Retention of heavy metals and Poly-Aromatic Hydrocarbons from road water in a constructed wetland and the effect of de-icing

Karin Tromp, **Ana T. Lima**,

Arjan Barendregt and Jos T.A. Verhoeven

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

ecohydrology research group

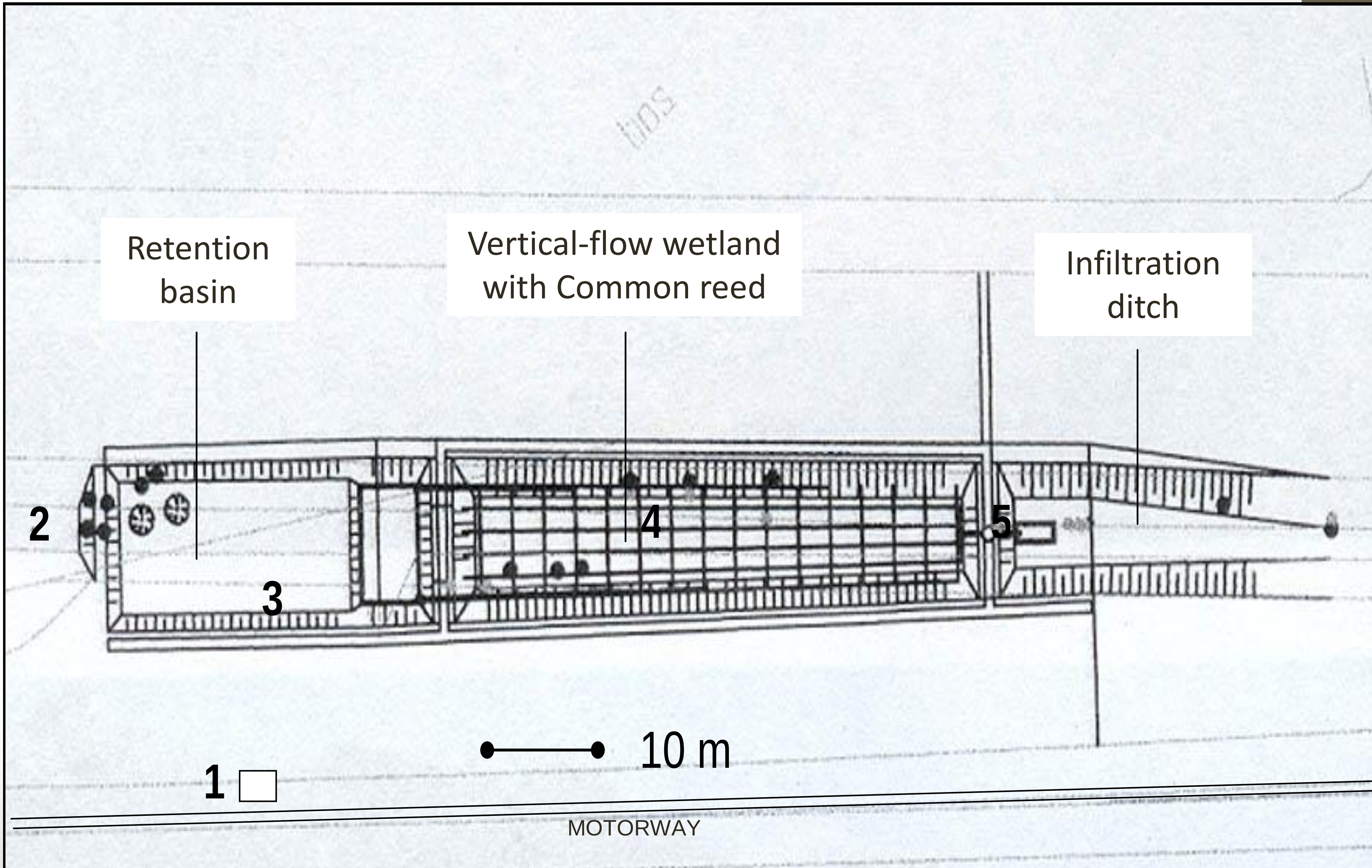
Utrecht Universiteit

Outline

- Road runoff
  - Polycyclic Aromatic Hydrocarbons (PAHs)
  - Heavy metals
- 1.8 ha of motorway collected water at gully pots
- Constructed wetland to complement runoff contaminant retention
- Monitored PAHs and Heavy metals for 1.5 years
- Major considerations and recommendations


Norwegian Sea
North Sea
Netherlands
EUROPE
Bay of Biscay
Black Sea
Turkey
Tunisia
50 km
50 miles
NORTH SEA
Den Helder
Leeuwarden
Assen
NETHERLANDS
Haarlem
AMSTERDAM
The Hague
Utrecht
Delft
Europoort
Rotterdam
Dordrecht
Amhem
Nijmegen
Tilburg
Eindhoven
GERMANY
BELGIUM
Maastricht
© wordtravels.com
Werkdroger
Drift
De Pijl
Laren
Brink
Hamdorff Eten & Drinken
Houtweg
Grintbank
Esseboom
Stationsweg
Nieuweweg
Velthuysenlaan
Hoefloo
Hilversumseweg
Van Wulfenlaan
E231
A1
Sint Janstraat
Engweg
Moleneweg
Klaaskampen
Vinkebaan
Hart Nibbriglaan
Rijksweg Oost
Zijtak
Ooghout
Herdersweg
Van Beeverlaan
Steffenshein
De Dissel
Veerweg
Slangenweg
N525

Road water infiltration facility

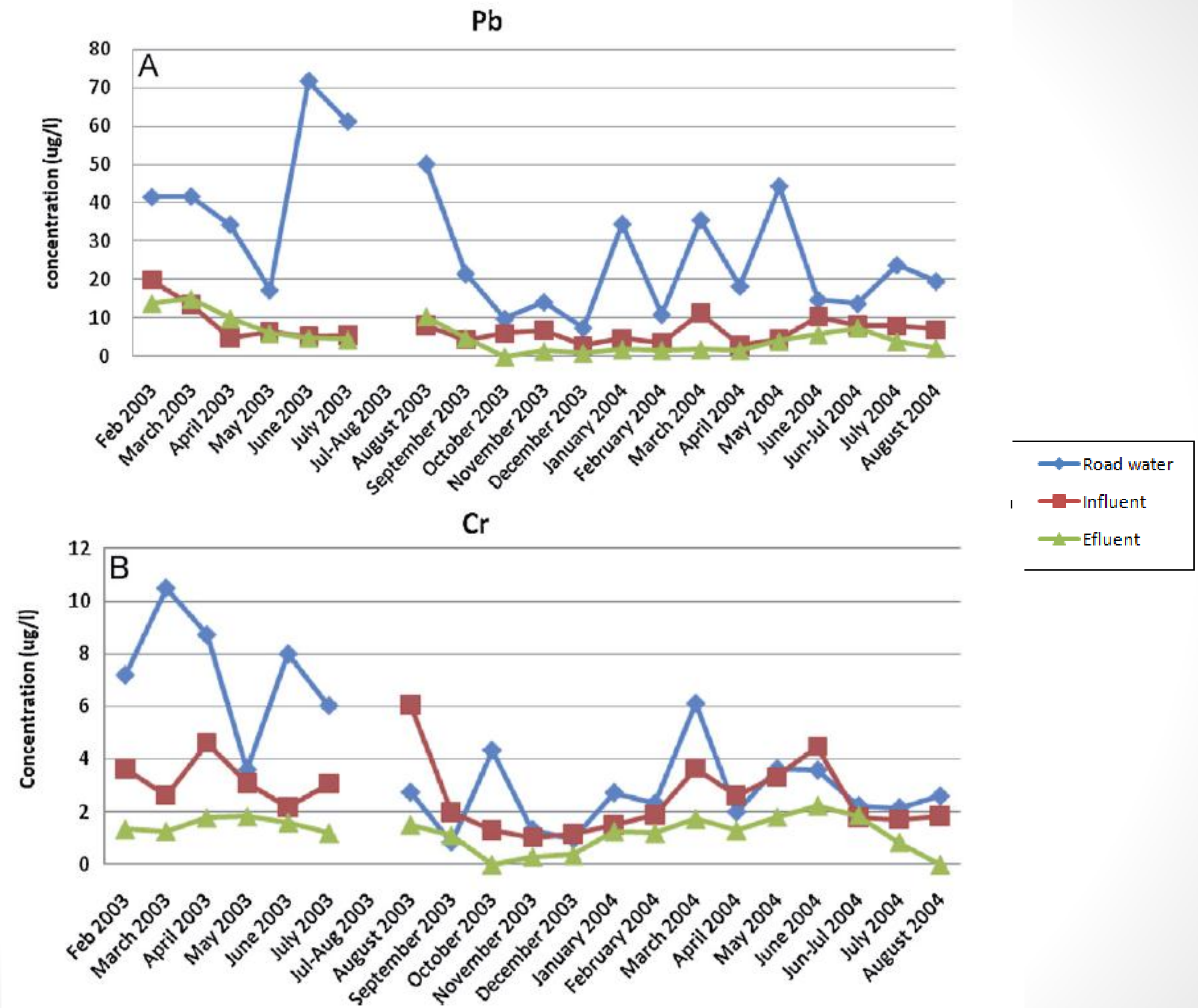


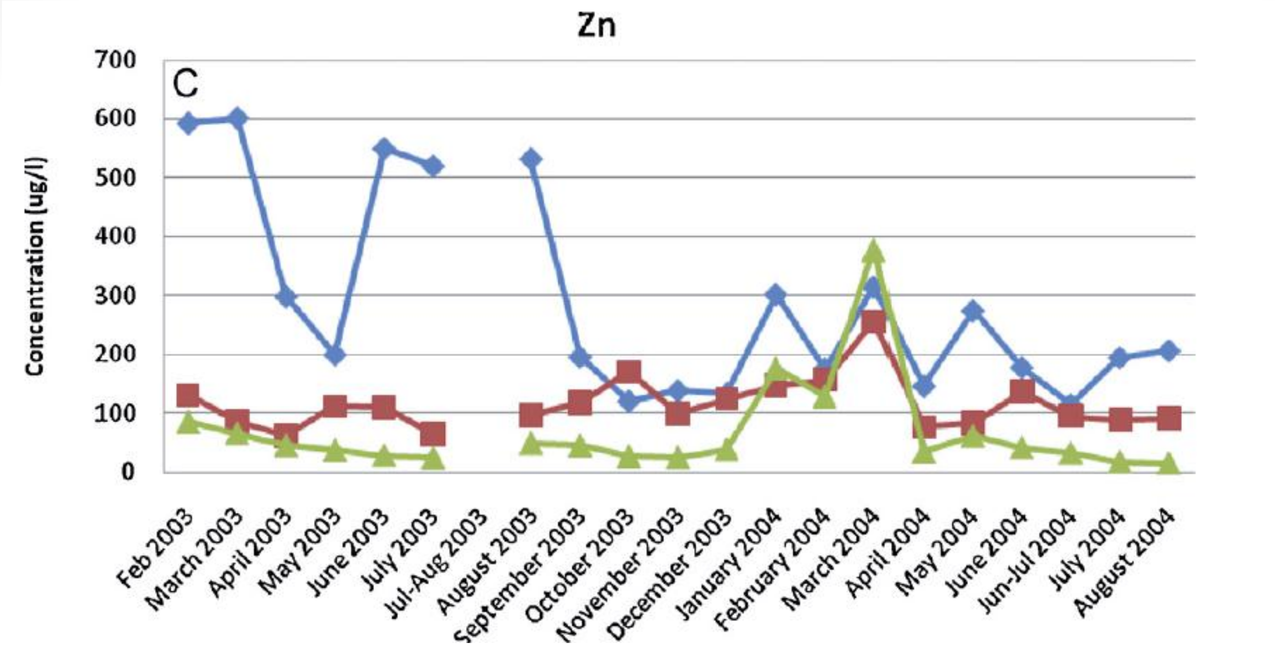
Research Questions

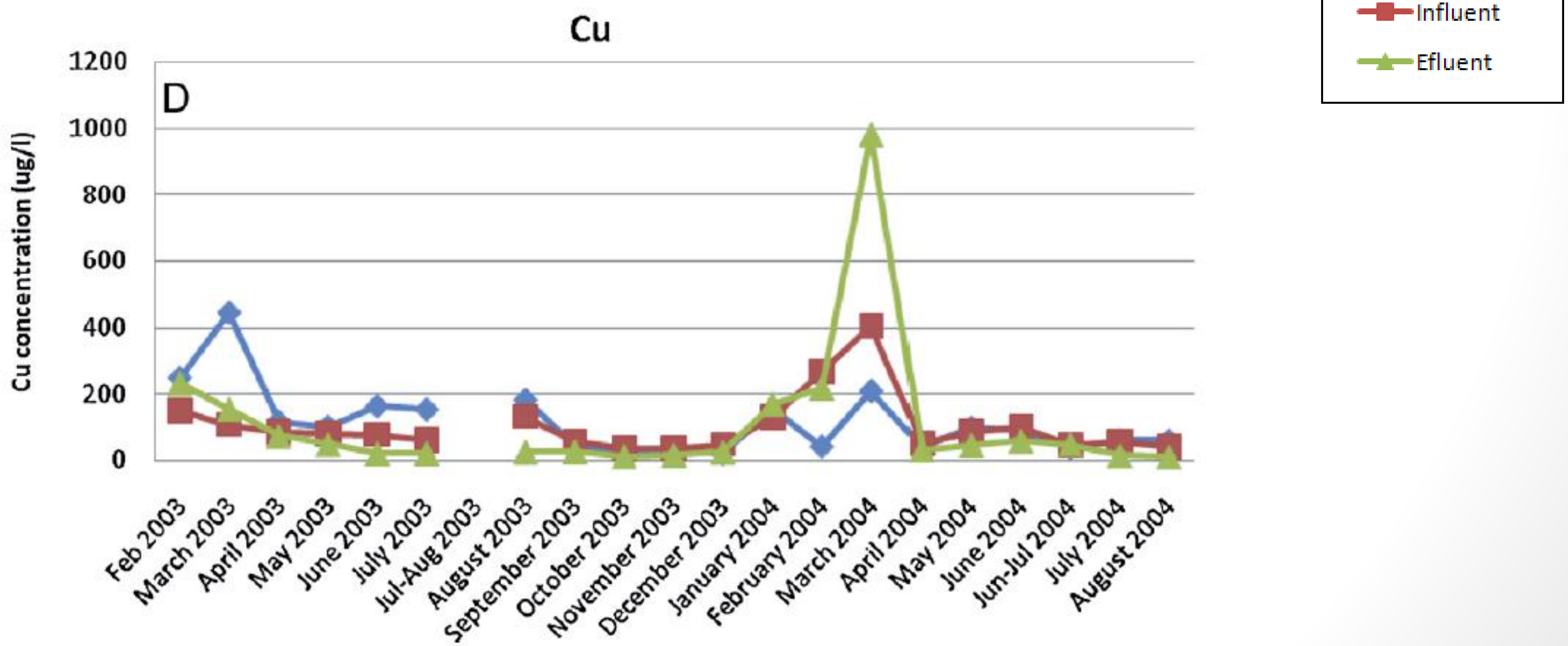
- (1) What are the reductions in concentrations going from road runoff via the sewer system (gully pots) towards the wetland and finally to the groundwater recharge point?
- (2) What are the effects of road management measures (sweeping, de-icing)?
- (3) What is the ‘best practice’ for the road and wetland management?

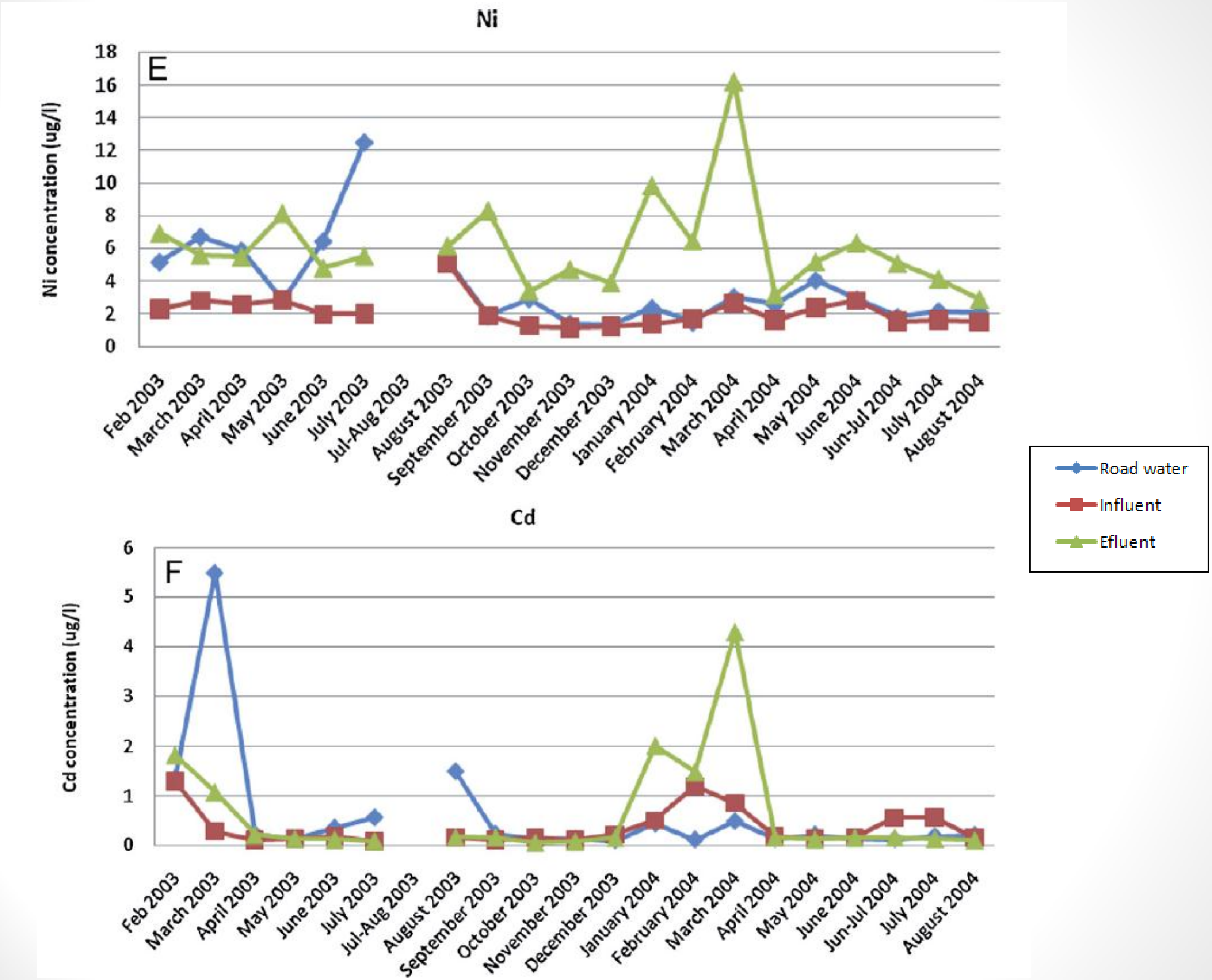
Research Questions

- (1) What are the reductions in concentrations going from road runoff via the sewer system (gully pots) towards the wetland and finally to the groundwater recharge point?
- (2) What are the effects of road management measures (sweeping, de-icing)?
- (3) What is the ‘best practice’ for the road and wetland management?


Pb
A
concentration (ug/l)
80
70
60
50
40
30
20
10
0
Feb 2003
March 2003
April 2003
May 2003
June 2003
July 2003
Jul-Aug 2003
August 2003
September 2003
October 2003
November 2003
December 2003
January 2004
February 2004
March 2004
April 2004
May 2004
June 2004
Jun-Jul 2004
July 2004
August 2004
Road water
Influent
Efluent
Cr
B
Concentration (ug/l)
12
10
8
6
4
2
0
Feb 2003
March 2003
April 2003
May 2003
June 2003
July 2003
Jul-Aug 2003
August 2003
September 2003
October 2003
November 2003
December 2003
January 2004
February 2004
March 2004
April 2004
May 2004
June 2004
Jun-Jul 2004
July 2004
August 2004


Zn
C
Concentration [ug/l]
700
600
500
400
300
200
100
0
Feb 2003
March 2003
April 2003
May 2003
June 2003
July 2003
Jul-Aug 2003
August 2003
September 2003
October 2003
November 2003
December 2003
January 2004
February 2004
March 2004
April 2004
May 2004
June 2004
Jun-Jul 2004
July 2004
August 2004

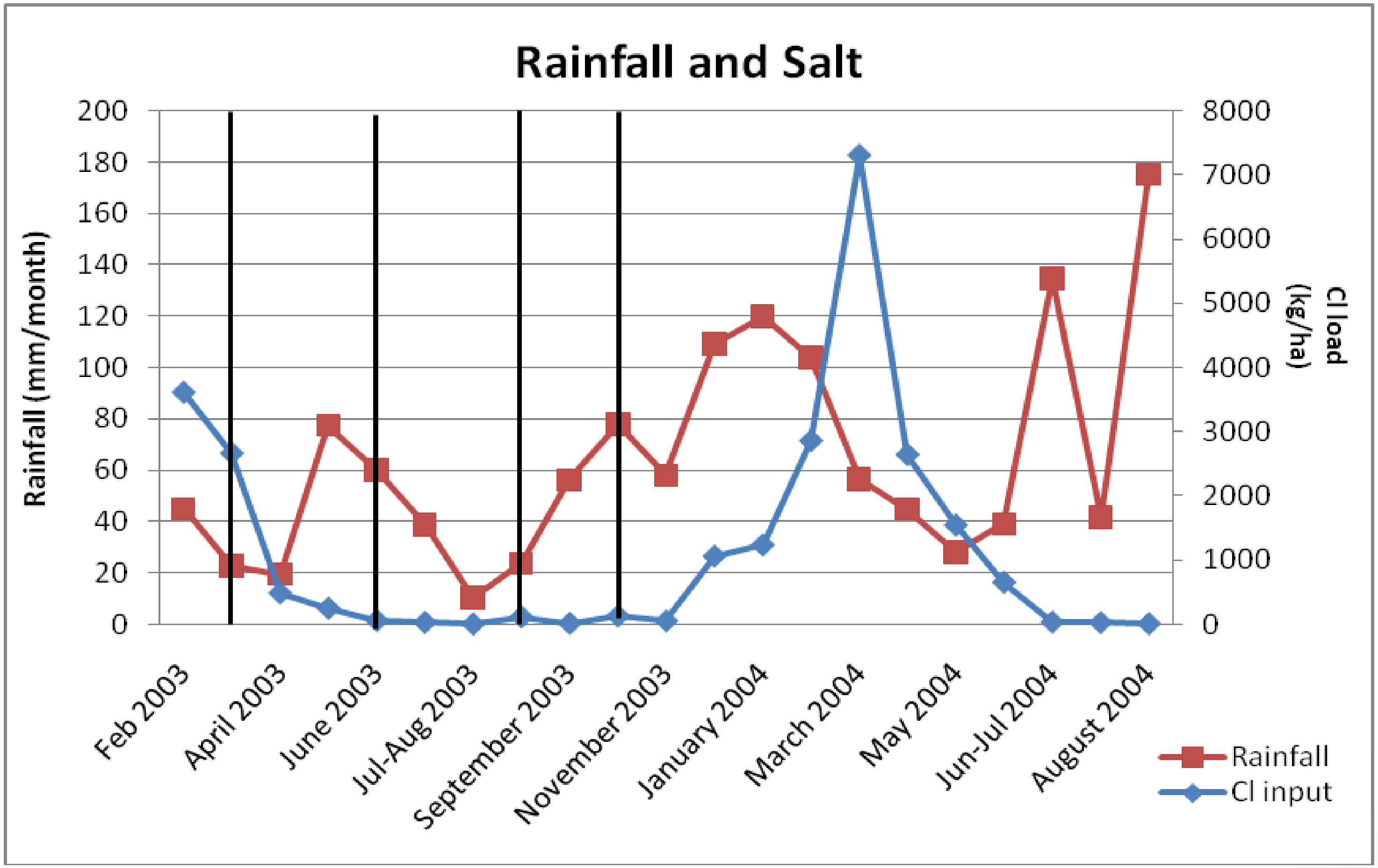

Cu
D
Cu concentration [ug/l]
1200
1000
800
600
400
200
0
Feb 2003
March 2003
April 2003
May 2003
June 2003
July 2003
Jul-Aug 2003
August 2003
September 2003
October 2003
November 2003
December 2003
January 2004
February 2004
March 2004
April 2004
May 2004
June 2004
Jun-Jul 2004
July 2004
August 2004
Road water
Influent
Efluent


Ni
E
Ni concentration (ug/l)
18
16
14
12
10
8
6
4
2
0
Feb 2003
March 2003
April 2003
May 2003
June 2003
July 2003
Jul-Aug 2003
August 2003
September 2003
October 2003
November 2003
December 2003
January 2004
February 2004
March 2004
April 2004
May 2004
June 2004
Jun-Jul 2004
July 2004
August 2004
Road water
Influent
Efluent
Cd
F
Cd concentration (ug/l)
6
5
4
3
2
1
0
Feb 2003
March 2003
April 2003
May 2003
June 2003
July 2003
Jul-Aug 2003
August 2003
September 2003
October 2003
November 2003
December 2003
January 2004
February 2004
March 2004
April 2004
May 2004
June 2004
Jun-Jul 2004
July 2004
August 2004

Research Questions

- (1) What are the reductions in concentrations going from road runoff via the sewer system (gully pots) towards the wetland and finally to the groundwater recharge point?
- (2) What are the effects of road management measures (sweeping, de-icing)?
- (3) What is the ‘best practice’ for the road and wetland management?

Main drivers



	Runoff (µg/L)			Influent (µg/L)			Effluent (µg/L)			Dutch Standards (µg/L) *	EU Standards (µg/L) †	EPA standards (µg/L)‡
	Min.	Average	Max.	Min.	Average	Max.	Min.	Average	Max.			
Cd	0.1	0.6 ± 1.2	5.5	0.1	0.4 ± 0.4	1.3	0.1	0.6 ± 1.1	4.3	2 | 0.4	0.08-0.25	0.25
Cr	0.8	4.1 ± 2.8	10.5	1.0	2.7 ± 1.3	6.1	0	1.2 ± 0.6	2.2	84 | 1.0	-	74/11
Cu	21.7	117.1 ± 101.8	445	36	103.5 ± 89	405	12.3	113.0 ± 215.4	980	3.8 | 15	-	1-1000[1]
Ni	1.3	3.8 ± 2.7	12.5	1.1	2.1 ± 0.9	5.1	2.9	6.1 ± 3	16.2	6.3 | 15	20	52
Pb	7.4	29.3 ± 18	71.7	2.7	7.1 ± 4.1	19.8	0	5.1 ± 4.3	15.0	220 | 15	7.2	2.5
Zn	115	289.8 ± 171	602	62	115.3 ± 44	256	15.1	67.8 ± 83	378	40 | 65	-	120

	Runoff (µg/L)			Influent (µg/L)			Effluent (µg/L)			Dutch Standards (µg/L) *	EU Standards (µg/L) †	EPA standards (µg/L)‡
	Min.	Average	Max.	Min.	Average	Max.	Min.	Average	Max.			
Cd	0.1	0.6 ± 1.2	5.5	0.1	0.4 ± 0.4	1.3	0.1	0.6 ± 1.1	**4.3**	2 | 0.4	0.08-0.25	0.25
Cr	0.8	4.1 ± 2.8	10.5	1.0	2.7 ± 1.3	6.1	0	1.2 ± 0.6	**2.2**	84 | 1.0	-	74/11
Cu	21.7	117.1 ± 101.8	**445**	36	103.5 ± 89	**405**	12.3	113.0 ± 215.4	**980**	3.8 | 15	-	1-1000[1]
Ni	1.3	3.8 ± 2.7	12.5	1.1	2.1 ± 0.9	5.1	2.9	6.1 ± 3	**16.2**	6.3 | 15	20	52
Pb	7.4	29.3 ± 18	71.7	2.7	7.1 ± 4.1	19.8	0	5.1 ± 4.3	**15.0**	220 | 15	7.2	2.5
Zn	115	289.8 ± 171	602	62	115.3 ± 44	256	15.1	67.8 ± 83	**378**	40 | 65	-	120

Max. – referring to the periods of de-icing

Heavy metal retention efficiencies

	Heavy metals removal % in sewer system					
	Cd	Cr	Cu	Ni	Pb	Zn
Total	40	39	13	48	76	60
Particulate	57	79	77	85	85	81
Dissolved	32	-33	-15	11	-14	34
	Heavy metals removal % in the wetland					
	Cd	Cr	Cu	Ni	Pb	Zn
Total	-74	51	-11	-213	28	42
Particulate	30	34	47	-13	67	84
Dissolved	-105	49	-15	-337	-37	24

PAHs overview

	Runoff (µg/L)			Influent (µg/L)			Effluent (µg/L)			Dutch Standards (µg/L) *	EU Standards (µg/L) †	EPA standards (µg/L)‡
	Min.	Average	Max.	Min.	Average	Max.	Min.	Average	Max.			
Anthracene	0.004	0.021 ± 0.02	0.08	0	0.003 ± 0.002	0.009	0	0.0009 ± 0.0013	0.004	0.08 | 0.0007	0.1	40000
Phenanthrene	0	0.20 ± 0.22	0.77	0	0.08 ± 0.12	0.39	0	0.02 ± 0.06	0.24	0.3 | 0.003	-	-
Fluoranthene	0	0.78 ± 0.95	3.65	0	0.06 ± 0.07	0.24	0	0.004 ± 0.012	0.05	0.5 | 0.003	-	140
Benzo(a)anthracene	0.04	0.19 ± 0.2	0.89	0	0.02 ± 0.02	0.07	0	0.0013 ± 0.0014	0.0034	0.03 | 0.0001	-	0.018
Chrysene	0.09	0.44 ± 0.51	2.17	0	0.05 ± 0.04	0.16	0	0.006 ± 0.010	0.039	0.9 | 0.003	-	0.018
Benzo(k)fluoranthene	0.03	0.12 ± 0.12	0.46	0.004	0.02 ± 0.01	0.05	0	0.0017 ± 0.0015	0.006	0.2 | 0.0004	0.003	0.018
Benzo(a)pyrene	0.06	0.25 ± 0.23	0.84	0.009	0.03 ± 0.02	0.11	0	0.0018 ± 0.0024	0.01	0.2 | 0.0005	0.05	0.018
Benzo(g,h,i)perylene	0.09	0.36 ± 0.34	1.27	0.01	0.06 ± 0.05	0.19	0	0.008 ± 0.009	0.03	0.5 | 0.0004	0.002	-

PAH retention efficiencies

PAH removal % in sewer system											
Phen	Anth	Fla	Pyr	B(a)A	Chry	B(b)F	B(k)F	B(a)P	DIB(a,h)A	B(g,h,I)P	Sum
60	86	92	87	89	89	87	85	88	82	84	86

PAH removal % in the wetland											
Phen	Anth	Fla	Pyr	B(a)A	Chry	B(b)F	B(k)F	B(a)P	DIB(a,h)A	B(g,h,I)P	Sum
69	70	94	91	94	88	93	91	94	93	87	87

Road management results

- The engineered system along the motorway of the **sewer** system (+ gully pots) and the remediation **wetland facility** retained PAHs and heavy metals

- Salts added to the road for de-icing increased heavy metal release from:
  - The sewer system
  - Wetland

- Although most metal concentrations were below the standards post treatment, Cu, Zn, Cd and Ni showed a dramatic increase during salt de-icing

- High release of Cu (65 higher than the standard)

Road management results

- The facility retained the PAHs very well, with retention efficiencies of 90–95%
- Environmental standards for water quality were never surpassed after the wetland filtering for PAHs

Research Questions

- (1) What are the reductions in concentrations going from road runoff via the sewer system (gully pots) towards the wetland and finally to the groundwater recharge point?
- (2) What are the effects of road management measures (sweeping, de-icing)?
- (3) What is the ‘best practice’ for the road and wetland management?

Management recommendations

- Modify the hydraulic management of the system to let the road water bypass it during de-icing

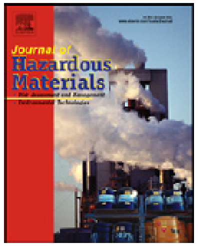
- PAHs and metals were well retained by the system during the rest of the year and reduce point source emissions

- Sediment and root mat of the wetland facility will have to be treated as hazardous waste at the end of its life time of 25 years.

Contents lists available at SciVerse ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat



Retention of heavy metals and poly-aromatic hydrocarbons from road water in a constructed wetland and the effect of de-icing

Karin Tromp[a,1], Ana T. Lima[b], Arjan Barendregt[c], Jos T.A. Verhoeven[a,*]

[a] Ecology and Biodiversity, Department of Biology, Utrecht University, Padualaan 8, 3584 CA Utrecht, The Netherlands
[b] Geochemistry, Dept. of Earth Science, Utrecht University, P.O. Box 80021, 3508 TA Utrecht, The Netherlands
[c] Interfacultary Institute for Risk Assessment Science, Toxicology Division, Utrecht University, P.O. Box 80177, 3508 TD Utrecht, The Netherlands

Thank you for your attention

Questions?

Ana Teresa Lima – lima.at@gmail.com
Jos Verhoeven – j.t.a.verhoeven@uu.nl