Deriving emission factors for municipal wastewater treatment plants in large river basins

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Background and objectives

Local emission = *EF · AR* (emission factor * "application rate")

Why emission factors

- large number of plants & parameters + costly analytics → lack of data
- the "science of extrapolation"
- municipal wastewater treatment plants: (one of) the most important pathways (depending on compound and location)
- EF also used in emission models (like MoRE model)

Challenge of Danube River Basin:

- heterogeneous socioeconomical situation, environmental policy, data availability

General objectives

- Develop an approach that can be used in heterogeneous river basins, for all types of point sources and beyond

Particular objectives

- Derive emission factors of municipal wastewater treatment plants in the Danube River Basin
- Account for uncertainties by defining variants (best / worst case)
- Simulate effects of future development of wastewater treatment infrastructure (UWWTD 1991 and UWWTD 2024)

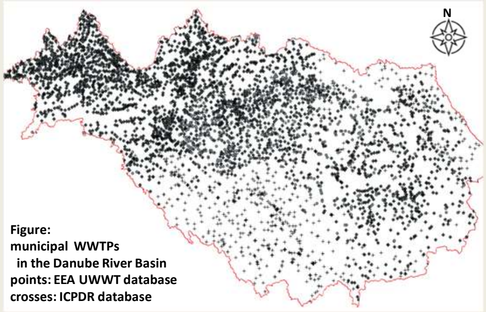


Figure: municipal WWTPs in the Danube River Basin points: EEA UWWT database crosses: ICPDR database

Derivation of emission factors for 9 heavy metals and 4 organic compounds

Database content & methodological approach

Data collected from various projects and regular national monitoring, harmonized database (Kittlaus et al. 2023).

Descriptive statistics

Looking for significant differences between groups by combined ANOVA + ROS

Example: copper (Cu) [μg /L]

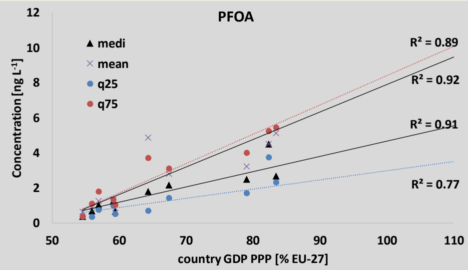
Data analysis (descriptive stats):

p value	AT	BG	HU	RO
AT	1.000	0.001	0.100	0.021
BG	0.001	1.000	0.001	0.001
HU	0.100	0.001	1.000	0.038
RO	0.021	0.001	0.038	1.000

	n	n > LOQ	median	mean	std	q25	q75
AT	22	22	41	42	17	27	52
BG	323	284	0.003	0.23	1.5	0.0020	0.0050
HU	71	71	56	63	55	26	71
RO	9	9	32	26	17	5.8	35

Recommended EF:

	base variant	best case variant	worst case variant
notreat	34	16	61
prim sec	10	5.6	18
tert	4.0	2.3	7.3



PFOS

region	countries	capacity class	n data	n > LOQ	median	mean	std	q25	q75	suggested further countries
"Upper DRB"	AT, DE, HR, SI	2000<=PE<10K	98	66	2.0	2.6	2.3	0.98	3.0	CH, IT
"Upper DRB"	AT, DE, HR, SI	10K<=PE<100K	563	415	3.0	7.4	36	1.9	4.1	CH, IT
"Upper DRB"	AT, DE, HR, SI	PE>=100K	480	415	5.0	13	45	3.0	8.0	CH, IT
"Middle DRB"	BA, CZ, HU, RS, SK	PE<100K	154	67	0.58	22	179	0.13	2.7	PL, ME,
"Middle DRB"	BA, CZ, HU, RS, SK	PE>=100K	100	76	3.6	7.0	14	1.5	7.8	PL, ME,
"Lower DRB"	BG, RO, UA	any	74	21	0.4	1.1	2.1	0.14	1.1	AL, MD, MK

Heavy metals

- Not enough data to reveal regional patterns
- For most elements, effluent concentrations drop with tertiary treatment

Organics

pharma: strong regional differences

PFAS: stronger (PFOA) or weaker (PFOS) correlation with economic development

both: more data needed for further categorization

Prioritizing further monitoring

Data collected from various projects and regular national monitoring, harmonized database (Kittlaus et al. 2023).

Descriptive statistics

Delineation of homogeneous groups by combined ANOVA + ROS

Calculation of scenarios on the development of WWTP infrastructure

Scenarios

sc0: current development of WW infrastructure

sc1: implementation of the EU UWWTD 1991:

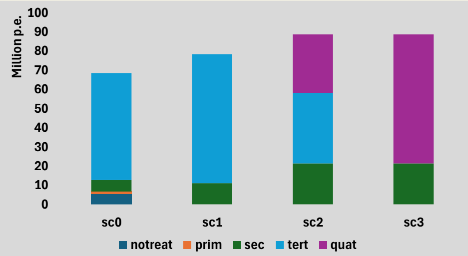
secondary treatment on agglomerations > 2000 p.e.

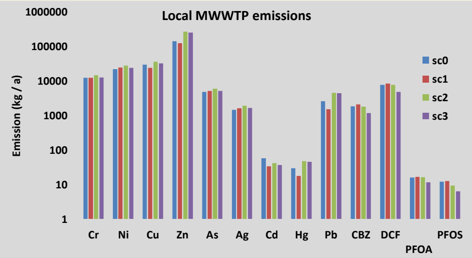
tertiary treatment on larger plants)

sc2: additional collection at agglomerations > 1000 p.e.

quaternary treatment at WWTP > 150 K p.e.

sc3: additional quaternary treatment at WWTP > 10 K p.e





Conclusions & outlook

Conclusions (EF)

Heavy metals

- Technology dependence
- Too few data to investigate regional variations

Organics

- Technology-independent, but significant regional variation
- Data gaps in the southeastern part of the Danube basin
- Pharmaceutical residues: country-specific values
- PFOA: strong correlation with economic development
- PFOS: differentiation by region and site size

Conclusions (scenarios & other)

New connections increase the loads

Substantial share of WWTPs need quat to reduce total loads

Method capable of optimizing new monitoring

Suggested methodology

1. **Delineate homogeneous regions based on inflow data**
2. **Create homogenous technology categories**
3. **Further categorize by treatment size (if data allows)**

Next steps

Pharmaceutical consumption data by countries?

Elaborated consideration of small agglomerations (p.e. < 2000)

References

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