Pharmaceuticals as new emerging contaminants in the Arctic environment:Implications and Perspectives

Roland Kallenborn[*,1,2], Julie Sofie Strømberg[1], Eva Brorstrøm-Lunden[3], Lars-Otto Reiersen[4], Terje Vasskog[5,6]

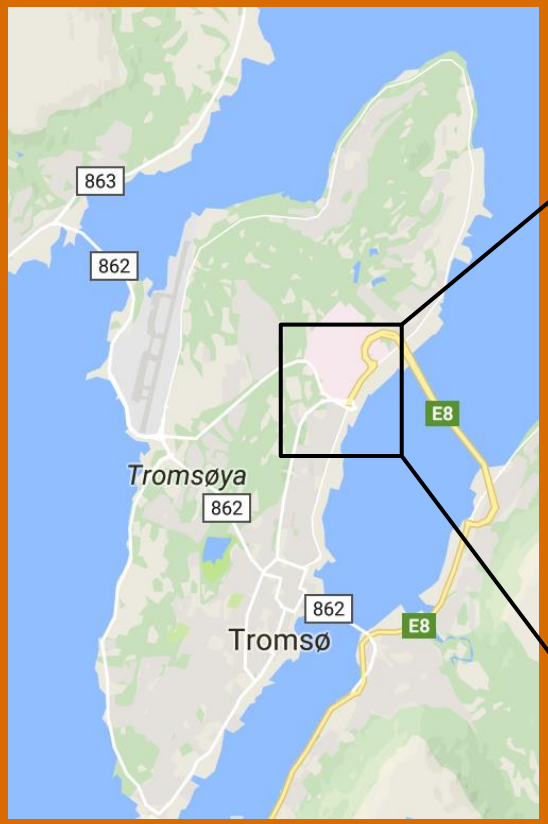
[1]Norwegian University of Life Sciences (NMBU), Faculty of Chemistry, Biotechnology and Food Sciences (KBM), NO-1432 Ås, Norway
[2]University Centre in Svalbard (UNIS), Department of Arctic Technology (AT), 9171 Longyearbyen, Svalbard, Norway
[3]IVL- Swedish Environmental Research Institute, SE-411 33 Gothenburg, Sweden
[4]Arctic Monitoring and Assessment Programme (AMAP), NO-0349 Oslo, Norway
[5]University of Tromsø, Department of Pharmacy, NO-9037 Tromsø, Norway
[6]NORUT Northern Research Institute, NO-9294, Tromsø

Pharmaceuticals and personal care products (PPCPs)

- Indicator chemicals for human activities
- **Sources:** Hygiene products, Cosmetics, supplementary food, Veterinary & Human therapeutic applications etc.
- **Accessibility:** PPCPs open available; vendors, stores; Medical therapy: Over the counter (uncontrolled) & Prescriptions (controlled)
- **Release:** Introduction mainly via Sewage and sewage treatment (faces & urine), Direct (husbandry, aquaculture), uncontrolled disposal of outdated products via sewage/ manure and/or garbage dumps.
- **Environmental relevance:** Many PPCPs are pseudo-persistent - Continuously present due to permanent replenishment (although considered as degradable).

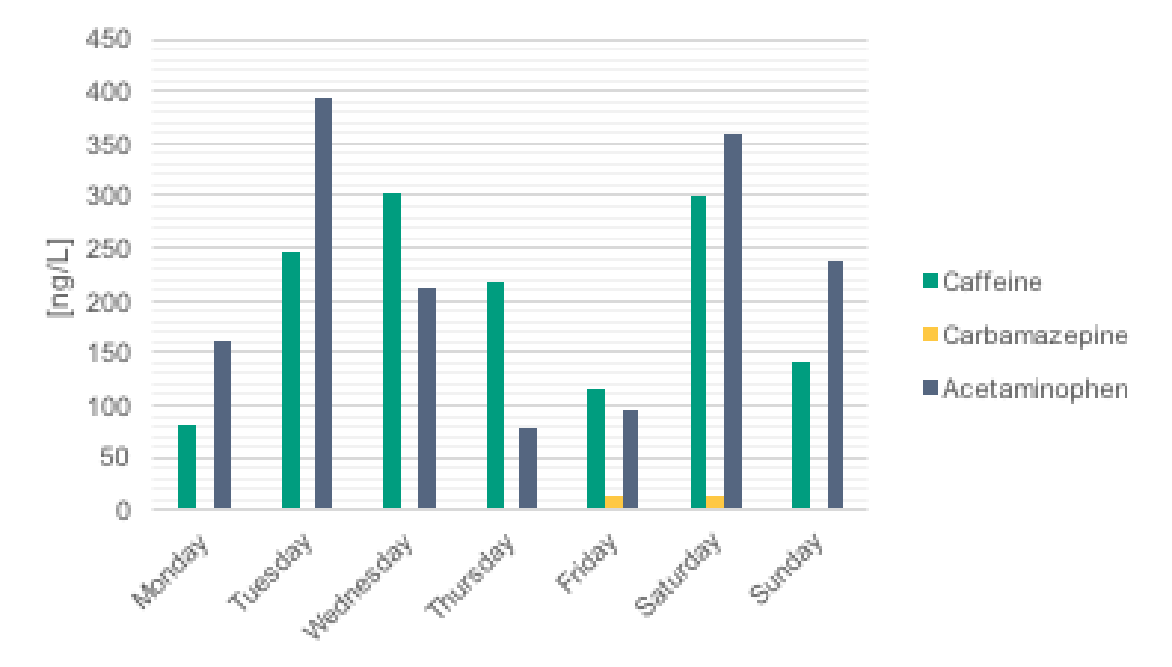
Photo: Wikipedia

Sampling Location in Tromsø: October 2016



3 km

PPCPs in Tromsø

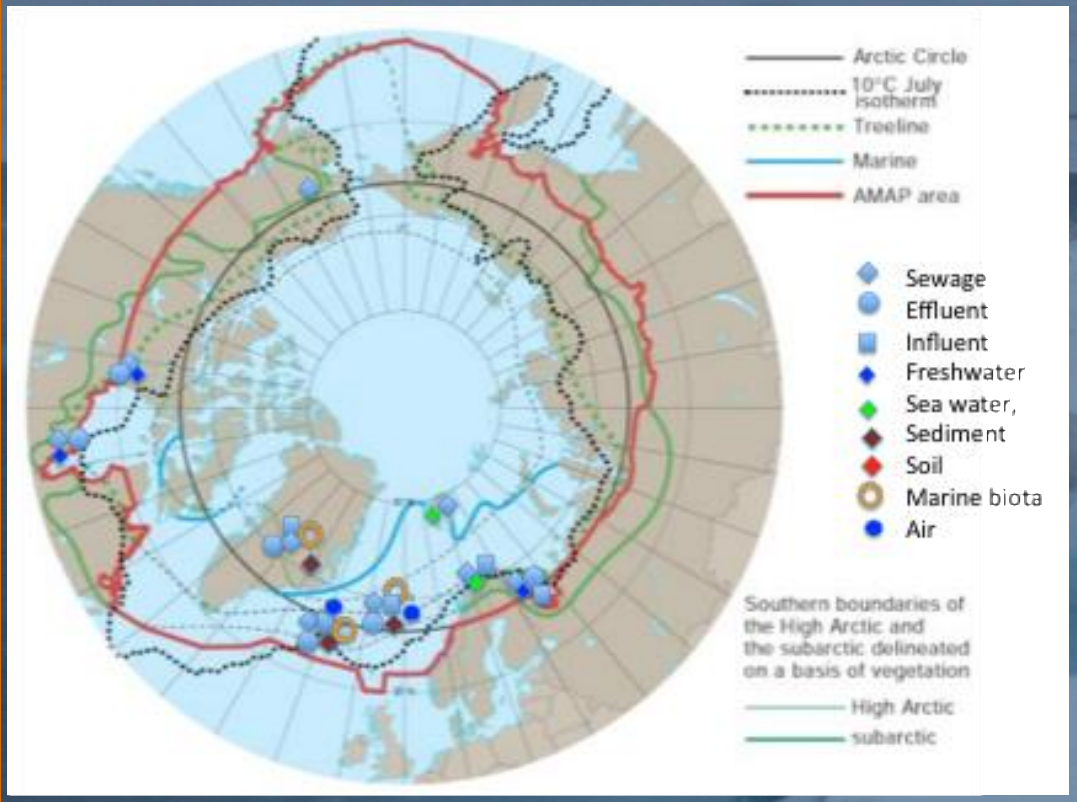


Caffeine, Carbamazepine and Acetominophen (Paracetamol) are the most abundant PPCP compounds (out of 25 target substances)in harbor water from Tromsø taken in 2016.

Caffeine levels for 2016 were at the same order of magnitude than first measured in 2004 (Weigel et al. 2004).

Arctic Monitoring and Assessment Programme (AMAP)

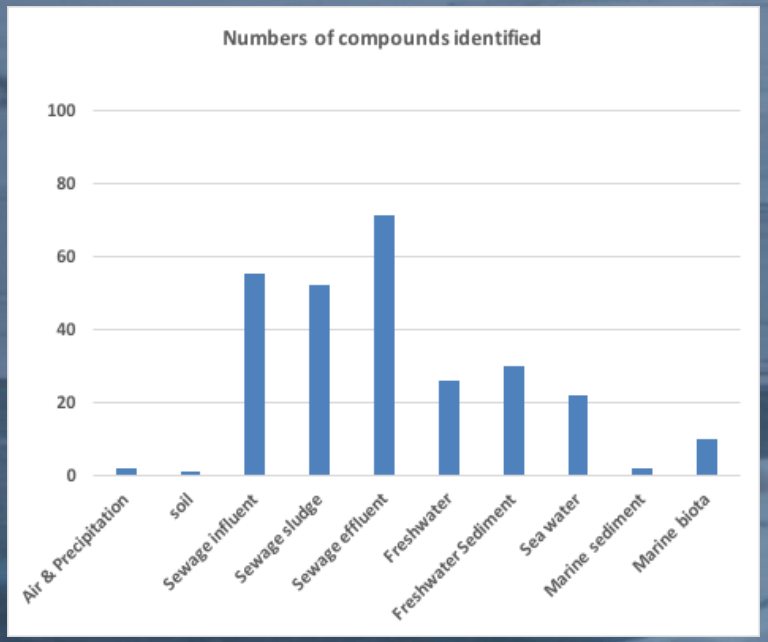
AMAP report 2015, Pollutants of Emerging Concern, Chapter 10: Pharmaceuticals and Personal Care Products (PPCPs) in the Environment

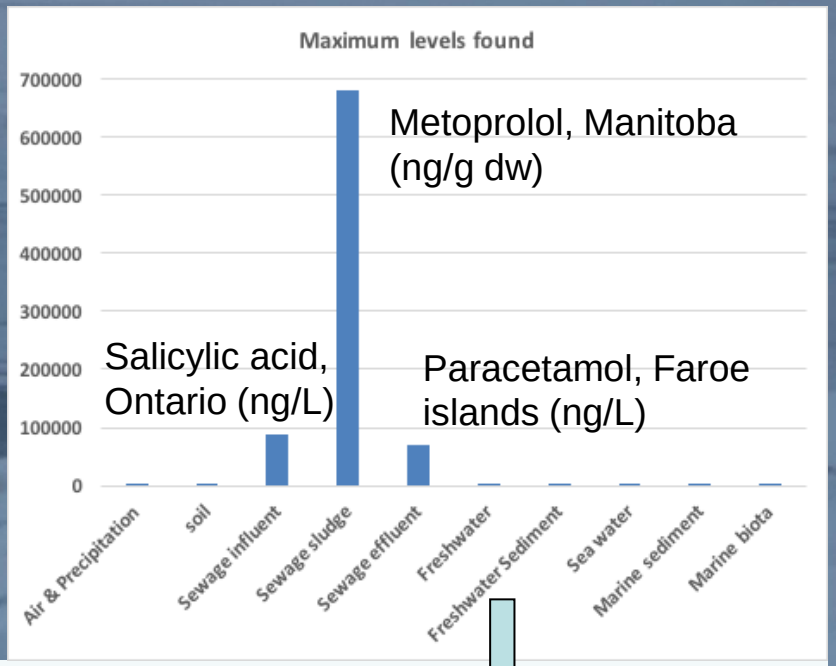


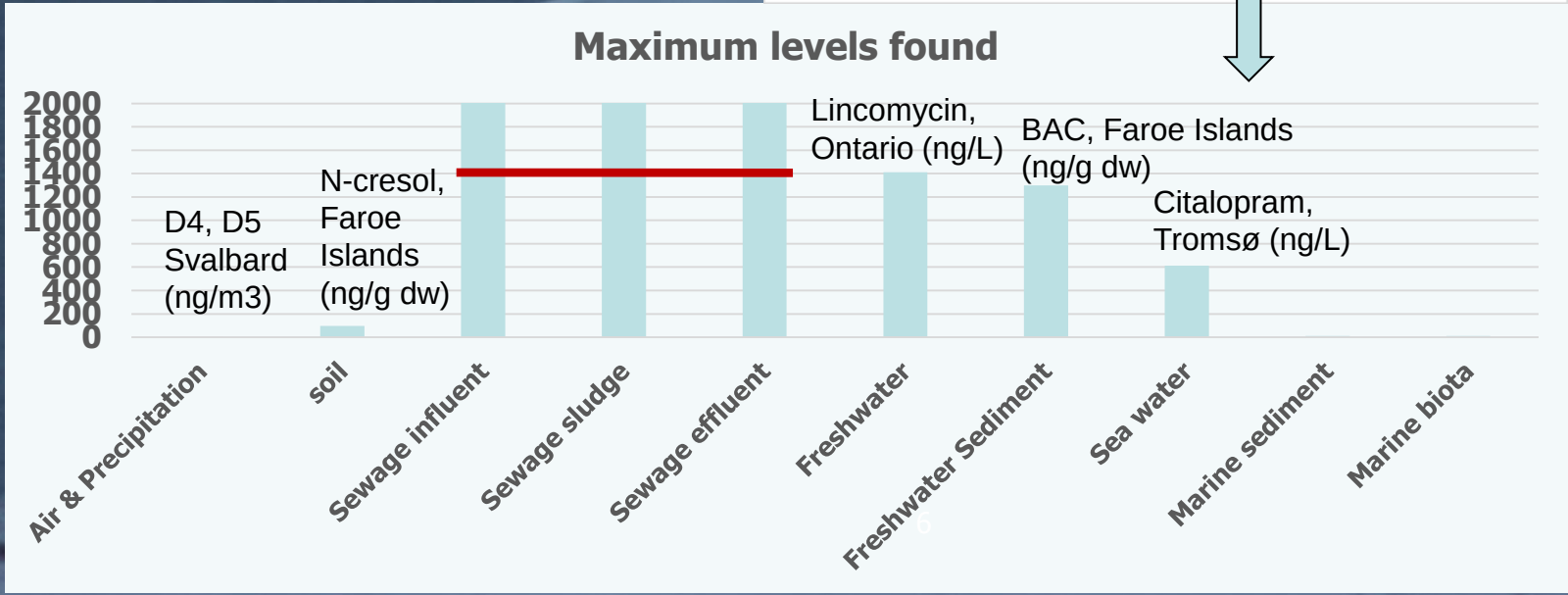
- 110 PPCPs (including transformation products) identified
- Based on 22 published reports
- 7 sample categories
- Conc. range: ppb – ppm
- Distribution patterns, environmental mobility, transformation pathways largely unknown

NORWEGIAN UNIVERSITY OF LIFE SCIENCES

PPCPs in the Arctic environment







Trend indications (Found in > 3 locations)

Sewage effluent [ng/L]; relevant comparison of maximum levels quantified

Location/ Region	Ibuprofen	Diclofenac	Aceminophen/ Paracetamol	Sertraline	Paroxetine	Citalopram
Ontario	4000	n.a.	740	n.a.	n.a.	n.a.
Greenland	2800	n.a.	25800	2	20,8	192
Iceland	5800	390	8540	299	89,3	69,2
Faroe Islands	4500	597	71500	23	149	540
Longyearbyen (Svalbard)	403	1074	n.a.	n.a.	n.a.	n.a.
Tromsø (North Norway)	448	48	n.a.	90	13	102

n.a. = not analysed

- No clear spatial trend identified
- Strong level variations are mainly governed by day-to-day fluctuations (application and usage patterns) a well as Sewage treatment technologies

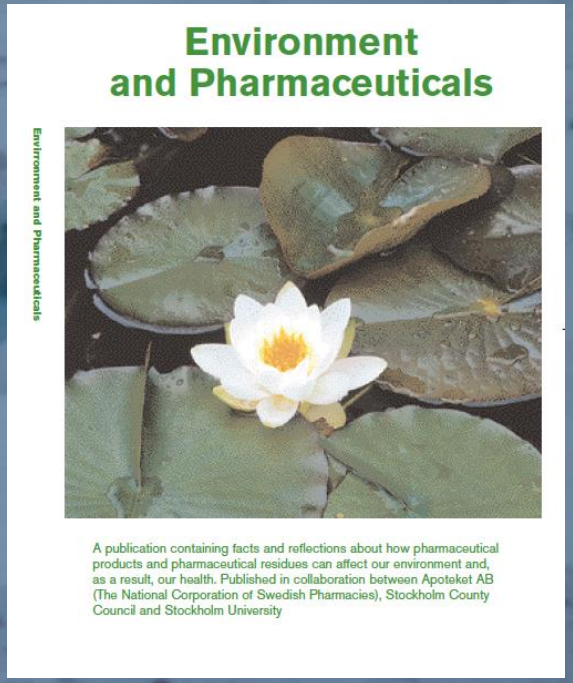
Comparison with other regions (examples)

Conc. Unit	Compounds	Sample matrix	Levels Arctic [max]	Other regions	Non Arctic sampling location	Reference
ng/m^3	Siloxanes (D4, D5)	Air	**4**	1100	Chicago	Yucuis et al. (2013) Chemosphere 92: 905-910
ng/g	cresol	soil	**96**	2000	Russian soil	Korenman et al. (2001) J. Anal. Chem. 56/2: 166-169
ng/L	Ibuprofen	Sewage influent	**87400**	3600	Källby (SWE)	Bendz et al. (2005) J. Haz. Materials 122/3: 195-204
ng/g	Metoprolol	Sewage sludge	**680000**	500	WWTP Terrassa, Spain	Radjenovic et al. (2009) Water Res. 43: 831-841
ng/L	Paracetamol	Sewage effluent	**71000**	150	Källby (SWE)	Bendz et al. (2005) J. Haz. Materials 122/3: 195-204
ng/L	Lincomycin	Freshwater	**1413**	40	Biscayne Bay (Florida US)	Wang & Garinaldi(2012) Anal. Bioanal. Chem. 404: 2711-2720
ng/g	BAC	Freshwater Sediment	**1300**	1500	Long Island (NY)	Li & Brownawell (2010) Env. Sci. Technol 44: 7561-7568
ng/L	Citalopram	Sea water	**612**	27	San Francisco Bay	Nödler et al (2014) Marine Pol. Bull. 85: 50-59
ng/g	Bisphenol A	Marine sediment	**11**	10500	Taiwan	Huang et al (2012) Environ. International 42: 91-99
ng/g	Siloxanes (D5)	Marine biota	**10**	36	Walleye (Canada)	Goldrick et al. (2014) 186: 141-148

Due to Arctic specific environmental conditions, application patterns and treatment strategies differences in environmental stability and degradation pathways were found.

Remediation and mitigation strategies

- Coordinated sanitation strategies required
- High technological standards for Sewage treatment for decentralized systems
- Community awareness: Disposal strategies and public awareness in the communities (i.e. pharmacies as return points for outdated pharmaceutical products)
- Continuous communication of all critical aspects with the public
- Development of sanitation technology for cold High North environments



Knowledge gaps identified

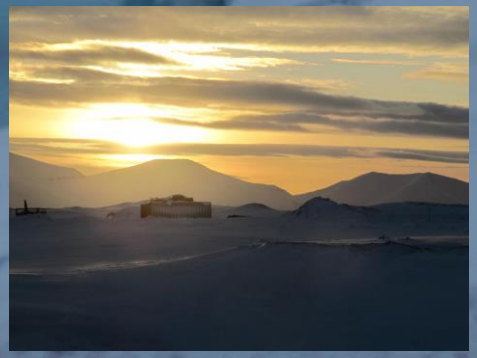
- Medium and long term monitoring data are not available
- Time and spatial trend investigations for PPCPs are needed.
- Comprehensive information on source apportionment and assessment of source strength is missing
- The elucidation of transformation processes as an integrated part of fate assessment is not available.
- Reliable environmental toxicology and effects studies for the Arctic environments are missing.
- Joint Research & Development strategies for PPCP remediation and abatement in the Arctic

Conclusions

- PPCPs are present in Arctic environments close to human settlements/ activities
- STP release into aquatic environments identified as major environmental source
- Level can reach μg range in contaminated sites
- No spatial trends identified in the registered studies
- Level can be higher than for middle latitude regions
- Low Technological standards or even absence of Sewage treatment
- Concentration range depends on usage patterns and sanitation treatment

Acknowledgement

- The Arctic Monitoring and Assessment Programme (AMAP) initiated the here presented survey
- Simon Wilson, Janet Pawlak (AMAP),)and Stefan Weigel (RIKILT, NL), contributed with advise, data and discussions.
- The AMAP/NCM project "Combined effects of Climate and Pollution" & and FP7 ArcRisk supported this study financially and with data.
- The flagship program "hazardous substances" of the FRAM Centre for Climate and Environmental Research in Tromsø, Norway supported the study "Transformation properties and environmental risk associated with pharmaceutical residues in the Arctic" (TraPha).



Thank you for your attention