Interreg
Baltic Sea Region

Co-funded by
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SUSTAINABLE WATERS
APRIORA

APRIORA risk assessment framework

APRIORA webinar | 2025-12-15
Lauri Äystö

interreg-baltic.eu/project/APRIORA

WATER-SMART SOCIETIES

Risk assessment framework

Goal

- Representative concentration data that 1) allows for load estimationand 2) is suitable for risk assessment
- Accessible modelling tool that allows authorities and WWTP operators to estimate contaminant concentrations in recipient
- Risk assessment method that 1) accounts not only for environmental risks, but also human health and AMR, and 2) allows WWTP prioritization

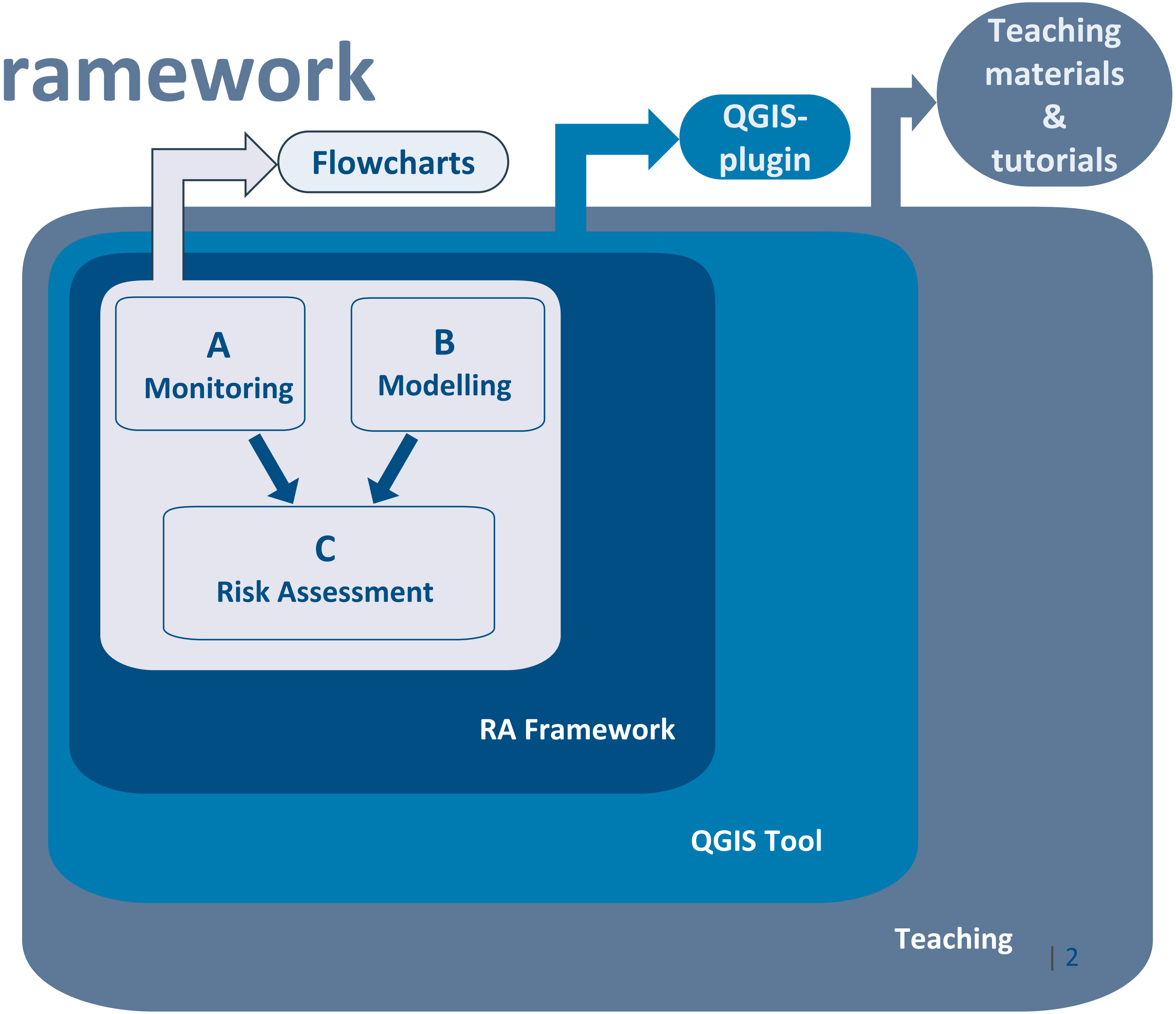



Photo: Ville Junttila

Module A: Monitoring

A: Monitoring

Submodule	Question to answer	Output
A1 - Selecting target compounds	Which contaminants should I monitor?	Compact, meaningful, and justified list of analytes
A2 - Selecting sampling sites and points	Where should I take my samples?	Sampling points in different sections of sewer network and different types of recipients
A3 - Selecting sampling time & frequency	When and how frequently should I take samples?	Justified plan for sampling frequency, taking regulatory status into consideration
A4 - Sampling, storage, and transport procedures	How should I take my samples and ensure they reach the lab in good condition?	Help in selecting apropppriate sampling modes for different sampling sites and guidance for sample storage & transport
A5 - Analyses	What happens to my samples after delivering them to the lab?	Basic understanding of the analytical process for chemical trace substances and AMR abundance
A6 - Data management	How do I process my data?	A statistically justified approach for data processing, avoiding substitution methods for censored data

Example parameter list

Name of contaminant	CAS No.	UWWTD proposal (EC, 2022a)	EQS proposal (EC, 2022b)	GW EQS proposal (EC, 2022b)	WL1 (2015/495)	WL2 (2018/840)	WL3 (2020/1161)	WL4 (2022/1307)	Swedish RBSP (HVMFS 2019:25)	Number of reference concentration exceedances[5]			Reference concentration [µg/l]
										Surface water	WWTP effluent	WWTP influent	
17a-ethinylestradiol (EE2)	57-63-6		X		X	X			X	38	21	11	0.0000170[1]
17b-estradiol (E2)	50-28-2		X		X	X			X	7	16	14	0.000180[1]
Amisulpride	71675-85-9	X								0	0	0	6.78[2]
Amoxicillin	26787-78-0					X	X			3	1	1	0.0780[3]
Azithromycin	83905-01-5		X		X	X				24	45	4	0.0190[1]
Candesartan	139481-59-7	X								0	0	0	124[2]
Carbamazepine	298-46-4	X	X	X						2	10	7	2.50[1]
Ciprofloxacin	85721-33-1					X	X		X	7	25	25	0.0890[3]
Citalopram	59729-33-8	X								0	0	0	4.14[2]
Clarithromycin	81103-11-9	X	X		X	X				6	30	3	0.130[1]
Clindamycin	18323-44-9							X		17	55	4	0.0440[4]
Clotrimazole	23593-75-1						X	X		12	8	2	0.0200[4]
Diclofenac	15307-86-5	X	X		X				X	870	89	46	0.0400[1]
Erythromycin	114-07-8		X		X	X				0	2	1	0.500[1]
Estrone (E1)	53-16-7		X		X	X				21	14	13	0.000360[1]
Fluconazole	86386-73-4						X	X		1	7	2	0.250[4]
Gualynurea	141-83-3							X		0	3	0	100[4]
Hydrochlorothiazide	58-93-5	X								0	0	0	9.02[2]
Ibuprofen	58560-75-1		X							86	20	44	0.220[1]
Irbesartan	138402-11-6	X								0	0	0	178[2]
Metformin	657-24-9							X		0	0	9	156[4]
Metoprolol	37350-58-6	X								0	0	0	19.0[2]
Miconazole	22916-47-8						X	X		0	0	0	0.200[4]
O-desmethylvenlafaxine	93413-62-8						X	X		28	5	5	0.0600[4]
Ofloxacin	82419-36-1							X		1	24	7	0.0260[4]
Primidone	125-33-7			(X)[1]						0	1	0	3.98[2]
Sulfamethoxazole	129378-89-8			X			X	X		21	27	9	0.100[4]
Triclosan	3380-34-5		X						X	5	16	21	0.0200[1]
Trimethoprim	738-70-5						X	X		4	35	18	0.100[4]
Venlafaxine	93413-69-5	X					X			15	48	9	0.0600[4]

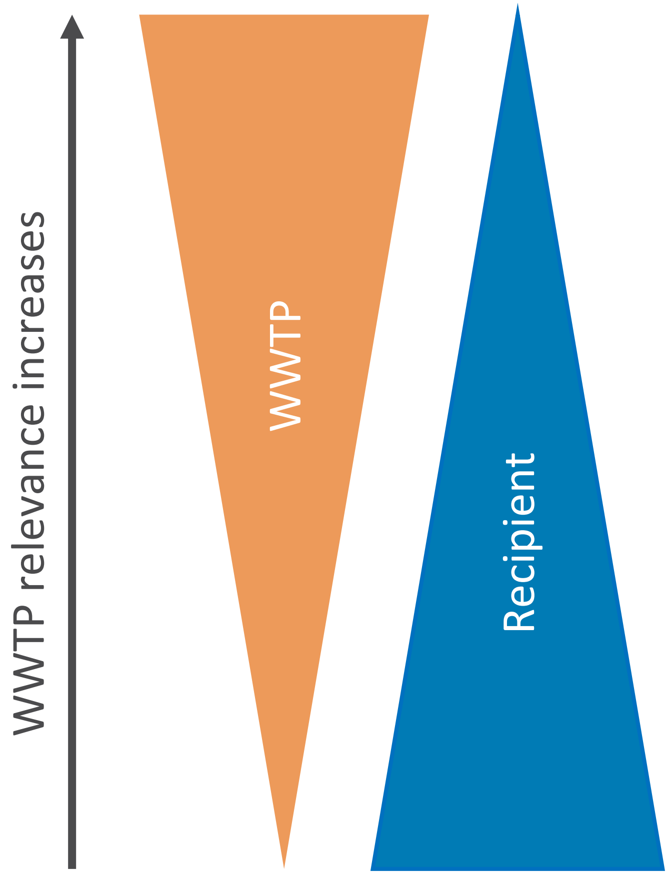
APRIORA piloting substances

[1] EC, 2022a
[2] Posthuma, L., van Gils, J., Zijp, M.C., van de Meent, D., de Zwart, D., 2019. Species sensitivity distributions for use in environmental protection, assessment, and management of aquatic ecosystems for 12 386 chemicals. Environmental Toxicology and Chemistry 38, 905–917. https://doi.org/10.1002/etc.4373
[3] WL3, 2020/1161
[4] WL4, 2022/1307
[5] Concentration data from UBA 2021

Sampling sites

Where should samples be taken?

- Focus on WWTPs as the primary source of pharmaceutical pollution
- Prioritize WWTPs, where discharge volume (or number of connected persons) is high compared to recipient flow
- Site types
    - Upstream from WWTP
    - WWTP influent
    - WWTP effluent
    - Downstream from WWTP
    - End of catchment
    - Points of interest



Sampling sites

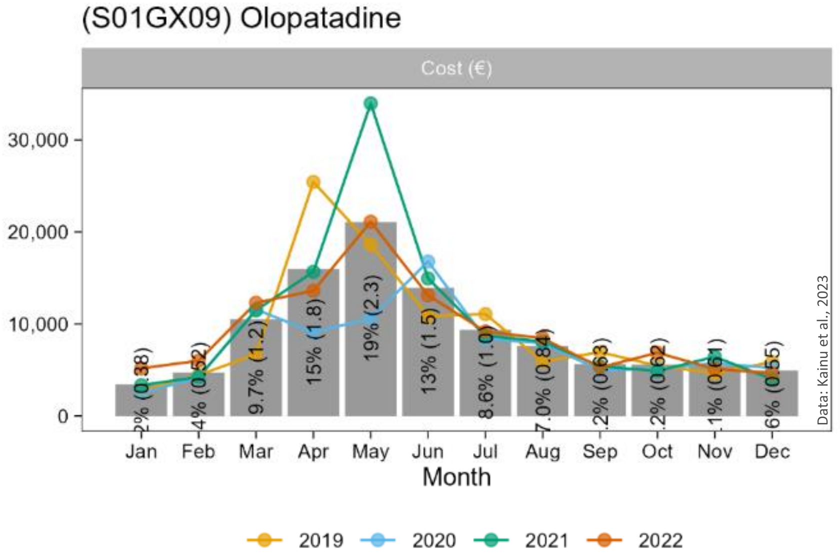
Some considerations…

- Consider using dilution factor for prioritization, consider using cumulative wastewater load
- Use actual number of connected persons in stead of PEs
- Sites in surface waters, upstream from suspected emission sources are important for pinpointing emissions
- The availability of other monitoring data should be considered when selecting sampling sites

WWTP	Notes	WWTP & recipient flow			Population			
		Recipient flow (m3/a)	Dilution factor		Population		Recipient flow / population (m3/(person*a))	
			Individual plant	Cumulative	Individual plant	Cumulative	Individual plant	Cumulative
A	Upstream sampling point could act as a “background”	126 000 000	111	111	13 200	13 200	9 600	9 600
B	Upstream sampling point could act as a “background”	198 000 000	417	417	8 000	8 000	25 000	25 000
C	The only WWTP in this tributary	284 000 000	36.6	36.6	66 200	66 200	4 300	4 300
D	Downstream from A & B	516 000 000	456	189	14 000	35 200	37 000	15 000
E	Downstream from A, B & D	669 000 000	476	161	12 300	47 500	54 000	14 000
F	Downstream from A, B, C, D & E. The last WWTP before household water intake	1 320 000 000	2000	105	4 510	118 000	293 000	11 000

- Suface water sampling sites are ideally located at or near stream gauging stations
    - Optionally, use regional models

Sampling frequency & timing



- Pharmaceutical discharges are driven by their consumption
    - Seasonal patterns are likely for some contaminants
- Environmental conditions affect concentrations & load (dilution & removal processes)
- As a bare minimum, the number of samples in surface waters should match the number of seasons in the region, meaning at least four samples per year
- Sampling frequency may be affected by consumption patterns
    - Discharged only by those using the compound
    - If monitoring compounds with very low consumption, or sites with low number of connected persons, sporadic sampling might not ”hit a pulse”

$$N_{pulses\ in\ WWTP\ catchment} = \frac{Cons_{nat}}{365} \times \frac{Pop_{WWTP}}{Pop_{nat}} \times \frac{1}{dose_{day}} \times n_T, \text{ where}$$

$N_{pulses\ in\ WWTP\ catchment}$ = Number of pulses containing the substance of interest (e.g. number of toilet flushes at the sampling location) [-]

$Cons_{nat}$ = Total annual pharmaceutical consumption data [kg/a]

Pop_{WWTP} = Population connected to the WWTP

Pop_{nat} = Total population

$dose_{day}$ = Typical dose per patient [kg/d]

n_T = Number of times a person goes to the toilet per day (default = 5)

APRIORA – Piloting

Monitoring – in action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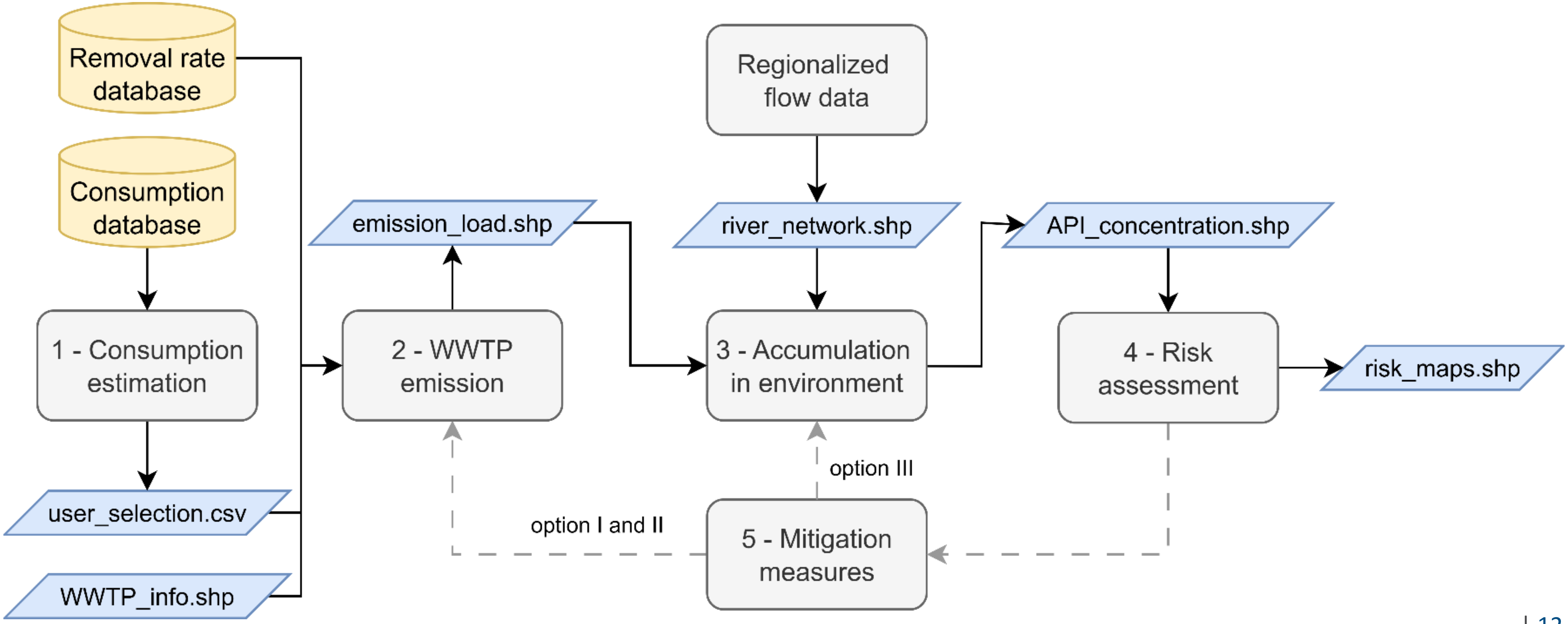
Module B: Modelling

B: Modelling

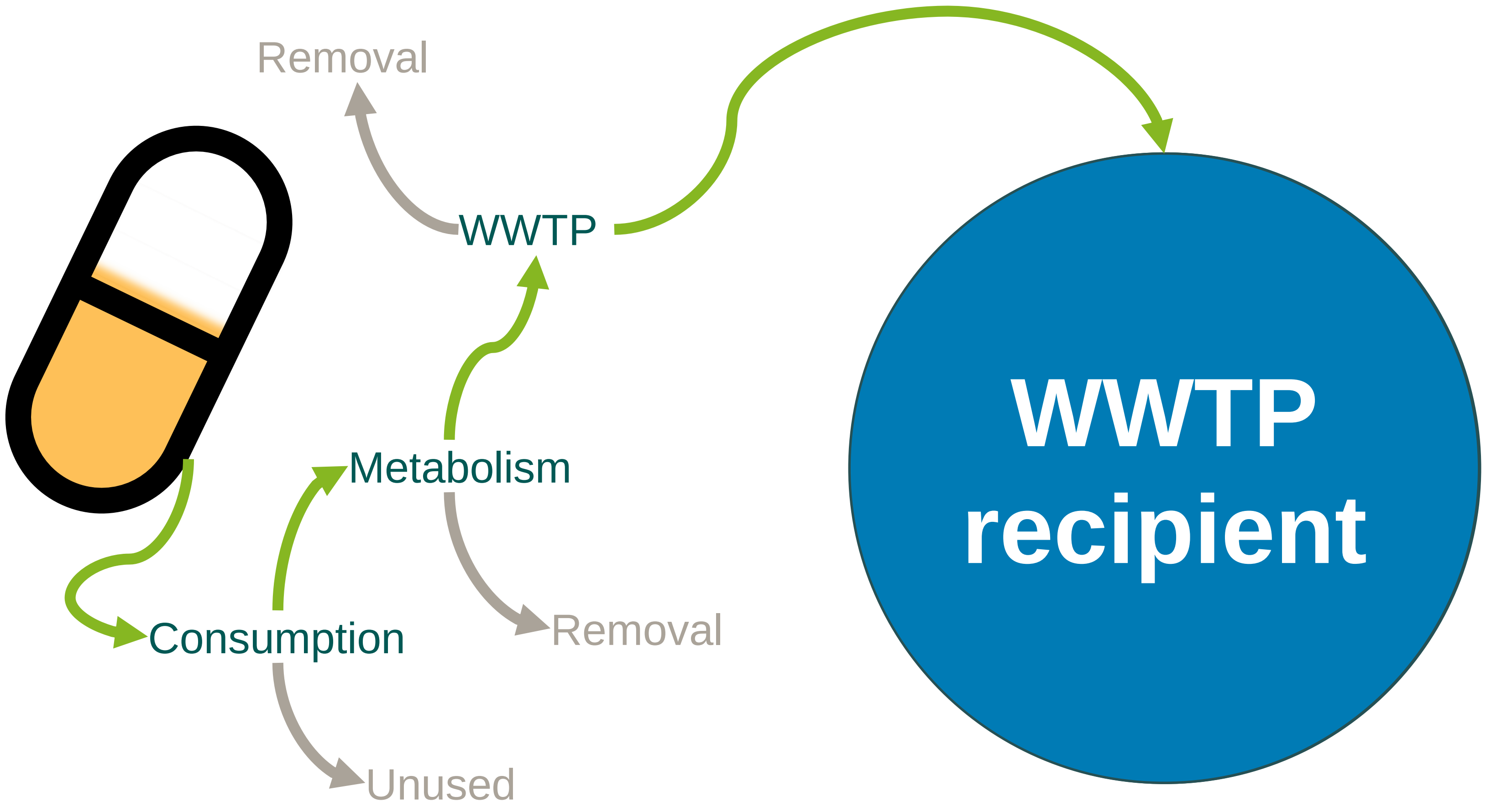
Submodule	Question to answer	Output
B1 - Consumption estimation	How much of the selected compound is used & excreted in my catchment?	Estimate of the regional annual per capita load to wastewaters
B2 - WWTP emission loads	How much of the compound is discharged into recipient waters via WWTPs in my catchment?	Annual WWTP- and substance-specific load
B3 - Flow estimation	What are the flow characteristics in my catchments?	Regionalized information of mean flow and mean low flow, further divided into subcatchments by WWTP locations
B4 - Accumulation in environment	What is the cumulative contaminant loading and concentration at different river sections?	Cumulative loading from all WWTPs upstream, and concentration estimates, accounting also for low flow conditions
B5 - Data management	Do the predicted concentrations match measured ones?	Guidance on adjusting the model, in case measured and predicted concentrations do not match
B6 - Mitigation measures	What can I do to mitigate the risks indicated by my concentration dataset?	Guidance on different mitigation options, and how to implement them in the calculation tool

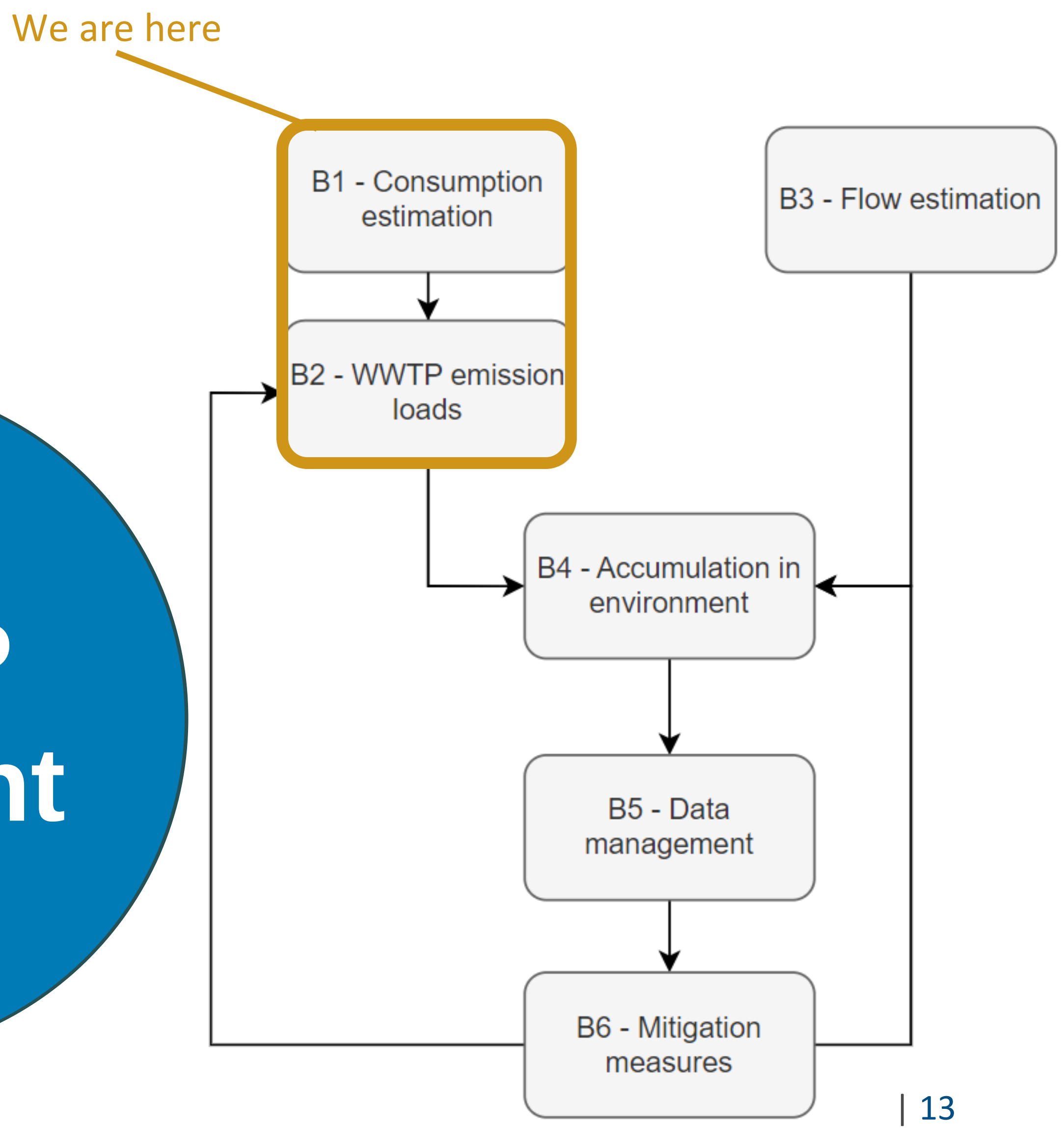
APRIORA output – tool

Technical transfer of model into QGIS



Estimating pharmaceutical load





Reality check

Can we estimate effluent concentration?

- Kisielius et al. (2024) measured 35 pharmaceuticals in 82 WWTPs across 8 countries and compiled sales data
- Predicted WWTP effluent concentrations calculated using three approaches

  PEC_{TRA} = Total residue approach

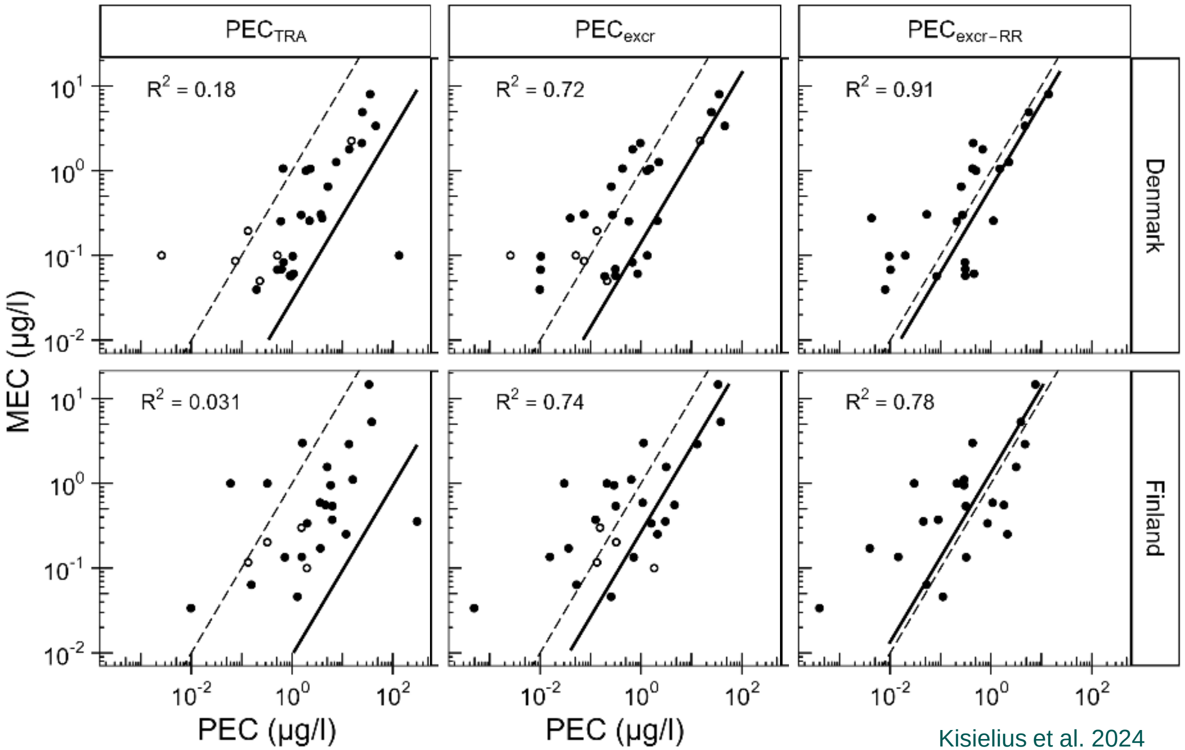
  ⇒ Quite conservative

  PEC_{excr} = PEC_{TRA} adjusted with human metabolism

  ⇒ Correlation improves

  $PEC_{excr\text{-}RR}$ = PEC_{excr} adjusted with WWTP removal rate

  ⇒ Correlation further improves



Kisielius et al. 2024

Estimating recipient flow

Why do we need it?

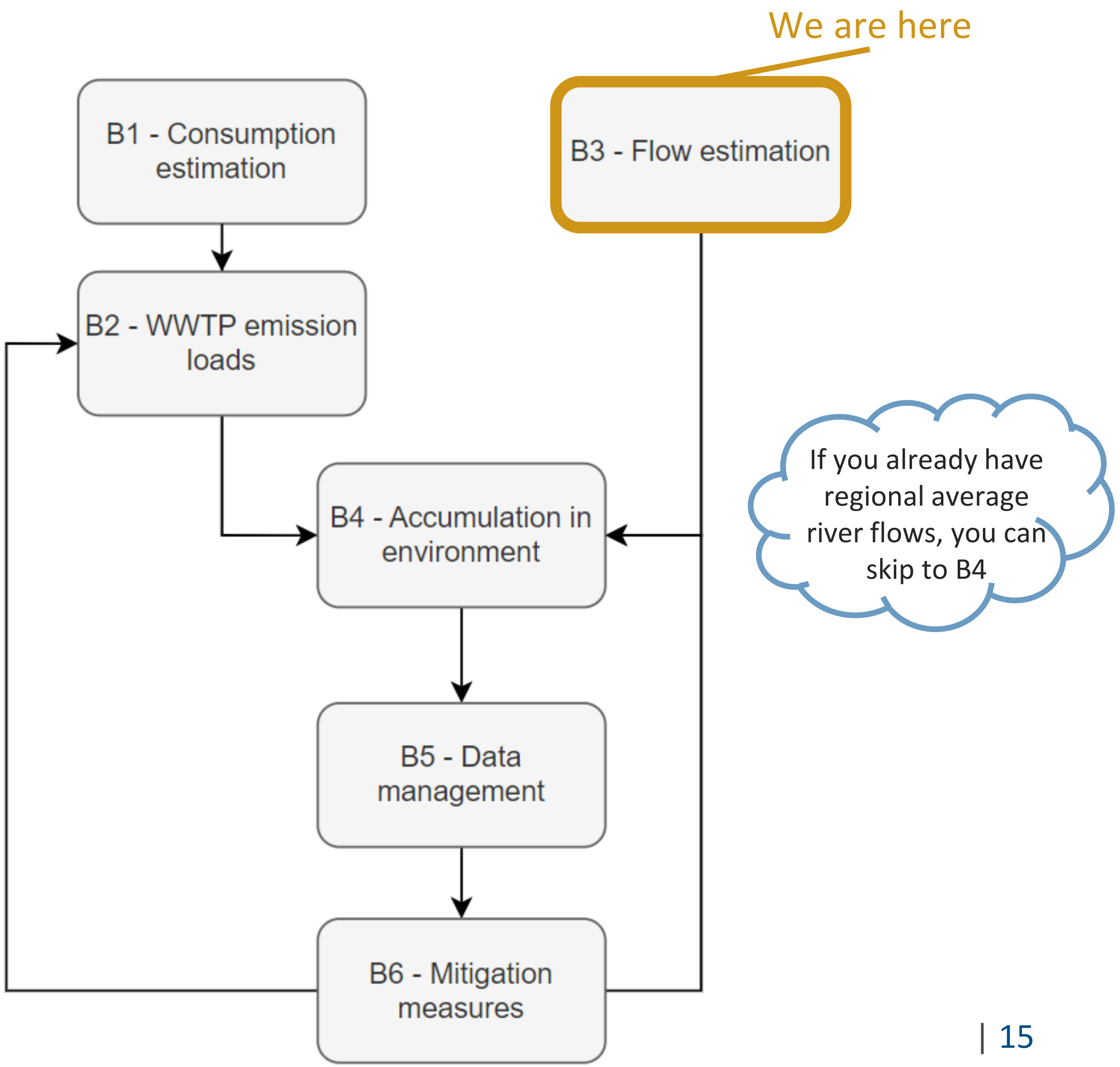
- To estimate environmental concentrations of selected contaminants.

Which resolution is the output?

- Annual mean flow and annual mean low flow

Why this resolution?

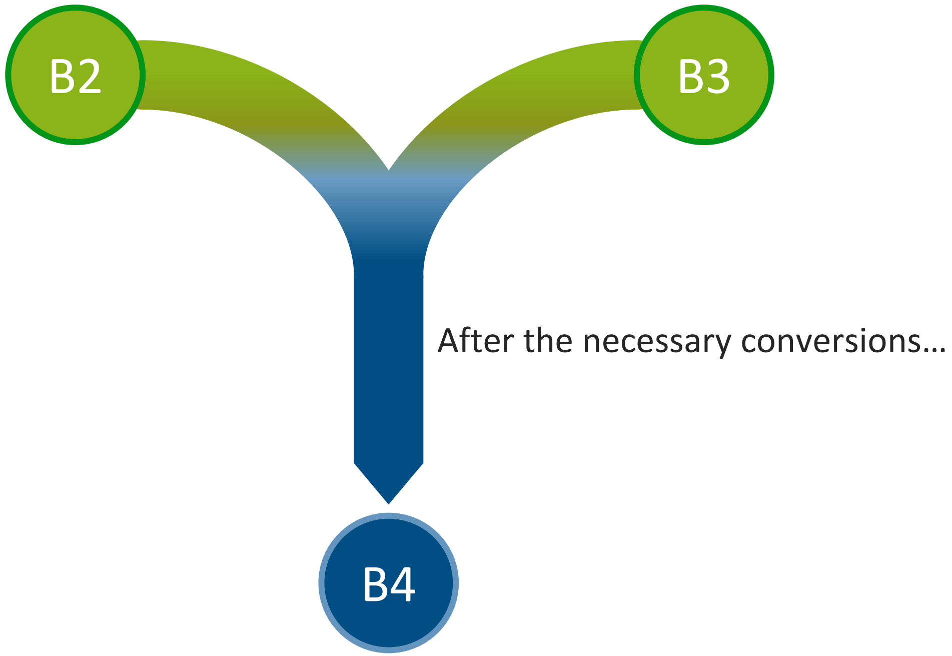
- Consumption statistics are in masses per inhabitant year (kg/i/a), so a better resolution is not necessary for this purpose.
- Low flow periods are ecologically sensitive and critical for risk assessment (lower flow = higher concetrations).



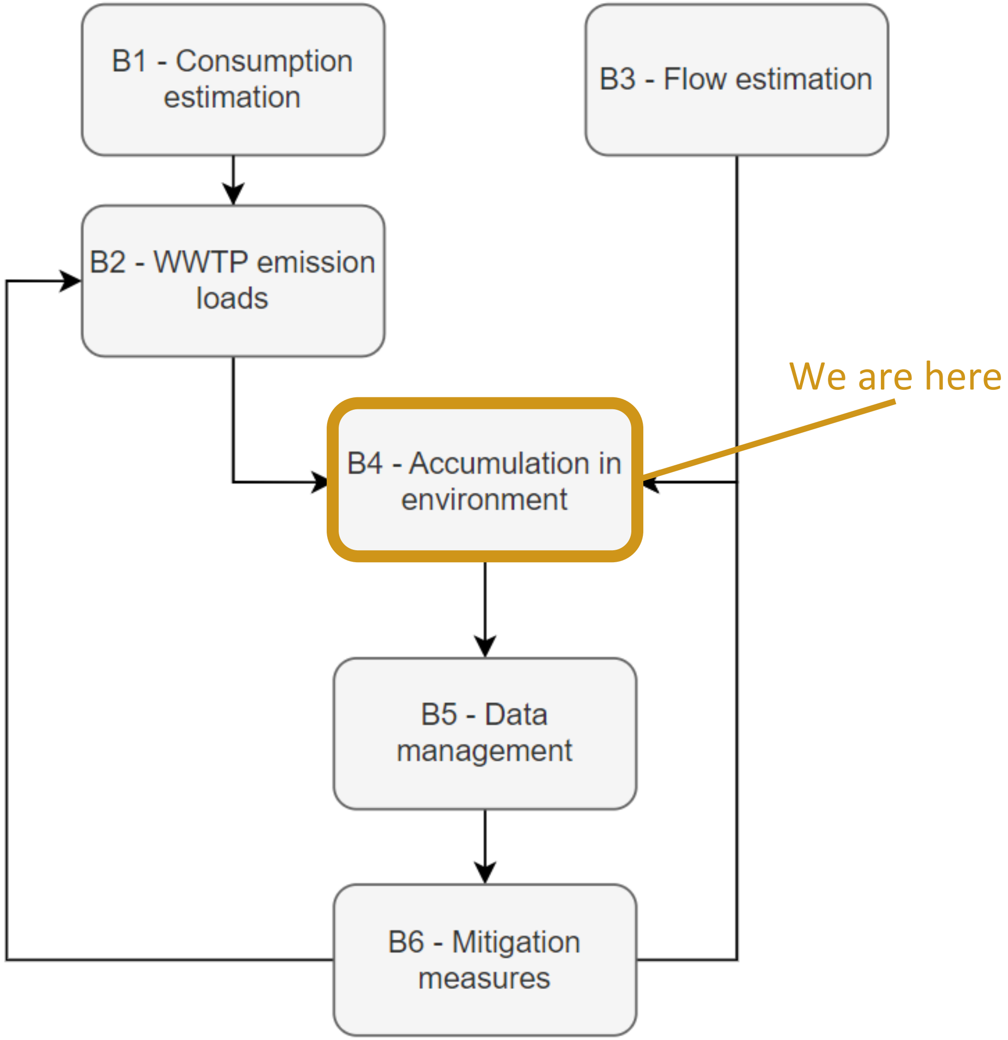
B4: Pollution Loads and Concentrations in the Environment

Yearly emission load [kg/a]

Mean flow and mean low flow [m³/s]



Predicted Environmental Concentration (PEC) of specific contaminant [ng/L]



APRIORA – Piloting

Model development & teaching in practice

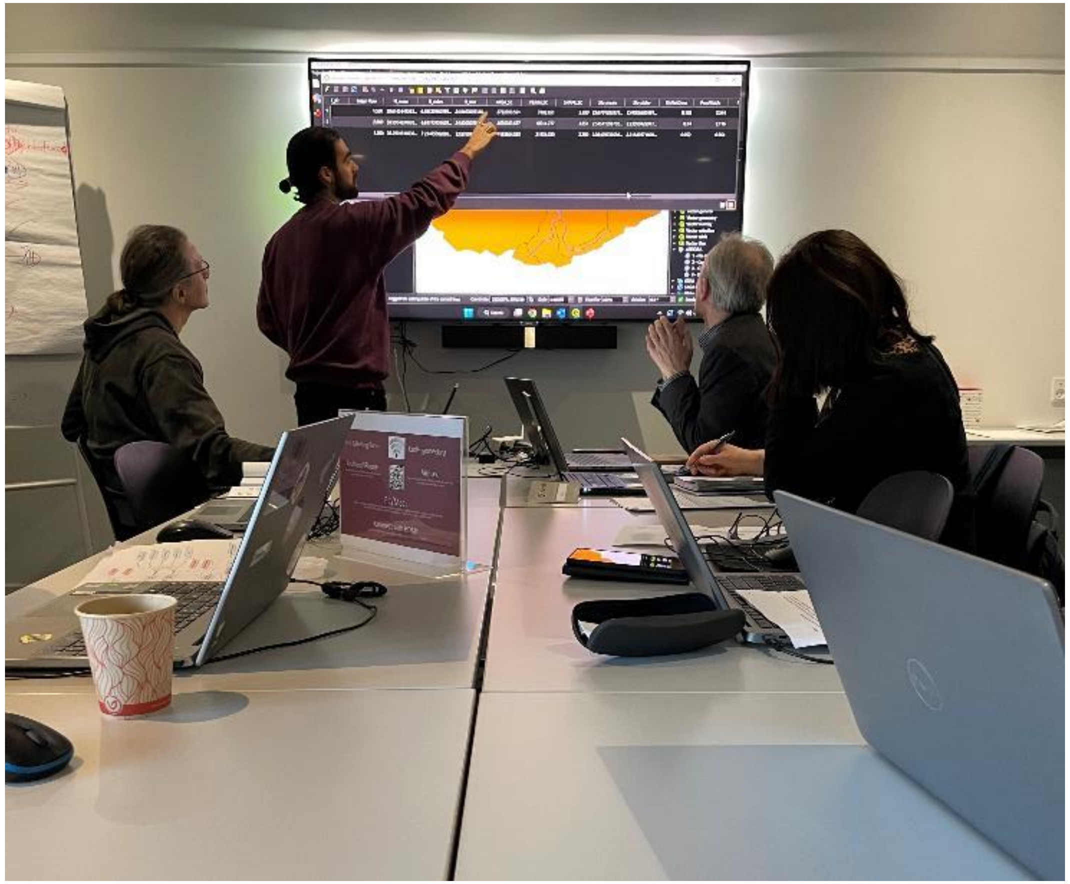
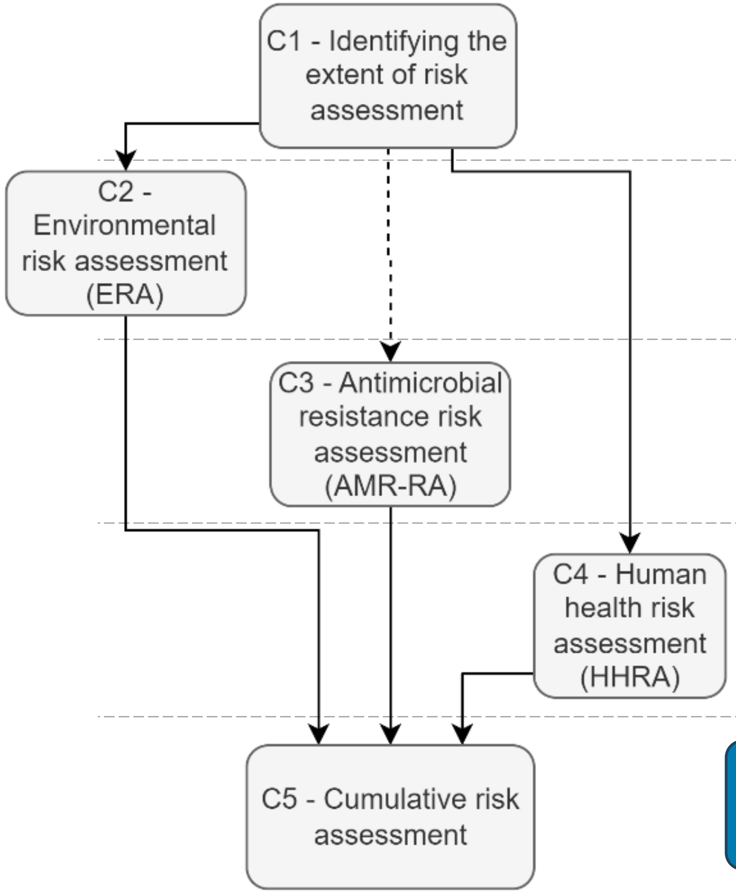


Photo: Lauri Äystö

Module C: Risk assessment

C: Risk assessment

Submodule



Question to answer	Output
What is the scope of the risk assessment required for my contaminant?	Guidance on determining whether to carry out an AMR assessment or not
How should I estimate if my contaminant causes a risk?	Guidance on acquiring ecotoxicological/regulatory threshold values and calculating risk quotients
How should I estimate if my contaminant causes a risk of promoting AMR?	Guidance on acquiring threshold values derived based on AMR promotion and calculating risk quotients
How should I estimate if my contaminant causes a risk to human health?	Guidance on approaches for estimating exposure via drinking water, swimming, and fish consumption along with guidance for calculating related hazard quotients
How do I summarise my results in a meaningful way that allows me to prioritize the WWTPs in my catchment?	Guidance on creating index values for comparing sites, and incorporating different risk assessments into a single value

Risk assessment (Env., human, AMR)

General approach

$$RQ = \frac{Conc.}{RefConc.}$$, *where*

RQ	=	*Risk quotient*
Conc.	=	*Concentration in relevant environmental compactment (predicted or measured)*
RefConc	=	*Reference concentration (e.g. EQS)*

- RQ>1 indicates risk
- For environmental risk assessment, ecotoxicological thresholds derived under EU WFD processes have been prioritized
- PNECs derived on AMR-basis are being developed by Gdansk University of Technology
- For human health risk assessment, reference dosages are difficult to obtain
    - Rough orientation values for drinking water are available
    - Work in progress…

Health Reference Values ("gesundheitlicher Orientierungswert" - GOW)

https://www.umweltbundesamt.de/sites/default/files/medien/5620/dokumente/listegowstoffeohnepsm-20230317-homepage_0.pdf

	GOW [µg/L]
No data avaiable	0,1
Less data, but mainly negative	< 0,3
Non-genotoxic	< 1,0
Non-genotoxic, harmful to germ cells nor neurotoxic	< 3,0

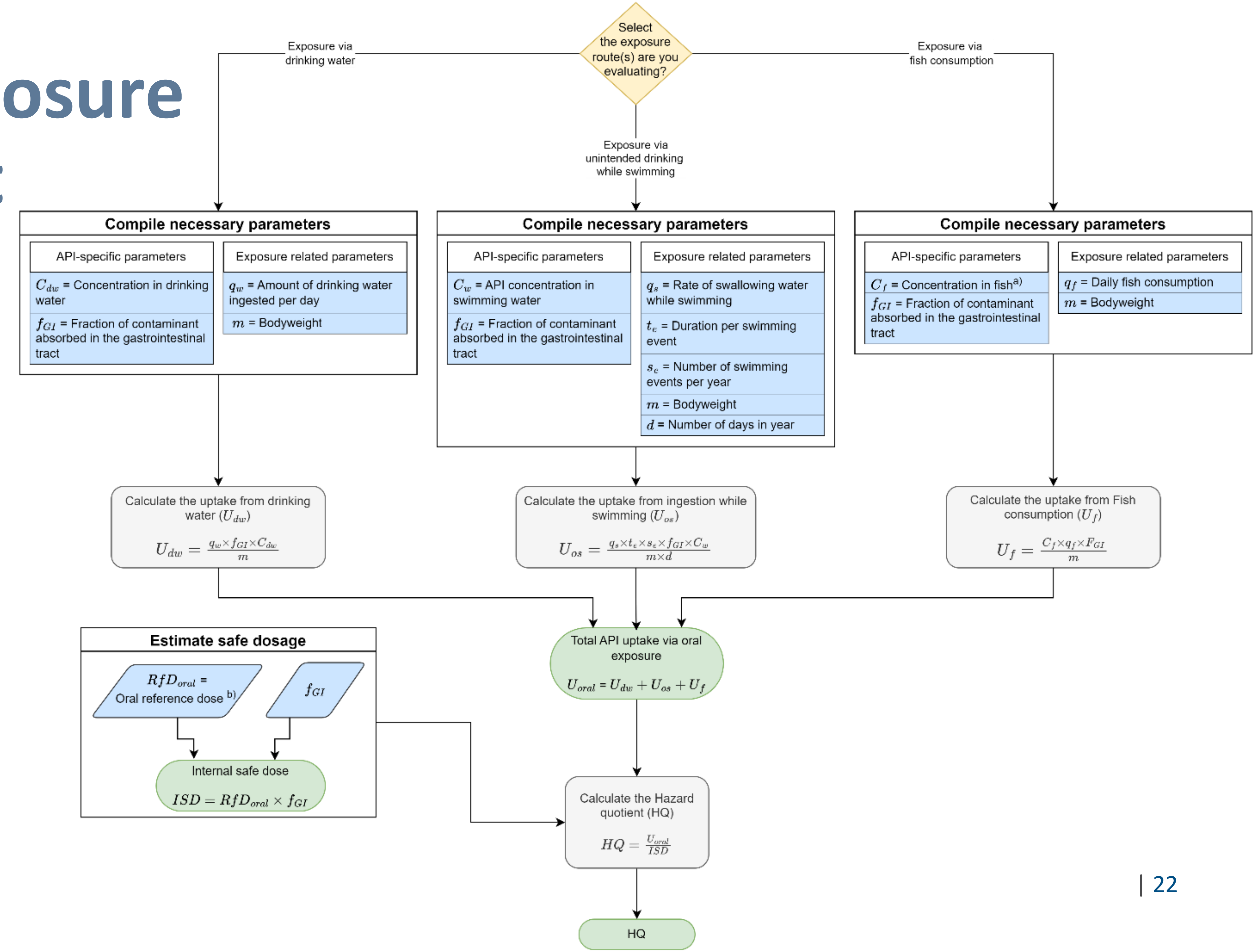
Exposure assessment (Env., human, AMR)

- Environmental risk assessment & AMR risk assessemt
  - Exposure assessment relies on predicted and measured concentrations

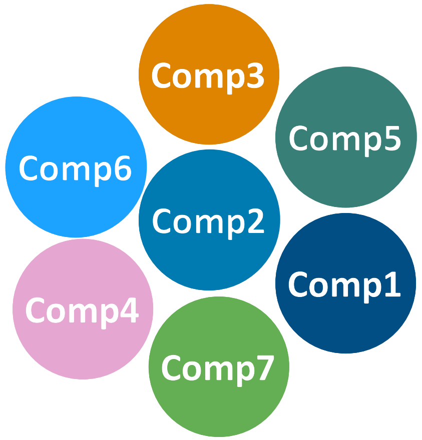
- Human health risk assessment
  1) Exposure via drinking water
  2) Exposure via unintended drinking while swimming
  3) Exposure via fish consumption

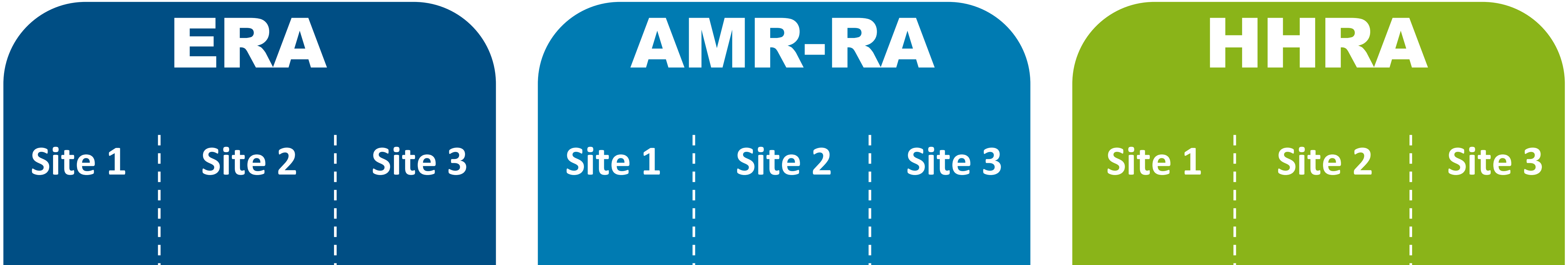
Total exposure

Human exposure assessment

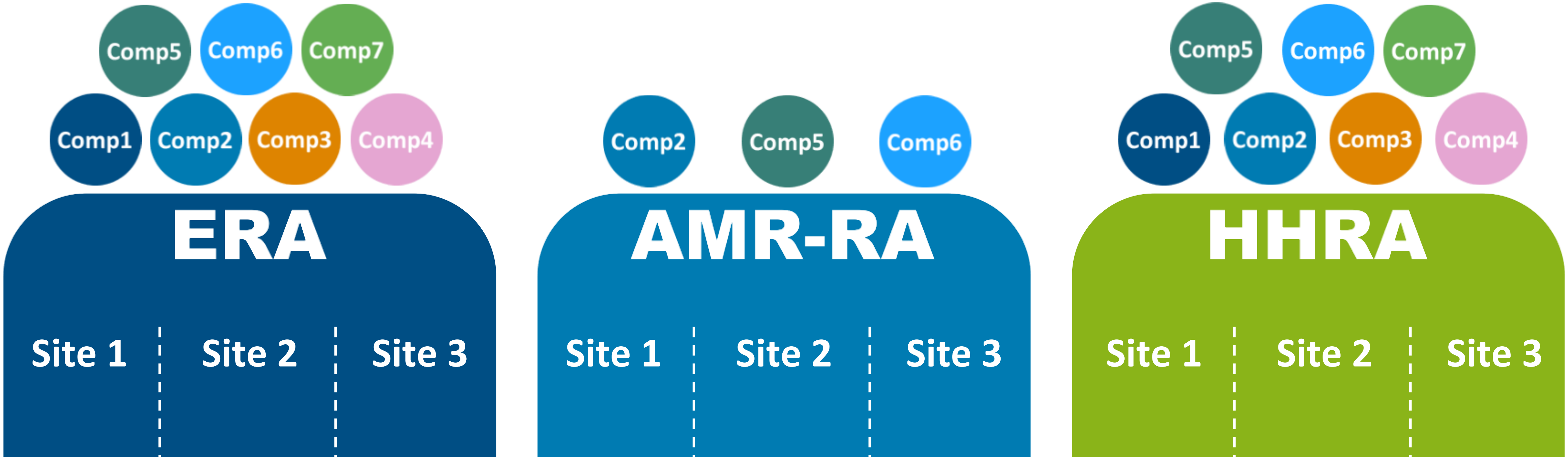


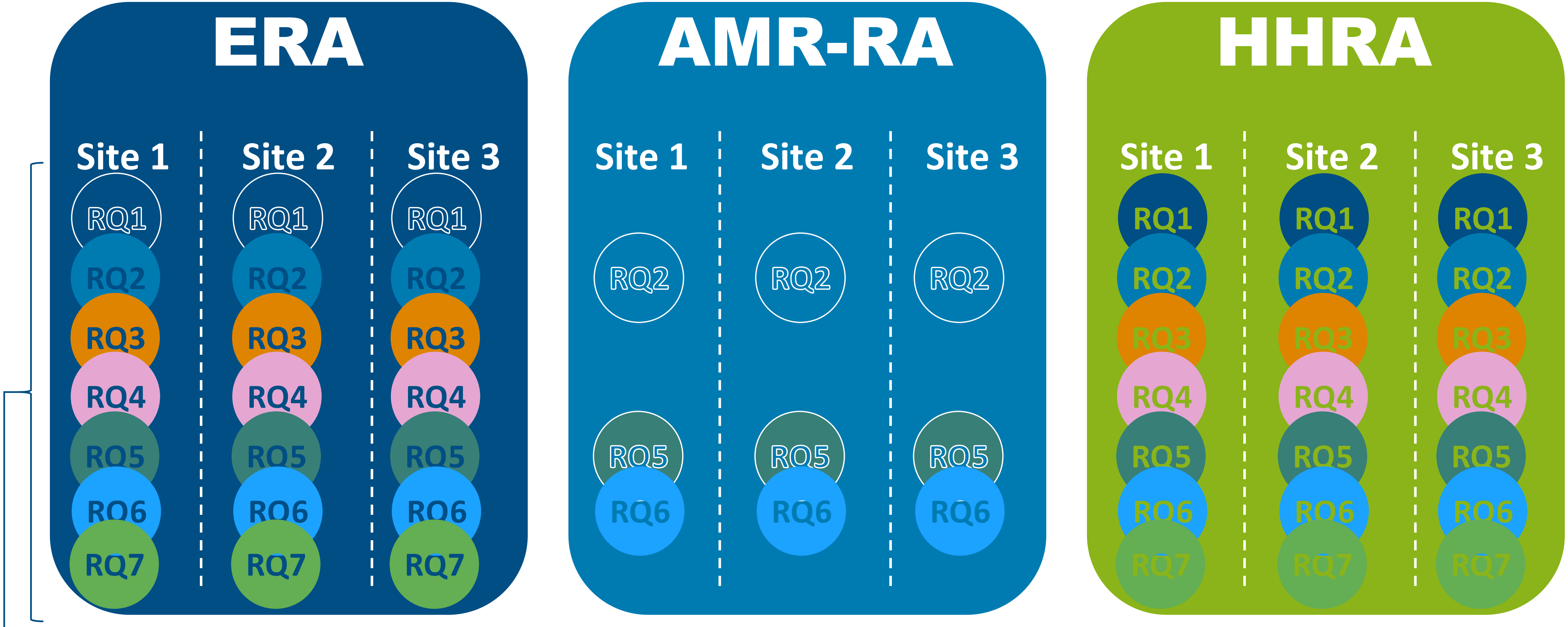
Cumulative risk assessment





Cumulative risk assessment



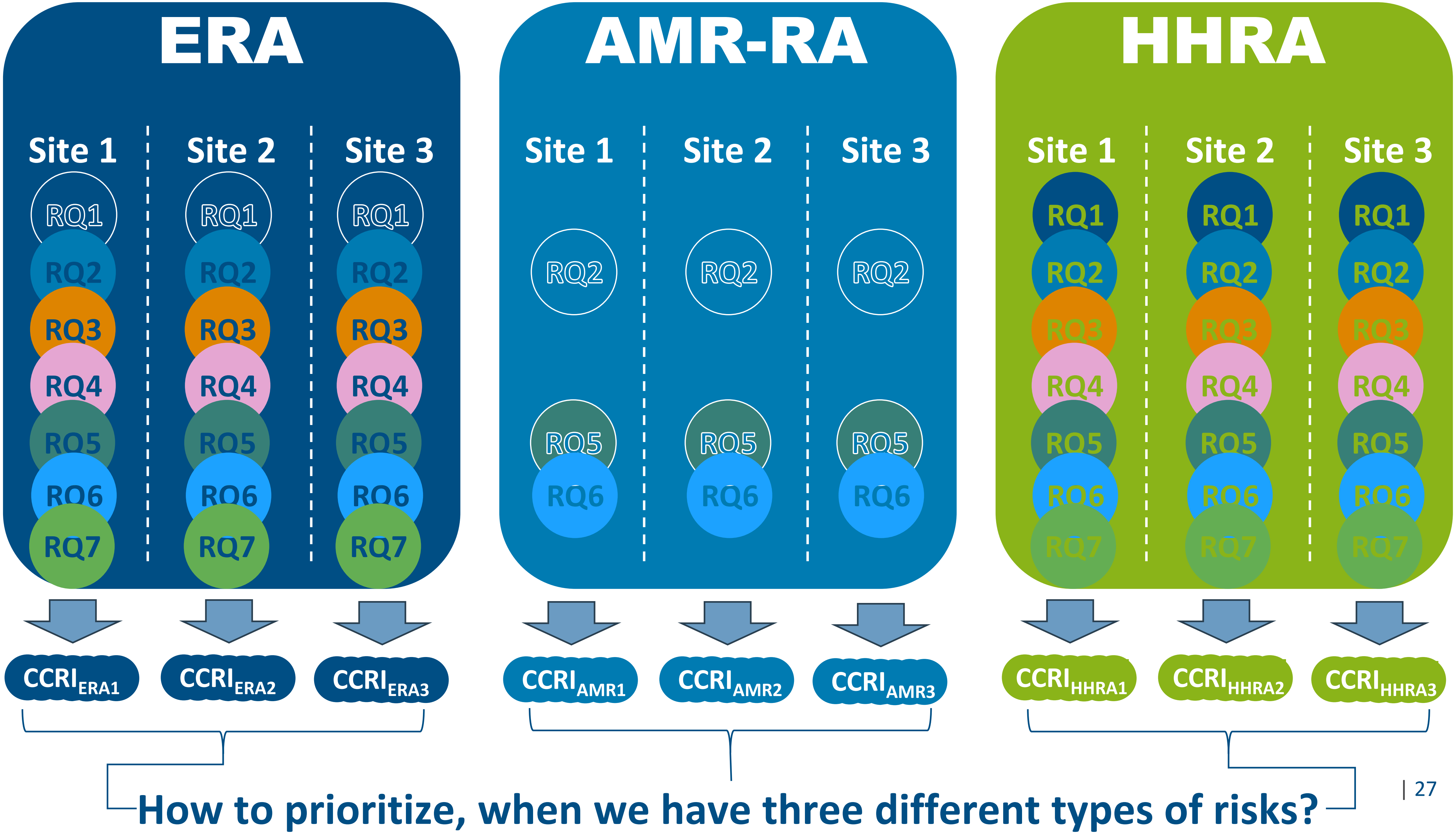


How to prioritize, when we have multiple RQs for each site?

Cumulative risk assessment

Solution

- Component Cumulative Risk Index (CCRI)
    - Summarises RQs within each risk category for each sampling site into an index value with fixed minimum and maximum values
    - Increasing the number of analytes will not result in increasing risk indication



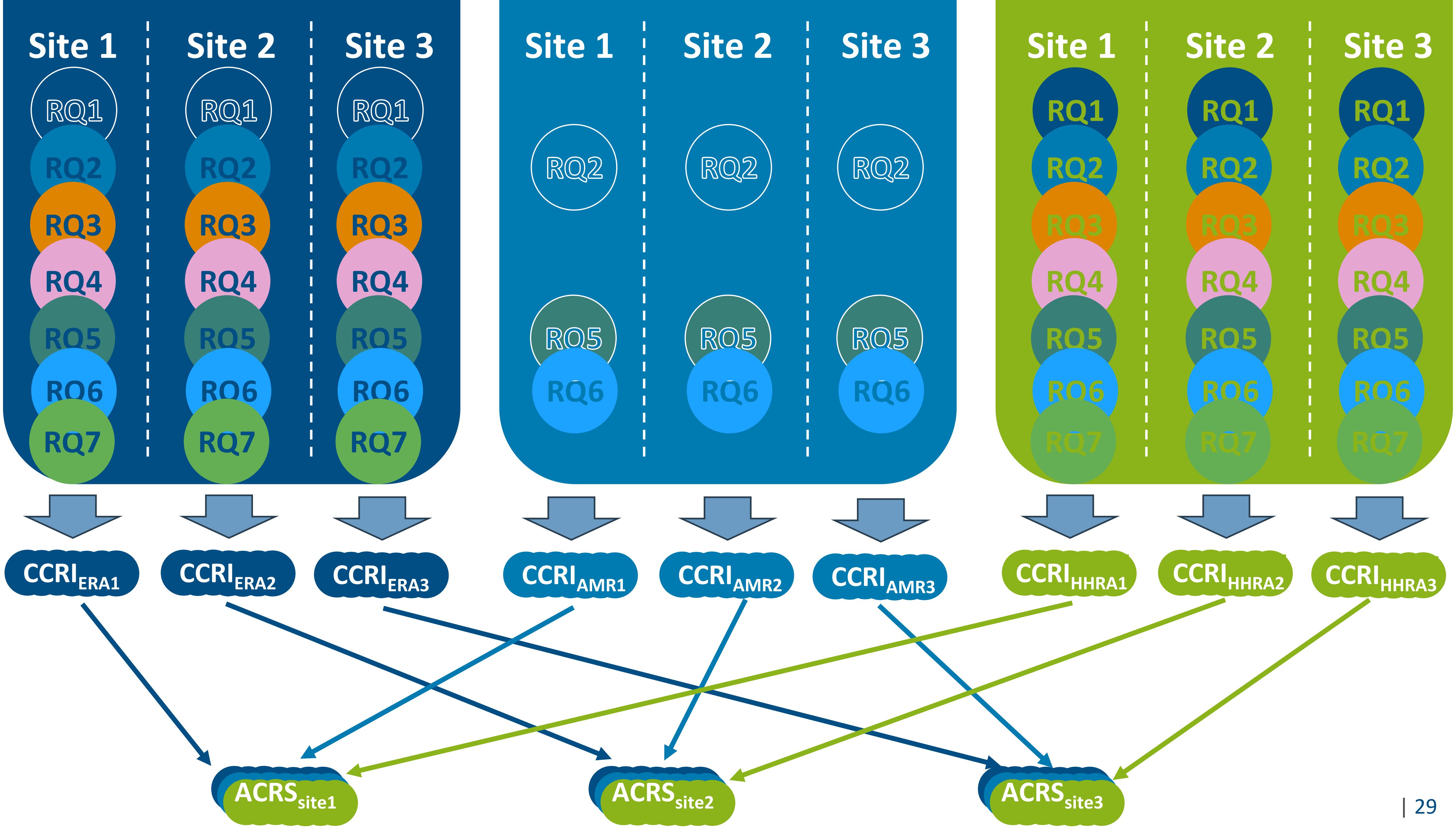
ERA
AMR-RA
HHRA
Site 1
Site 2
Site 3
RQ1
RQ2
RQ3
RQ4
RQ5
RQ6
RQ7
CCRI ERA1
CCRI ERA2
CCRI ERA3
CCRI AMR1
CCRI AMR2
CCRI AMR3
CCRI HHRA1
CCRI HHRA2
CCRI HHRA3
How to prioritize, when we have three different types of risks?

Cumulative risk assessment

Solution

- Component Cumulative Risk Index (CCRI)
    - Summarises RQs within each risk category for each sampling site into an index value with fixed minimum and maximum values
    - Increasing the number of analytes will not result in increasing risk indication

- Aggregated Component Risk Score (ACRS)
    - Summarises site- and risk category- specific CCRIs into an index value, which will allow for prioritizing sites
    - The user will have the option of implementing their own weighing factors for ACRS calculation
    - ACRS increases => priority should increase


Site 1
Site 2
Site 3
RQ1
RQ2
RQ3
RQ4
RQ5
RQ6
RQ7
Site 1
Site 2
Site 3
RQ2
RQ5
RQ6
Site 1
Site 2
Site 3
RQ1
RQ2
RQ3
RQ4
RQ5
RQ6
RQ7
CCRI_ERA1
CCRI_ERA2
CCRI_ERA3
CCRI_AMR1
CCRI_AMR2
CCRI_AMR3
CCRI_HHRA1
CCRI_HHRA2
CCRI_HHRA3
ACRS_site1
ACRS_site2
ACRS_site3

APRIORA – conclusions and outlook

- Piloting the framework ongoing since 11/2024
- Model quality still needs to be further evaluated
- QGIS-plugin to be published in 2026, but already accessible via local repository
- Better information on threshold concentrations for AMR and health risks is needed

Contacts

Lauri Äystö
Lauri.aysto@syke.fi

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References

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