

- Flow meters
  Q1 – inflow to the pilot
  Q2 – inflow to ozonation
  Q3 – inflow to GAC filter 1
  Q4 – inflow to GAC/IER filter 2
  Q5 – backwash flow GAC filter 1
  Q6 – backwash flow GAC/IER filter 2
  Q7 – inflow to GAC/IER filter 2 (when filters operated in series)
  QA – backwash air flow

- UV254.1 – UV absorbance (dissolved organics) after DF filter
- UV254.2 – UV absorbance (dissolved organics) after ozone oxidation
- UV254.3 – UV absorbance (dissolved organics) after GAC/IER filters
- Turb.1 – turbidity after DF filter
- Turb.2 – turbidity after GAC/IER filters.

Monitoring level I – Laboratory monitoring of conventional parameters

Daily monitoring will be performed at the environmental analysis laboratory of the water utility, where the piloting is performed. Laboratory analyses will be also used to calibrate the online sensors.

The monitoring of wastewater treatment efficiency will be based on laboratory measurements, with a minimum scope covering:

- COD (chemical oxygen demand)
- DOC (dissolved organic carbon)
- SS (suspended solids)
- Total nitrogen
- $N\text{-}NH_4$
- $N\text{-}NO_3$
- Total phosphorus
- $P\text{-}PO_4$

Monitoring level I – Laboratory monitoring of PFAS and POP

Monitoring level IIIa – analysis of PFAS

PFAS measurement is planned on two levels: targeted analyses and analyses of total absorbable organic fluorine as a sum parameter.

Targeted analyses:

The latest targeted analysis proposed in the updated Water Framework Directive priority substance list is targeting 24 different PFAS, which are individually analysed via liquid chromatography tandem mass spectrometry (LC-MS-MS) and then summed up according to their relative potency factors (RPFs) to a perfluorooctanoic acid (PFOA) equivalent. As this is proposed to be one of the standard methods of PFAS analysis in the water matrix going further, the project aims to use it if possible. As most standard laboratories in the region are currently only offering a sum of 23 PFAS of the proposed list (excluding the new PFAS called C6O4 - perfluoro ([5-methoxy-1,3-dioxolan-4-yl]oxy) acetic acid), it will probably also be left out from project analyses due to its extra cost. The final decision on the scope of the PFAS compounds to be analysed will be made after taking into account the analytical capabilities of the laboratory that will perform the analyses.

Sum parameters – AOF

As the targeted analysis of PFAS is very expensive and due to the specific PFAS substances used in society being constantly changed (until a wider restriction or ban), it might be more feasible to use a nontargeted sum parameter for stakeholders like WWTPs. Currently, absorbable organic fluorine (AOF), which can be analysed by using combustion ion chromatography (AOF-CIC) is a promising parameter, the use of which will be explored in the EMPEREST piloting phase if possible.

Monitoring level IIIb – analysis of other organic micropollutants

As the analysis of micropollutants is very expensive, the results of previous analyses conducted from the effluents were used for WWTPs who had them. The piloting WWTPs will tender analysis of the organic micropollutants based on the advised priority classifications highlighted in Table 2 and new information gathered during the WP2. The priority classes outlined range from A to D, with class A substances expected to give the most information on the efficiency of the effluent treatment technologies and class D the least. The higher the priority class, the more often these specific substances are also proposed to be analysed, while the specific frequency will be up to the piloting WWTPs to decide in collaboration with the other project partners and based on budget availability.

The compounds listed in A-C or A-D priority classes are advised to be analysed by each piloting WWTP at least twice during their piloting phase, with one analysis recommended to be done from a composite effluent sample before the piloting phase begins to further validate which A-C priority class substances the specific WWTPs should focus on the most.

Table 1. Advised prioritisation of organic micropollutant chemical analysis for piloting WWTPs. Priority classes are based on previous effluent analysis at the WWTPs, current regulations and upcoming legislative changes.

Priority Class A[1]	Priority Class B[2]	Priority Class C[3]	Priority Class D[4]
Chloroalkanes, C10-13	Amisulprid	Diuron	Other WFD Annex X substances and potential new substances proposed to be added there
Tributyltin compounds	Carbamazepine	Isoproturon	
Polychlorinated biphenyls (PCBs)	Citalopram	Naphthalene	
Hexabromocyclododecanes (HBCDD)	Clarithromycin	Tetrachloroethylene	
Phthalates (including DEHP)	Diclofenac	Polychlorinated dibenzofurans (PCDFs)	
	Hydrochlorothiazide	Terbutryn	
	Metoprolol	Silver (Ag)[5]	
	Venlafaxine	Hexachlorobenzene	
	Benzotriazole	Benzene	
	Candesartan		
	Irbesartan		
	Mixture of 4-methylbenzotriazole and 6-methylbenzotriazole		

[1] Substances previously found in high concentrations in at least one piloting WWTP's effluent. Each piloting WWTP will focus on the relevant ones to their own facility.

[2] Substances proposed as evaluation criteria for advanced effluent treatment technologies by the new UWWTD update proposal. As the recast directive has not been approved yet, the substances under this class might change accordingly.

[3] Substances that have been detected in piloting WWTPs effluents above LOQ values, giving potential reference points and showing degradation effects.

[4] Although silver is not an organic substance, it is of increasingly high concern in wastewater.

The final decision on the scope of the micropollutants to be analysed will be made after considering results of routine analyses conducted by the WWTP operator and analytical capabilities of the laboratories that will perform the examinations.

6. Overall transfer strategy of the mobile pilot plant from one location to another

During the duration of project both pilot plants will be tested at three wastewater treatment plants. The duration of testing period including the transfer of the pilot is aimed to be 5 months.

Deinstallation (1 week)

- Efficient deinstallation of the pilot plant from the current WWTP connections.
- Careful packing and securing of movable parts to ensure safe transport.

Transport (1 week)

- Loading the container onto a HDS truck for secure transportation to the designated location.
- 1-2 compact sea containers will be transported.

Reinstallation (1 week)

- Unpacking and installation of the mobile plant at the specified site.
- To ease the reinstallation, the details for the preparation of the installation are provided and agreed prior transportation and installation.
- Operator of the pilot plant at the previous piloting site will be involved for supervision of the reinstallation.

Startup (1-3 weeks)

- Provision of comprehensive technical support during the installation and start-up phase of the plant.
- On-site assistance to address any technical issues and ensure a smooth commissioning process.
- All process units will be tested during the start-up phase.
- Operator of the pilot plant at the previous piloting site will be involved for supervision of the startup.

Test phase (up to 3 months)

The pilot plant is designed in such a way that it is possible to test various configurations of the wastewater treatment process.

The selected configuration of the process will be tested during the pilot study period.

Detailed piloting programme will be developed individually for each test phase based on previous experiences and on the technological needs of a particular WWTP, where the pilot is tested.

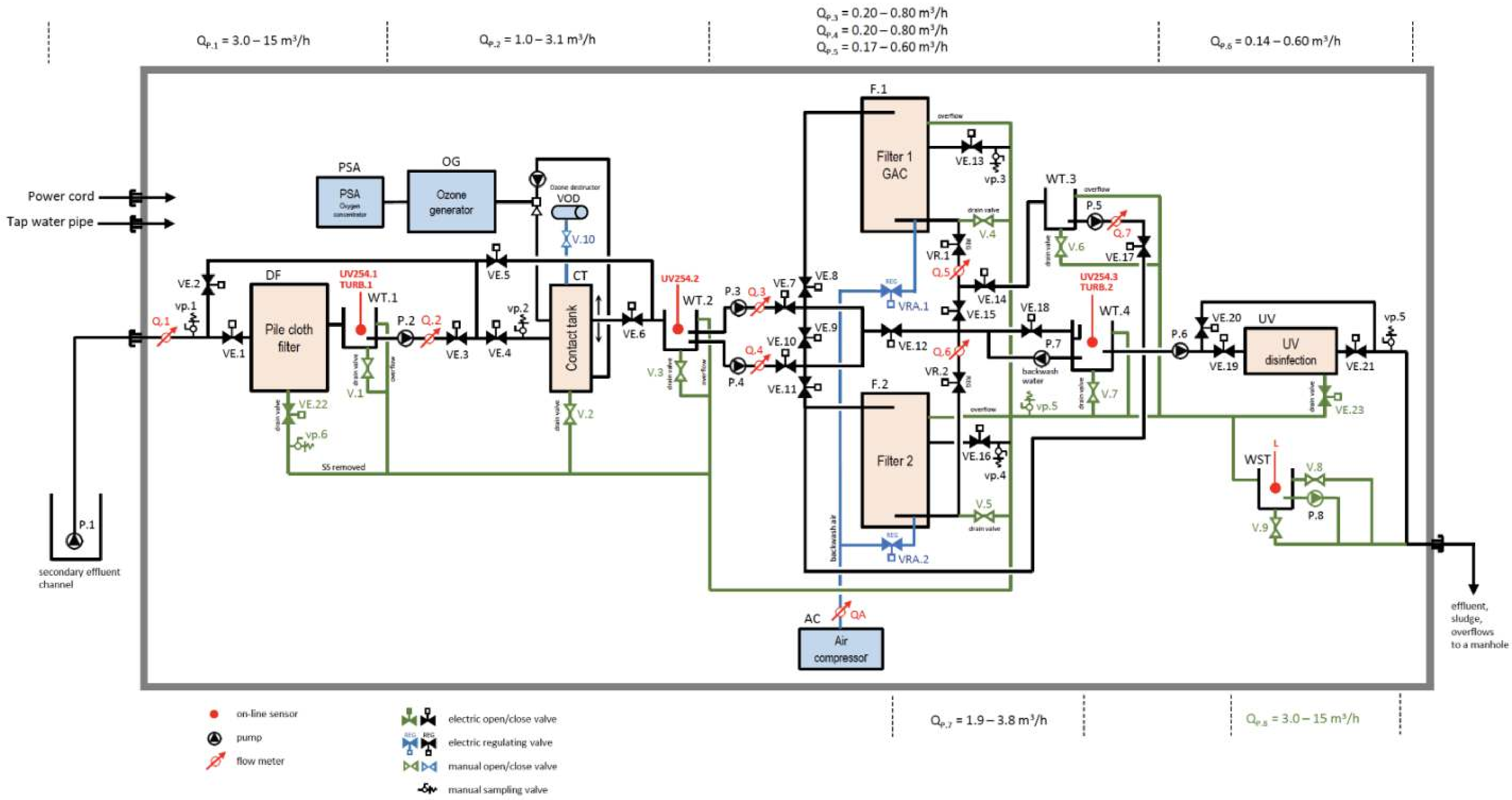
7. Reference

[1] “EUR-Lex - 32000L0060 - EN - EUR-Lex.” Accessed: Nov. 27, 2023. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32000L0060&qid=1694525318258

8. Annexes

Technological scheme of mobile pilot plant by Gdansk Water Utilities

Below is the full technological scheme of the mobile pilot plant.



$Q_{P.1}$ = 3.0 – 15 m³/h
$Q_{P.2}$ = 1.0 – 3.1 m³/h
$Q_{P.3}$ = 0.20 – 0.80 m³/h
$Q_{P.4}$ = 0.20 – 0.80 m³/h
$Q_{P.5}$ = 0.17 – 0.60 m³/h
$Q_{P.6}$ = 0.14 – 0.60 m³/h
Power cord
Tap water pipe
PSA
PSA
Oxygen concentrator
OG
Ozone generator
Ozone destructor
VOD
V.10
CT
Contact tank
DF
Pile cloth filter
UV254.1
TURB.1
WT.1
UV254.2
WT.2
Q.1
Q.2
Q.3
Q.4
Q.5
Q.6
Q.7
vp.1
vp.2
vp.3
vp.4
vp.5
vp.6
VE.1
VE.2
VE.3
VE.4
VE.5
VE.6
VE.7
VE.8
VE.9
VE.10
VE.11
VE.12
VE.13
VE.14
VE.15
VE.16
VE.17
VE.18
VE.19
VE.20
VE.21
VE.22
VE.23
V.1
V.2
V.3
V.4
V.5
V.6
V.7
V.8
V.9
P.1
P.2
P.3
P.4
P.5
P.6
P.7
P.8
VR.1
VR.2
VRA.1
VRA.2
REG
F.1
Filter 1
GAC
F.2
Filter 2
overflow
drain valve
SS removed
WT.3
WT.4
UV254.3
TURB.2
backwash water
backwash air
UV
UV disinfection
WST
L
AC
Air compressor
QA
secondary effluent channel
effluent, sludge, overflows to a manhole
on-line sensor
pump
flow meter
electric open/close valve
electric regulating valve
manual open/close valve
manual sampling valve
$Q_{P.7}$ = 1.9 – 3.8 m³/h
$Q_{P.8}$ = 3.0 – 15 m³/h

Description of the procurement subject

Some detailed technical solutions of the pilot station described in the Terms of Reference may differ from those actually implemented on the pilot station due to changes made during the construction works.

TERMS OF REFERENCE

The construction and delivery of a complete pilot installation for municipal wastewater treatment, consisting of a filtration-ozone oxidation-activated carbon adsorption-UV disinfection system in a shipping container housing

Author:
Marek Swinarski

June 2023

Contracting authority

Gdańska Infrastruktura Wodociągowo-Kanalizacyjna Sp. z o.o.

Address: ul. Kartuska 201, 80-122 Gdańsk

Contact details:

www.giwk.pl

tel. (58) 326 67 00

fax: (58) 326 67 01

e-mail: ez@giwk.pl.

Subject of the order

The subject of the order is the construction and delivery of a complete pilot wastewater treatment system in a shipping container housing, designed for testing the removal of organic micropollutants from municipal wastewater. The basic components of the pilot technological system include a drum filter, an ozone oxidation system, activated carbon adsorption, and UV disinfection. The technological diagram of the pilot plant is presented in Appendix 1.

The Contractor is obliged to thoroughly verify the correctness of the adopted technical and technological solutions in order to ensure the proper functioning of all elements of the pilot plant. Any proposals for changes to the adopted solutions require the approval of the Contracting authority.

Before commencing the construction of the pilot plant, the Contractor is obliged to submit a detailed design concept of the plant for approval to the Contracting authority, which shall include, among other things:

- arrangement of devices in the container
- routing of pipelines
- dimensions of tanks
- technical parameters of devices, pipes and connectors.

Place of delivery

Wastewater treatment plant Gdańsk-Wschód

Address: ul. Benzynowa 26, 83-011 Gdańsk

Description of the procurement subject

The schematic diagram of the pilot technological system is presented in Appendix 1.

<u>The schematic diagram does not indicate cut-off valves for pumps, air compressors, or elements of the ozone production and ozone dosing system.</u>

1. ISO 1CCC High Cube storage-office container

All elements of the pilot plant will be mounted in an ISO 1CCC High Cube - 20ft HC container. The container must be divided into two rooms: the electrical switchgear and control cabinet room, and the room for the wastewater treatment system. Each of the rooms should have a separate entrance.

External container dimensions (± 10 mm):

- length: 6,058 mm
- width: 2,438 mm

- height: 2,896 mm.

Internal container dimensions (± 10 mm):

- length: 5,890 mm
- width: 2,350 mm
- height: 2,685 mm.

Door clearance (± 10 mm):

- width: 2,338 mm
- height: 2,585 mm.

An opening with proper roofing and sealing must be made in the container ceiling to enable the installation of two filtration columns with a height of 3.30 meters (section 2.9).

The container must be thermally insulated (walls U = 0.489 W/m^{2}K, roof U = 0.3 W/m^{2}K, floor with styrofoam insulation). The internal lining of the container must be made of AISI 304 stainless steel. The container structure must be grounded.

Quick couplings allowing easy (without the use of tools) connection of the following connections must be placed on the external side of the container walls:

- Electrical energy
- Tap water (flexible garden hose)
- Raw wastewater pump discharge hose made of flexible synthetic material resistant to the corrosive effect of wastewater
- Wastewater and sludge discharge hose from the process train (sludge from drum screen cleaning and UV lamp cleaning, backwash from granular bed filters, and overflows from process tanks), made of flexible synthetic material resistant to the corrosive effect of wastewater.

The equipment for the container includes:

Sink

- Made of AISI 304 stainless steel
- Hose pipe fitting to connect flexible hose with a diameter of ½ inch
- 10-meter long flexible hose with a quick coupling of ½ inch.

Fans

- Quantity: 3 pieces
- Exhaust fans
- Mounting location: 1 piece in the switchgear room, 2 pieces in the technological part
- Voltage: 230V AC
- Air flow rate of at least 400 m^3/h for the technological part
- Stainless steel housing and rotor
- Fan operation controlled by thermostats (independently in the switchgear room and technological part).
- Manual activation of fans with electrical switches inside the container
- Equipped with blinds or covers preventing the penetration of atmospheric precipitation into the interior of the container.

Lighting

- Minimum 300 lx lighting intensity in the container
- LED lighting used.
- Lighting fixtures and installation accessories made in IP65 (station room) and IP55 (switchgear).

Electrical sockets

- 3 sockets with a voltage of 230V AC
- 1 three-phase socket with a voltage of 400V AC, 16A
- IP65 sockets in the technological room and IP44 sockets in the switchgear room.

Heating

- Electric heaters with a thermostat in each of the designated parts of the container
- Heater power selected according to the needs of individual rooms
- Material of construction: selected appropriately for corrosive atmosphere C3.

2. Technological devices

2.1. Main wastewater pump (P.1)

- Portable submersible pump
- Rugged and durable pump designed to operate on a continuous duty basis
- The pump's capacity appropriately adjusted to the drum filter's capacity (refer to point 2.2). The preferred pump capacity is 3.00 m^3/h. It is permissible to use a pump with a higher capacity that is adjusted to the drum filter's capacity (excess wastewater discharged through the overflow from the intermediate tank WT.1 after the drum filter)
- Power supply voltage: 230/400 V AC
- Motor adapted to work with a frequency converter (minimum insulation class F)
- Pump powered by a frequency converter installed in the container or integrated in the pump
- When selecting the pump, the geometric lifting height of at least 7.0 m and the length of the discharge pipe of 60 meters must be taken into account.
- Pump material resistant to the corrosive effect of wastewater
- Discharge pipe
  - length: 60 m
  - synthetic material resistant to the corrosive effect of municipal wastewater.

2.2. Drum filter (DF)

- Drum filter type HDF800 Hydrotech or similar model
- Automatic self-cleaning system with flushing nozzles
- The preferred filter capacity is 3.00 m^3/h. It is permissible to use a drum filter with a higher capacity (excess wastewater discharged through the overflow from the intermediate tank WT.1 after the drum filter)
- Mesh size of 10 µm
- The filtration should occur from the inside of the drum to the outside, and the cleaning process should not interrupt the filtration
- The cleaning process initiated manually
- Automatic cleaning based on a timer or programmed difference in the level of wastewater inside and outside the drum measured by a level sensor
- The filter's material should be stainless steel and plastic resistant to the corrosive properties of municipal wastewater
- The filter should have a drain hole in the bottom with an open/close valve.

2.3. Intermediate wastewater tank (WT.1)

- Internal dimensions: length 400 mm, width 300 mm, height 500 mm

– Working volume: 54 dm^3 (for a working depth of 450 mm)
– Overflow at a height of 450 mm from the bottom for excess wastewater removal
– Bottom drain with an open/close ball valve
– Tank material: AISI 316 stainless steel
– Sensors installed in the tank:
    - UV254 absorbance
    - turbidity.

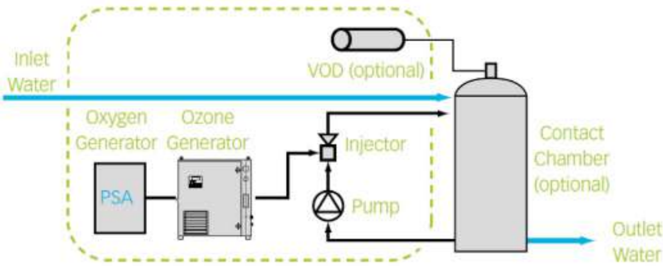
2.4. Intermediate wastewater pump (P.2)

– Rugged and durable pump designed to operate on a continuous duty basis
– Minimum required pump flow rate – 1,0 m^3/h
– Maximum required pump flow rate – 3,1 m^3/h
– Power supply voltage: 230/400 V AC
– Motor adapted to work with a frequency converter (minimum insulation class F)
– Pump powered by a frequency converter installed in the container or integrated in the pump
– Pump material resistant to the corrosive effect of wastewater.

2.5. Ozone production and dosing system (OG)

– Complete set consisting of an oxygen generator, an ozone generator and a dosing system
– Compact type ozone generator Ozonia CFS1 or similar
– Oxygen generator based on PSA technology
– Maximum ozone production: 37 g/h
– Adjustable ozone production from 10% to 100% of maximum capacity
– Closed circuit water cooling system
– Pump-injector system for dosing ozone to wastewater, with necessary equipment such as a manometer
– Piping and injector made from PVC-U, ozone pipes made from PTFE
– Ozone analyzer BMT for measuring the concentration of ozone in the produced gas
– Ozone analyzer for measuring ozone concentration in wastewater
– Alarm sensor for ozone in the air inside the container
– Modbus RTU or TCP communication protocol
– Control signals and alarms for:
    - production status
    - gas valve status
    - alarm status.

Schematic diagram of the ozone oxidation system:



2.6. Ozone contact tank (CT)

- Maximum working volume of the tank: 1,000 dm^3
- Tank dimensions - to be determined at the detailed concept design stage
- Bottom drain opening with open/close valve
- Possibility of adjusting the contact time by changing the height position of the flexible drain hose above the tank bottom
- Tank equipped with Vent Ozone Destructor (VOD) unit
- Tank material: AISI 316 stainless steel.

2.7. Intermediate wastewater tank (WT.2)

- Internal dimensions: length 300 mm, width 300 mm, height 500 mm
- Working volume: 41 dm^3 (for working depth of 450 mm)
- Upper overflow at a height of 450 mm from the bottom for excess wastewater removal
- Bottom drain with an open/close ball valve
- Tank material: AISI 316 stainless steel
- UV254 absorbance sensor installed in the tank

2.8. Intermediate wastewater pump after ozonation contact tank (P.3, P.4)

- Quantity: 2 pieces
- Rugged and durable pump designed to operate on a continuous duty basis
- Minimum required pump capacity - 0.20 m^3/h
- Maximum required pump capacity – 0,80 m^3/h
- Power supply voltage: 230/400 V AC
- Motor designed to work with a frequency converter (minimum insulation class F)
- Pump powered by a frequency converter installed in the container or integrated in the pump
- Pump material resistant to the corrosive effect of wastewater.

2.9. Granular bed filters (F.1, F.2)

- Quantity: 2 pieces
- Filter diameter of 35 cm
- Total height of the filter column – max 240 cm
- Filtration bed height – max 140 cm
- Height of the underdrain chamber – 0.10 m
- Flow of wastewater to the filters should be calm and gravitational
- Each filter should have two overflows above the filtration bed:
  - overflow 1 at a height of 230 cm from the bottom of the filtration column - for maintaining a constant level of wastewater above the filtration bed, removal of excess wastewater flowing into the filter and removal of filter backwash wastewater
  - overflow 2 at a height of 160 cm from the bottom of the filtration column - for lowering wastewater level before starting the filter backwash, equipped with an electrically operated open/close valve
- Filtration columns should be constructed and installed in such a way as to allow for easy and safe replacement of the filtration bed
- Material of the filtration column: plexiglass
- Material of the filter base and drainage: stainless steel AISI 316
- Equipment for each of the filters includes:

  - Open/close valve on the inlet pipe to the filter
  - Two upper overflows
  - Open/close valve on the overflow dedicated to lowering the level of wastewater before starting the backwashing process
  - Bottom drain with open/close ball valve for emptying the filtration column of wastewater
  - Flowmeter and control valve to maintain a constant flow through the filter and flow of wastewater for backwashing on the outlet/inlet pipe of the filter
  - Open/close valve on the pipe supplying air for backwashing
  - Piezometer indicating the pressure drop across the filter
- Backwashing the filters with wastewater after granular bed carbon filters
- Automatic backwashing with air and wastewater
- Control of backwashing based on the length of the set filter cycle or by measuring the flow rate of the filtrate
- Possibility of operating the filters in a parallel or series arrangement
- Type of filtration bed: granular activated carbon that is appropriately selected to remove micropollutants from wastewater.

2.10. Intermediate wastewater tank (WT.3)

- Internal dimensions: length 30 cm, width 30 cm, height 50 cm
- Working volume: 41 dm^3 (for working depth of 45 cm)
- Upper overflow at a height of 45 cm from the bottom for excess wastewater removal
- Bottom drain with an open/close ball valve
- Tank material: AISI 316 stainless steel.

2.11. Intermediate wastewater pump after granular bed filter F.1 (P.5)

Parameters analogous to those for pumps P.3 and P.4:

- Rugged and durable pump designed to operate on a continuous duty basis
- Minimum required pump capacity - 0.17 m^3/h
- Maximum required pump capacity – 0,60 m^3/h
- Power supply voltage: 230/400 V AC
- Motor suitable for operation with a frequency converter (minimum insulation class F)
- Pump powered by a frequency converter installed in a container or integrated in the pump
- Pump material resistant to the corrosive effect of wastewater.

2.12. Air compressor (AC)

- Required maximum compressor capacity: 100 L/min
- Oil-free compressor
- Compressor equipped with air tank and pressure regulation system
- Power supply: 230/400 V AC.

2.13. Intermediate tank and filter backwash wastewater tank (WT.4)

- Working volume: 600 dm3
- Dimensions - to be determined during the detailed conceptual design stage
- Upper overflow for excess wastewater discharge

- Inflow to the tank through an upper overflow located above the overflow for excess wastewater discharge
- Bottom drain with an open/close ball valve
- Tank material: AISI 316 stainless steel
- Installed on-line measurements in the tank:
  - UV254 absorbance
  - Turbidity.

2.14. Intermediate wastewater pump after granular bed filters (P.6)

- Rugged and durable *pump designed* to *operate* on a *continuous duty* basis
- Minimum required pump capacity - 0.14 m^3/h
- Maximum required pump capacity – 0,60 m^3/h
- Power supply voltage: 230/400 V AC
- Motor suitable for operation with a frequency converter (minimum insulation class F)
- Pump powered by a frequency converter installed in a container or integrated in the pump
- Pump material resistant to the corrosive effect of wastewater.

2.15. Pump for backwashing granular bed filters (P.7)

- Rugged and durable pump
- Minimum required pump capacity – 1,9 m^3/h
- Maximum required pump capacity - 3.8 m^3/h
- Power supply voltage: 230/400 V AC
- Motor designed to work with frequency converter (minimum insulation class F)
- Pump powered by a frequency converter installed in the container or integrated in the pump
- Pump material resistant to the corrosive effect of wastewater.

2.16. UV lamp for wastewater disinfection (UV)

- Low-pressure UV lamp
- UV lamp power adjusted for wastewater flow rates in the range of 0.14 – 0,60 m^3/h
- Wastewater transmittance measurement
- Radiation intensity measurement
- System for adjusting the radiation power of the UV lamps
- Reactor material: AISI 316L steel
- Radiation dose of 400 J/m^2 at UV transmittance T 1 cm 60%
- UV radiation monitoring system to ensure proper operation of the device
- Automatic mechanical cleaning system to ensure the maximum amount of UV light enters the wastewater
- Drain valve for evacuation of solids after mechanical cleaning.

2.17. Tank for overflows and solids (WST)

- Working volume: 300 dm^3
- Dimensions - to be agreed upon during the detailed concept design stage
- Upper overflow enabling gravitational removal of wastewater and solids from the container
- Bottom drain with an open/close ball valve

- Tank material: AISI 316 stainless steel
- Sensors installed in the tank:
    - wastewater level

2.18. Pump for evacuation of overflows and solids (P.8)

- Rugged and durable pump designed to operate on a continuous duty basis
- Maximum required pump capacity - properly adjusted to the sum of maximum outflows from tanks and granular bed filters – 15 m^3/h
- Power supply voltage: 230/400 V AC
- Motor adapted to work with a frequency converter (minimum insulation class F)
- Pump powered by a frequency converter installed in the container or integrated in the pump
- Pump material resistant to the corrosive effect of municipal wastewater
- When selecting the pump, the geometric lifting height of at least 7.0 m and the length of the discharge pipe of 60 m must be taken into account
- Material of the discharge pipe - synthetic material resistant to corrosive effect of municipal wastewater.

3. Measurement devices

The locations of the measurement instruments are shown in the diagram in Appendix 1.

3.1. Wastewater level sensor in the drum filter

- Level sensor provided by the filter manufacturer.

3.2. Level sensor in the tank for overflows and sediments (L)

- LX-80-8 Geolux radar sensor or similar
- Beam angle: 5°
- Measurement accuracy: ± 2 mm
- Resolution: 0.5 mm
- Dead zone: 20 cm
- Operating temperature: from -40°C to +85°C
- Output: possibility of communication, Modbus, analog 4-20 mA
- Degree of protection: IP68
- Housing material: stainless steel or aluminum.

3.3. UV 254 nm absorbance probe (UV254.1, UV254.2, UV254.3)

- Quantity: 3 pieces
- Optical measurement in UV light at 254 nm
- Measuring range: from 0 to 600 1/m
- Measurement slot length: 5 mm
- Automatic interference compensation for turbidity/suspension
- Integrated ultrasonic cleaning system
- Measurement window material: sapphire glass
- Operating temperature: from 0 °C to +40 °C
- Integrated analog-to-digital signal converter
- Removable cable with waterproof connector (IP 68, up to 1 bar with connection cable)

- Minimum requirements for probe body material: titanium and plastics resistant to the corrosive effect of wastewater
- No wearing parts or regular maintenance required.

3.4. Turbidity probe (TURB.1, TURB.2)

- Quantity: 2 pieces
- Optical measurement method - measurement of scattered light at an angle of 90° in accordance with EN ISO 7027
- Measured parameter: NTU, FNU
- Measuring range (automatically switched): from 0 to 4,000 FNU
- Integrated ultrasonic cleaning system
- Measurement window material: sapphire glass
- Operating temperature: from 0°C to +40°C
- Integrated analog-to-digital converter for measurement signal
- Detachable cable with universal waterproof connector (IP 68, up to 1 bar with connection cable)
- Minimum requirements for probe housing material: AISI 316Ti stainless steel and plastics resistant to corrosive wastewater
- No consumables or regular maintenance required.

3.5. Universal converter for wastewater quality measuring probes

The measuring system is based on digital probes and converters connected via a RS485, Modbus RTU or Ethernet communication network. The measuring system will use a shared, dedicated operator panel allowing for full diagnostics of the measuring probes.

The control and measuring system is based on a multi-channel converter capable of accommodating up to 20 measuring probes with a portable display. The operator panels simultaneously act as the main controller and emergency controllers. Each converter must have a "backup" system applied. All measuring probes must be connected to the converter using a shielded 2-wire cable. The system must also have a single power source.

The system should be expandable using appropriate modules connected in any combination (not only in series).

Technical specifications of the universal converter:

- Quantity: 1 piece
- Multi-module converter system for connecting up to 20 measuring probes with a system maintenance function in case of failure of the main converter (controller)
- Ability to connect probes measuring various parameters
- Portable LCD display with system controller function
- Adapted to interchangeable configuration of digital probes
- Power supply: 230 V
- Input: up to 20 digital sensors
- Output: possibility of communication via Profibus, Modbus, analog 4-20 mA, EtherNet/IP
- Operating temperature: -20 °C to +55 °C
- Protection level: IP66
- No mechanically worn out elements e.g. fan

3.6. Wastewater flow meters (Q.1-Q.5)

- Quantity: 3 pieces

- Mounting location: drain pipes from granular bed filters
- Flow meters selected for the following wastewater flow rates:
  - Flow meter Q.1 on the inflow to the pilot plant - appropriately selected for the capacity of pump P.1.
  - Flow meter Q.2 after the drum filter: 1,0 – 3,1 m^3/h
  - Flow meters Q.3 and Q.4 after the ozone contact tank: 0.20 – 0,80 m^3/h
  - Flow meters Q.5 and Q.6 on the outflows from the granular bed filters: 0.20 – 3.80 m^3/h
  - Flow meter Q7 after the granular bed filter F.1: 0.17 – 0,60 m^3/h
- Siemens MAG5100 W flow meter with MAG6000 transmitter or similar
- Measurement method: electromagnetic
- Measurement accuracy: no more than 0.4%
- Detection of empty pipelines
- Medium temperature: from -10°C to +70°C
- Ambient temperature: from -40°C to +70°C
- Sealed, fully welded housing construction
- Protection class IP67
- Internal memory storing sensor calibration data and converter settings
- Equipped with Modbus RTU (RS485) communication option
- Converter mounted separately.

3.7. Air flow meter for granular bed filter backwashing (QA)

- Thermal mass flow meter
- Flow meter properly selected for the range of airflow at the measurement point from 50 to 100 dm^3/min
- Analog current output 4-20 mA
- Modbus RTU communication support.

3.8. Electrical energy meter

- Meter for measuring energy consumed in three-phase circuits.
- Direct measurement
- Energy consumption displayed in kilowatt-hours (kWh)
- Compliant with the European Directive on Measuring Instruments (MID)
- Used for billing purposes based on the energy consumption.

4. Electrically actuated control valves

4.1. Control valves for wastewater outflow from the granular bed filters and inflow of backwash wastewater (VR.1, VR.2)

- Quantity: 2 pieces
- Proportional flow control to the control signal
- Flow rate: 0.15 - 3.50 m^3/h
- Control signal: 4-20 mA current or 0-10 V voltage
- Working pressure: 0-8 bar

- Operating temperature: 0-50 °C
- Protection class: IP65
- Material: stainless steel AISI 316.

1. The use of pneumatic valves is permitted.

4.2. Control valves for the inflow of backwash air to the granular bed filters (VRA.1, VRA.2)

- Quantity: 2 pieces
- Proportional flow control to the control signal
- Flow rate: 50 - 100 dm^3/min
- Control signal: 4-20 mA current or 0-10 V voltage
- Working pressure: 0-8 bar
- Operating temperature: 0-50 °C
- Protection class: IP65
- Material: stainless steel AISI 316.

The use of pneumatic valves is permitted.

5. Shut-off valves

5.1. Electrically actuated shut-off valves (VE.1 - VE.22)

- Quantity: 22 pieces
- 24/DC coil,
- Working pressure: 0-8 bar,
- Operating temperature: 0-50 °C
- Protection class: IP65
- Material: stainless steel AISI 316
- Possibility of manual valve opening/closing.

The use of pneumatic valves is permitted.

5.2. Manual shut-off valves (V.1 - V.10)

- Quantity: 10 pieces
- Material: stainless steel AISI 316.

5.3. Manual sample collection valves (vp.1 - vp.4)

- Quantity: 4 pieces
- Stainless steel AISI 316 ball valves.

6. Gravity and pressure wastewater pipes

The wastewater pipes (gravity and pressure) must be made of materials resistant to the corrosive action of wastewater, ozone-treated wastewater, or ozone. It is permissible to use materials such as PE, PVC, stainless steel AISI 316, appropriately selected for the transported medium.

7. Electrical system

7.1. Electrical connection

The electrical connection of the pilot plant should be made in the form of a 32A/5 400V 3P+N+PE receiver plug, e.g. type PCE 525-6, with an IP44 protection degree. The plug should be installed on the external wall of the container, on the side of the main switchboard. The power cable should be routed to the main switchboard.

To measure electricity consumption, a direct measurement three-phase sub-meter with a Modbus RTU RS485 communication port should be used.

In the main switchboard, a main switch of the FR type with an overvoltage coil should be installed. Safety buttons (pushed, unlocked by rotation) should be installed in the following places:

- in the main switchboard room - on the main switchboard facade
- in the technical equipment room - next to the entrance doors.

The buttons should be connected with a fire-resistant cable of type NHXH-J FE180/E90 2x1.5.

In the main switchboard, a class B+C protector in a 3N system and class D protectors should be installed. The container structure should be grounded (main grounding busbar installed in the pilot station room).

7.2. Main electrical distribution board (MDB)

The main distribution board should be installed in a frame steel cabinet with a protection rating of IP55 and dimensions adapted to the installed equipment (minimum 1800 × 800 × 300 mm), placed on a 200mm high base. The cable approaches should be located at the bottom through the side wall of the base. A divided floor with a lip seal should be used in the cabinet. A three-phase direct measurement submeter with an RS485, Modbus RTU communication port should be installed in the MDB.

On the facade of the distribution board, the following should be installed:

- operator panel
- safety switch.

7.3. Cable routes

Inside the container, cable routes should be made of stainless steel mesh cable trays. A removable sealable bushing should be installed between the pilot technical room and the main switchboard. Cable trays should be equipotentialized.

7.4. Drives for pumps P.1 – P.8

The pump drives will be variable frequency drives (VFDs). The VFDs with an IP20 (21) rating should be installed in the main distribution board. The technical parameters of the VFDs are as follows:

- Power supply 230V/400V, 50 Hz
- RS485 Modbus RTU communication port
- Auxiliary power supply 24 VDC
- Electronics coating compliant with 3C3 standard
- Possibility of remote panel mounting
- Possibility of installing VFDs next to each other without maintaining gaps.

The wastewater pump motors must be compatible with the VFD, i.e.:

- Power supply 230V/400V, 50 Hz
- Insulation class at least F.

Cables to the receivers - dedicated for power supply from the VFD (shielded Topflex type). The cable screens should be grounded according to the VFD manufacturer's recommendations.

8. Control system

8.1. Main wastewater pump (P.1)

- Indication of pump operating status - on/off
- Turning on and off the pump from the operator panel
- Pump flow rate setpoint adjustment from the operator panel (m^3/h)
- Pump flow rate control using signal from the flow meter Q.1
- Pump flow rate indication based on the flow meter Q.1 readings (m^3/h)
- Monitoring of current, power and frequency - readings from the frequency converter
- Counting of operating time (h)
- Indication of frequency converter fault states.

8.2. Intermediate wastewater pump after drum filter (P.2)

- Indication of pump operating status - on/off
- Turning on and off the pump from the operator panel
- Pump flow rate setpoint adjustment from the operator panel (m^3/h)
- Pump flow rate control using signal from the flow meter Q.2
- Pump flow rate indication based on the flow meter Q.2 readings (m^3/h)
- Automatic pump flow rate change during granular bed filter backwashing, in accordance with the flow values specified in the control system
- Pump operating time with increased flow rate during granular bed filter backwashing according to the time specified in the control system (min)
- Monitoring of current, power and frequency - readings from the frequency converter
- Pump operating time counter (h)
- Fault status indication of the frequency converter.

8.3. Intermediate wastewater pumps after ozone contact tank (P.3, P.4) and after the filter F.1 (P.5)

- Indication of pump operating status - on/off
- Turning the pump on/off from the operator panel
- Pump flow rate setpoint adjustment from the operator panel (m^3/h)
- Pump P.3 flow rate control using signal from the flow meter Q.3
- Pump P.4 flow rate control using signal from the flow meter Q.4
- Pump P.5 flow rate control using signal from the flow meter Q.7
- Pumps flow rate indication based on the flow meter Q.3, Q.4 and Q.7 readings (m^3/h)
- Monitoring current, power, and frequency - readings from the frequency converter
- Accumulating operating time (h)
- Signaling frequency converter faults.

8.4. Intermediate wastewater pump after the granular bed filters (P.6)

- Indication of pump operating status - on/off
- Turning on and off the pump from the operator panel
- Pump flow rate setpoint adjustment from the operator panel (m^3/h)
- Pump flow rate control using a frequency converter
- Pump flow rate indication based on the pump characteristics and rotational speed (m^3/h)
- Monitoring of current, power, and frequency - readings from the frequency converter
- Counting of pump operating time (h)

– Frequency converter fault indication.

8.5. Pump for granular bed filter backwashing (P.7)

- Indication of pump operating status - on/off
- Turning on and off the pump from the operator panel
- Pump flow rate setpoint adjustment from the operator panel (m^3/h)
- Pump flow rate control using signal from the flow meter Q.4 (backwashing filter F.1) or Q.5 (backwashing filter F.2)
- Pumps flow rate indication based on flow meter Q.4 or Q.5 readings (m^3/h)
- Automatic pump flow rate change after starting and ending the granular bed filter backwashing, according to flow rates set in the control system
- Pump working time with increased flow rate after starting granular bed filter flushing according to time set in the control system (min)
- Monitoring of current, power and frequency - readings from the frequency converter
- Pump operating time counter (h)
- Frequency converter fault status indication.

8.6. Pump for overflow and sediments (P.8)

- Indication of pump operating status - on/off
- Turning on and off the pump from the operator panel
- Automatic turning on and off the pump with a level sensor in the tank WST
- Pump flow rate indication on the operator panel - based on pump characteristics and rotational speed (m^3/h)
- Current, power, and frequency monitoring - readings from the frequency converter
- Operating time counting (h)
- Frequency converter fault indication.

8.7. Air compressor (AC)

- Manual on/off switch
- Indication of the operating status - on/off, and power supply status
- Indication of the correct pressure in the installation (bar)
- Indication of the air flow rate on the operator panel - based on the readings of the flowmeter QA (m^3/h)
- Adjustment of the air flow rate with control valves VRA.1 and VRA.2
- Manual adjustment of air pressure
- Automatic activation for starting filter backwashing with air
- Automatic deactivation after finishing filter backwashing with air
- Compressor operating time after starting filter backwashing according to the time set by the operator in the control system (min).

8.8. Oxygen concentrator (PSA)

- Manual on/off switch
- Indication of the operating status - on/off, and power supply status
- Automatic switch-off when starting the filter backwash process
- Automatic switch-on after finishing the filter backwash process
- Automatic shutdown upon detecting ozone in the room.

8.9. Ozone generator (OG) with dosing system

- Manual on/off control
- Indication of the operating status of the ozone generator - on/off, power supply status
- Indication of the operating status of the wastewater circulating pump - on/off, and power supply status
- Ozone detection in the room indication
- Ozone production setting from the operator panel (g/h)
- Ozone production display (g/h)
- Ozone concentration in the produced gas display (%)
- Ozone dose display (mg/l)
- Automatic switch-off when starting the filter backwash process
- Automatic switch-on after finishing the filter backwash process
- Automatic shutdown upon detecting ozone in the room
- Operation parameter readings using Modbus communication.

8.10. Ozone destructor (VOD)

- Manual on/off switch
- Indication of the operating status of the ozone generator - on/off, and power supply status.

8.11. Granular bed Filters (F.1 and F.2)

- Two operating modes for filters: parallel or series
- Filters operated at a constant filtration speed set by the operator by changing the degree of opening of the control valve on the filter outlet
- Filters should be backwashed with air and wastewater after the granular bed filters (with pump P.7)
- Lowering water level before starting the filter backwash with air
- Two filter backwashing modes:
    - according to the cycle time of the filter set by the operator (d)
    - based on measurements of the wastewater flow through the filter - backwash starts when the flow reaches the minimum value (m^3/h)
- Backwash rates set by the operator (m/h):
    - the recommended backwash wastewater flow rate - 40 m/h
    - the recommended backwash air flow rate - 70 m/h
- Backwash run time set by the operator (min):
    - the recommended air backwash time - 10 min
    - the recommended wastewater backwash time - 10 min.

8.12. UV lamp (UV)

- Indication of the operating status - on/off, and power supply status
- Indication of UV intensity measurement
- Indication of wastewater transmittance measurement
- Indication of the current lamp power
- Regulation of lamp power depending on the wastewater flow rate
- Automatic cleaning system activated either by measuring the UV radiation sensor or by a timer.

8.13. Regulation valves for wastewater outflow from the granular bed filters (VR.1, VR.2)

- Indication of valve opening degree

- Opening, closing, and setting the desired valves position from the operator panel
- Automatic control of valves opening based on flow measurement of wastewater with flow meters Q.4 and Q.5 to maintain the specified flow of wastewater through the filters in the control system
- Automatic full valve opening to start backwashing the filters with wastewater.

8.14. Air supply control valves for the granular bed filters (VRA.1, VRA.2)

- Indication of valve opening degree
- Opening, closing, and setting of valve position from the operator panel
- Automatic opening when starting the filter backwashing with air
- Automatic closing after finishing the filter backwashing with air.

8.15. Electrically operated shut-off valves (VE.1 - VE.22)

- Indication of valve opening/closing
- Opening and closing valves from the operator panel
- The working positions of individual valves (open/closed) must be automatically adjusted according to the following technological system operating states:
    - operation of the filters F.1 and F.2 in parallel configuration
    - operation of the filters F.1 and F.2 in series configuration
    - wastewater treatment
    - UV lamp cleaning
    - backwashing granular bed filters.

8.16. Parameters that should be monitored from the operating panel

- Flow rate of the pumps P.1 – P.8 (m^3/h)
- Indication of valve opening/closing
- Wastewater level in drum filter DF (cm)
- Wastewater level in the tank for overflows and sediments WST (cm)
- Turbidity at measuring points TURB.1 and TURB.2 (NTU, FNU)
- Absorbance at measuring points UV254.1, UV254.2 and U254.3 (1/m)
- Ozone concentration in the produced gas (%)
- Ozone production (g/h)
- Ozone dose to wastewater (mg/l)
- Ozone concentration in wastewater (mg/l)
- Retention time in ozone contact tank (min)
- Empty bed contact time in the filter F.1 (min)
- Empty bed contact time in the filter F.2 (min)
- Filtration rate in the filter F.1 (m/h)
- Filtration rate in the filter F.2 (m/h)
- Backwash air flow rate in the filter F.1 (m/h)
- Backwash air flow rate in the filter F.2 (m/h)
- Backwash wastewater flow rate in the filter F.1 (m/h)
- Backwash wastewater flow rate in the filter F.2 (m/h)
- UV radiation intensity (W/m^2)
- Transmittance of wastewater (%)
- Current power of UV lamp (W).

9. PLC controller, HMI operator panel, router

9.1. PLC controller

The control unit will be a PLC controller with the following parameters:

- 24 VDC power supply
- RJ45 Ethernet communication port, with Modbus TCP protocol support
- 2 RS485, Modbus RTU communication ports (Master)
- The number of binary and analog inputs/outputs will be adapted to the implemented control and automation system
- It is necessary to provide a reserve of: 4 binary inputs, 4 binary outputs, 2 analog inputs, and 1 analog output
- Analog inputs with a minimum resolution of 12 bits.

It is assumed that Modbus RTU bus number 1 will handle the inverters and electric energy meter, while Modbus RTU bus number 2 will handle the technological measurement system.

9.2. HMI Operator Panel

Technical parameters:

- Graphic operator panel
- 24 VDC power supply
- Modbus TCP (Ethernet) communication port, RJ45 connector
- Screen diagonal: minimum 10 inches
- Resolution: minimum 800 x 480 px.

9.3. Router

Technical parameters:

- Router with built-in recorder and GPRS communication modem
- Power supply 24 VDC
- Minimum 4 RJ45 ports.

For 24V DC control circuits, a buffer power supply with battery backup should be used (minimum 30 minutes of backup time).

10. Data transmission and visualization

The control and monitoring system is based on a graphical operator panel located at the pilot plant, as well as remote monitoring that allows for process control from anywhere using a standard web browser. All elements of the pilot plant will be visually displayed, along with the parameters of each device and real-time values measured by the monitoring equipment. Data transmission will use a distributed cloud server (such as Talk2M or an equivalent) that enables secure, encrypted VPN connections between the object controller and the operator's computer located anywhere with internet access. The solution must also provide the ability to monitor and control the pilot plant from a mobile phone.

The router equipped with a GPRS modem and at least 4 LAN ports (RJ45) is expected to be used. The PLC controller, HMI panel, and measurement transducer should be connected to the router.

The connection to the pilot plant must allow for a connection from a web browser and have full control over the object, such as:

- Remote connection to the controller for diagnostic purposes or to make program changes
- Changes to device operating parameters
- Access to historical data

- Observation of trends
- Observation of alarm history.

In return, the system must allow for sending alarms in the form of e-mail and/or SMS. An example of such a solution is e-Won Flex. Data can be observed on a local HMI panel installed on the facade of the main distribution panel RG.

The operator panel application and remote access interface should be developed in Polish and English, with the option for the user to choose. The final list of signals and the appearance of screens/tables/charts should be agreed upon with the Contracting authority during the implementation stage.

Warranty

The contractor is obligated to provide a 24-month warranty for all elements of the pilot station.

Drawing

Appendix 1. Schematic diagram of the pilot wastewater treatment system.

The diagram does not show the shut-off valves for pumps, air compressors, ozone production and dosing system elements.

Schematic diagram of the pilot wastewater treatment system