Micropollutants, Solids and Nutrients Removal from Urban Run-Off

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Sustainable Urban Water Management Seminar

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Content of presentations

- Which Priority pollutants, Solids and Nutrients?
- Sources and Levels of Micropollutants in urban surface run-off
- Micropollutants in road run-off water
- Decision Support to decide treatment/not?
- Recommended strategy to decide treatment of run-off water
- Experiences from tunnel-wash water
- Example from surface water run-off collection and re-use in California USA
- Swiss strategy to decide on Micropollutants and treatment for Wastewater treatment plants – new micropollutants
- Areas for improvement

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Priority Pollutants controlled today?

- Routinely Hydrocarbons, PAH, PCB and heavy metals
- Routinely solids (SS)
- Nutrients (N/P)
- Sometimes turbidity
- Sometimes total organic loading (TOC, COD, BOD)
- Sometimes specific conductivity, salt content and sometimes Cl, SO_4

Priority Pollutants to be focused in future and why?

- Pesticides, Detergents, Plastic components, Pharmaceuticals, PFAS ?
- Impact on fish catch; -e.g. restrictions on catching cod From Kragerø to Sweden
- Endangered species and environmental diversity
- Sustainable development, holistic impacts including energy efficiency
- Algae growth, oxygen demand, Microplastics control
- Solids, turbidity, types of particles, Humus, colour

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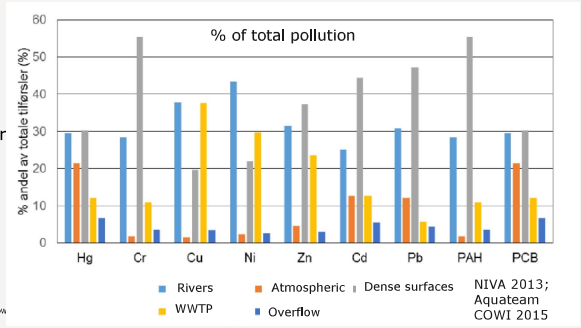
Priority pollution in surface-runoff? Here: Pollution to inner Oslofjord

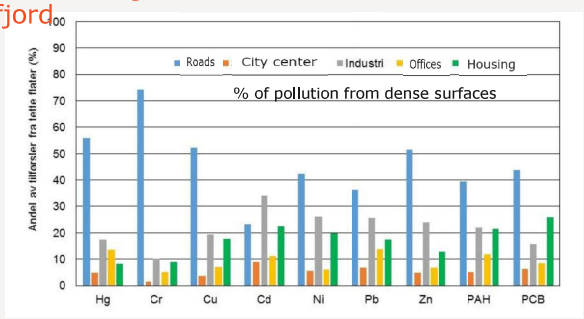
- Rivers main source for Cu, Ni and PAH
- Dense sufaces main source for Hg, Cr, Zn, Cd, Pb and PCB



NIVA 2013; Aquateam COWI 2015

Roads are dominating source from dense surfaces to inner Oslofjord

- Tyres – defines as Microplastic is a source to Zn and a major source??



Industry

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Surface water run-off quality

- Heavy metals:
  - Pb (mainly particulates);
    Zn (50% particulates); Cd (50% particulates); Cu (50 % particulates)
- Organic priority pollutants
  - PAH (> 90 % particulates); PCB (> 90 % particulates)
- Suspended solids
- Oil-hydrocarbon
- Nutrients (phosphate, nitrogen)
- Road salt (NaCl, 100 % soluble)

Heavy metals discharge from surface run-off, 2012

• Arsen	783 kg/år
• Kvikksølv	19,6 kg/år
• Bly	2 529 kg/år
• Kadmium	46 kg/år
• Kobber	4709 kg/år
• Krom	1482 kg/år
• Nikkel	1562 kg/år
• Sink	22 393 kg/år

Organic PP discharge from surface run-off, 2012

• Nonylfenoler	187 kg
• PAH	221 kg/år
• PCB	7,7 kg/år
• DEHP (ftalat)	1 695 kg/år

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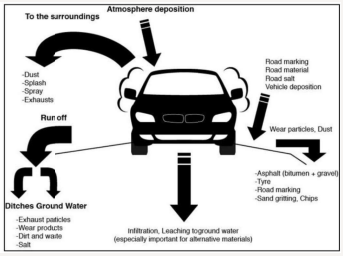
Sources of Micropollutants on roads

- Primary sources of micropollutants from roads
  - Tyres Largest source of microplastics (MP)
  - Asphalt and concrete
  - Brakes
  - Brake fluids
  - Road markings
  - Car coatings
  - Corrosion inhibitors
  - Automotive coolants
  - Fuels, oils and lubricants
  - Others



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Measured concentrations in leachate of artificial tyres in distilled water and acid rain and in run-off and snow

- BT and MeSBT found in Rainfall events and Snow in concentrations from 3-70 µg/l
- MBT, Aniline and DCHA found in snow in concentrations from 4-30 and 40-50 µg/l, accordingly.

Chemical	Short name	Cas-no	Distilled water		"Acid rain" (pH=4)	
			Average (SD) (µg/L) [1]	Detection limit (µg/L) # below DL [2]	Average (SD) (µg/L) [1]	Detection limit (µg/L) # below DL [2]
Mercaptotenzothiazol	MBT	149-30-4	414 (334)	0.5 (9/14)	144 (181)	0.5 (5/11)
Benzothiazol	BT	95-16-9	550 (357)		402 (336)	
Methylbenzothiazol	MeBT	120-75-2	254	2 (13/14)	83	2 (12/13)
2-Methylthio benzothiazole	MeSBT	615-22-5	87 (72)		37 (28)	
N-Isopropyl-N'-phenyl-1,4-phenylenediamine	IPPD	101-72-2	33 (10)	15 (5/13)	94 (63)	15 (5/13)
N-(1,3-dimethylbutyl)-N'-phenyl-1,4-phenylenediamine	6PPD	793-24-8	40 (29)	10 (5/14)	1685 (3147)	10 (3/12)
N,N'-ditolyl- and N,N'-diphenyl-p-phenylenediamine	DPPD/ DTPD	74-31-7 / 620-91-7		80 (14/14)		80 (13/13)
Aniline		62-53-3	14 (14)		13 (14)	
Dicyclohexylamine	DCHA	101-83-7	134 (173)		185 (218)	
Cyclohexyamine	CHA	108-91-8	543 (877)	1 (4/14)	434 (1017)	1 (4/13)

1) This column shows the average concentration. The standard deviation (SD) is shown in brackets.
2) This column shows the detection limit (DL) concentration. The number of samples below the detection limit compared to the total number of sanples in shown in brackets.

Measured in environmental media

Tyres
- Challenge: different chemicals are measured in different studies
- BT measured in all
- PAH levels reduced by 10 due to EU regulation

Asphalt- much less than tyres
- MP added to asphalt; elastomers, plastomers, natural rubber
- PAH low levels

Other organic micropollutants also included

Environmental medium	BT Benzothiazole Casno 95-16-9	OHBT Hydroxybenzothiazole Casno 934-34-9	24MoBT 2-Morpholinobenzothiazole Casno 4225-26-7
Leaching from CRM in 5 x 24h (mg/kg)	100	36	20
Urban run-off (ng/L)	378-1210 (D*) 46.6-152 (P*)	721-6910 (D) 60-114 (P)	198-278(D) <10 (P)
Highway settling pond water (ng/L), n=7	<50 (D)	50-516 (D)	5-13.5 (D)
Highway settling pond sediment (µg/kg)	<20	<20	1.16 – 1.31
Urban particulate matter (µg/kg)	393-813	696-893	63.2-107
Road dust highway (µg/kg)	149	90.2	1.68
Road dust residential (µg/kg)	78.7	24.6	2.45

CRM = Crumb Rubber Material, D = dissolved, P = particle bound

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Recommendation to measure a variety of organic micropollutants in road run-off

CEDR Transnational Road Research Programme. Call 2016-Environmentally Susainable roads: Surface and Groundwater quality. MICROPROOF; Micropollutants in Road Run-Off; Feb 2018

- Tyres: Benzothiazoles (benzothiazole, mercaptobenzothiazole, benzothiazolone, hydroxybenzothiazole, benzothiazole-2-sulfonate), amines (cyclohexylamine, dicyclohexylamine, hydroxydiphenylamine, aminodiphenylamine), aniline
- Brakes and brake fluid: polyglycol ethers, Boric-acid-ester, Tributylphosphate, Triethanolamine
- Car coatings: hexa(methoxymethyl)melamine, nonylphenol ethoxylates, octylphenolethoxylates, bisphenol A
- Coolants: benzotriazole, tolyltriazole, mercapto benzothiazole, Sodium borate, Sodium Boric acid
- Other: diisodecyl phthalate, di(2-ethylhexyl)phthalate

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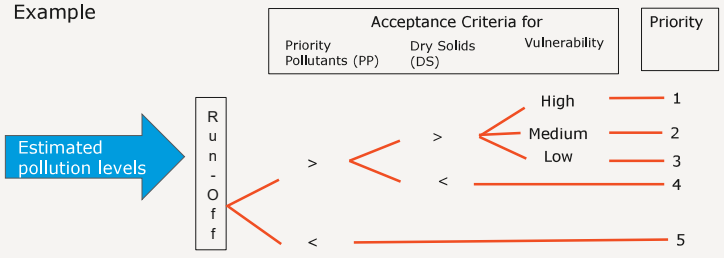
We need a Decision Support System for selecting treatment for PP in road run-off water

Example



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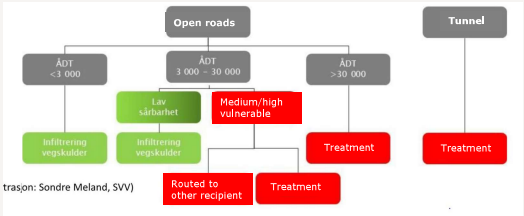
Recommended focus on treating Surface Run-Off water

- Road in tunnel, always treatment
- Based on traffic loading (ÅDT= Yeary daily traffic) + medium and high vulnerability recipients



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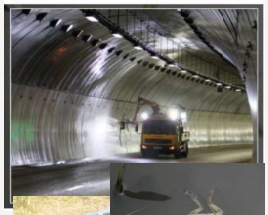
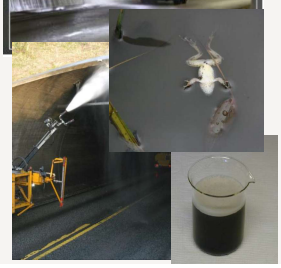
Example: Tunnel Wash-water

- = Road Run-Off in «high concentration»:
  - Detergents complexing Cu and Zn
  - Toxic to bacteria and «animals» in local collection basins

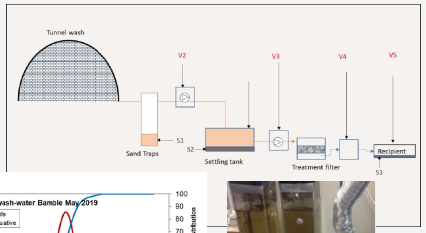


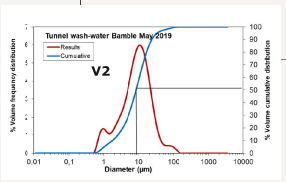


Tunnel Wash-water; Recommended Water treatment

Based on test results from R&D laboratory studies

- Sand Traps
- Sedimentation Basin (4-5 weeks)
- Filtration prior to discharge to recipient





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Tunnel wash-water quality example

Tunnel Wash-water Nordbytunnelen	OiW mg/l	PAH µg/l	Tot-P mg/l	Tot-N mg/l	TOC mg/l	SS mg/l
Summer (2014)	3,2	5	5,6	11,5	155	544
Winter (2015)	27	120	35	15	654	28000
Good quality (FW)	0,07	11.3	11	0,4	3,5	3
To local WWTP	20		10	60	200	400
Good quality coast (SW)	0,07	2,4	12	0,25		

Emerging pollutants:
- Micro-Plastics (MP)
- New PP
- Toxicity

Tunnel Wash-water Nordbytunnelen	Zn µg/l	Cu µg/l	Cr µg/l	Pb µg/l	Hg µg/l	Cd µg/l	Tox. TU
Summer (2014)	**2400**	**350**	**44**	**20**	**0,02**	**0.4**	**5**
Winter (2015)	**44000**	**4400**	**1100**	**500**	**0,3**	**56**	**2**
Good quality (FW)	11	7,8	3,4	1,3	0,05	0,08	0,01
To local WWTP	500	200	50	50	2	2	2
Good quality coast(SW)	2,9	0,64	3,4	2,2	0,05	0,24	0,01

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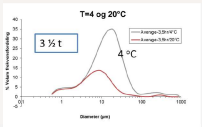
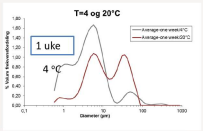
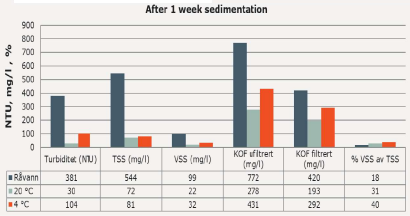
Results lab tests

- Sedimentation important
- Anaerobic degradation important to reduce COD (organic detergent) and form sulphide binding Zn and Cu
- Small solids amount







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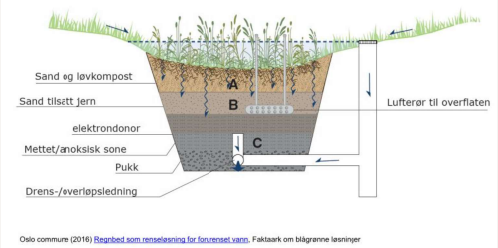
Used treatment concepts for surface run-off

- Sand traps
- Rainbeds
- Slow infiltration and
  - Adsorption to iron
  - Leaves
  - Anaerobic degradation
- Collection and treatment of snow

Rainbed to treat contaminated surface run-off



Oslo commune (2016) Regnbed som renseløsning for forurenset vann. Faktaark om blågrønne løsninger

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Treatment of urban surface run-off

- Sand traps efficient for removing micropollutants (>> 50 %)
- Cleaning roads efficient (not documented removal rate)
- When sand traps are filled- poor function
- Cleaning of sand traps when 50 % of storage volume is filled → 40-50 % of pollutants in surface run-off can be removed
  - Norway has 100 000-200 000 Sand traps
- Collection and treatment of snow – important!!

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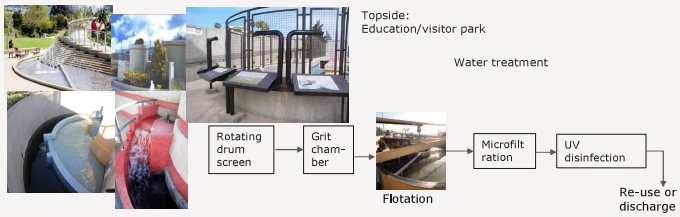
California example: Treatment for PP, N/P, solids and micropollutants

Santa Monica Urban Runoff Recovery Facility;SMURRF 2013;



Only partial water soluble PP removed

Swizz strategy to manage micropollutants in sewage

- **Background**; Fishnet project showed declinin fish yield in Switzerland. National R&D program «endocrine disruptors showed wastewater (WW) main point source to pollution of surface water.
- **Objective:** Evaluate installation of additional tretament steps for WWTP
- **Result** (2006-2011):
  - > 1 ng/EE2/l → lack of male fish
  - Species diversity reduced by WWTP discharges
  - Concentration of 11 micropollutants; e.g. fragrantes, flame retadants (PFAS), Pharmaceuticals, Pesticides, Benzotriazol
  - Focus on removal of problematic substances; very difficult (Pharmaceuticals) or impossible (natural estrogens)
  - Identified treatment technologies; Ozone + SF; GAC; Ozonr + GAC (BAC)

Existing Treatment and impact on removing micropollutants

Biological treatment and impact on micropollutants removal;

- MBR, Biofilter; Measuring in plants: most compounds comparable tretament, and only partially removed.
- Lab tests and modelling; Model fits, but not for all compounds
- New technology needed!!

Swizz strategy to manage micropollutants in sewage

Legislation scope:

- Load reduction on D/S water (recipients)
- Protect sensitive waters (ecotoxicology)
- Protect drinking water (DW) resources (precaution)

Source control; Regulating specific compound (Pesticides)

WWTP upgrading: Cost < 20 €/pe/year; until 2040: 120-130 WWTPs (50% WW)

- >80 000 pe (load reduction)
- > 24 000 pe discharging into lakes (DW protection)
- > 8 000 pe with > 10% dilution in receiving water (protect the environment)
- Exemptions

Treatment technology for removing micropollutants

- Sorption to sludge: relevant for a few compounds
- Degradation achievs only partial removal; transformation products of similar structure often formed: Does it eliminate detoxification?Wetland achievs littel Micropollutants removal
- Spots for advanced treatment was identified
- Additional steps to increase removal of PP > 80 % identified; lab and pilot tests
- Currently 9 full scale plants in operation
  - 5 steps with with GAC
  - 4 steps with ozone followed by sand filtration
  - Bioactive granular activated carbon (BAC), which is combined with Ozone has been identified as an interesting alternative

Uncertainty and areas for improvement.

- Do we include the right Priority Pollutants
- Naturally Organic Matter (NOM) is a vehicle transporting heavy metals and priority pollutants; The Oslofjord is brown after heavy/long-lasting rainfall; NOM a vacuum cleaner for Prioity Polllutants. Colour in surface water increased from 20 to 60 mg Pt/L (from 1995-2015) in many drinking water sources.
- Solids Guidelines developed for naturally eroded material, not for blasted masses; EIFAC; 1982

Suspendert stoff(mg/l)	Effekter på fisket
< 25 mg/l	Ingen skadelig effekt
25-80 mg/l	Godt til middels godt fiske. Noe redusert avkastning
80-400 mg/l	Betydelig redusert fiske
> 400 mg/l	Meget dårlig fiske, sterkt reduser: avkastning

Thanks for listening

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