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Flowcap: load assessment with passive sampling in drainage effluent. Field experiment in the Minerals Policy Monitoring Programme (LMM)

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Introduction

The Dutch Minerals Policy Programme (LMM) monitors the quality of water leaching from agricultural lands[1,2]. Effluent from subsurface drainage tubes is one of the water types addressed in the LMM. Concentrations in drainage effluent are normally measured by grab samples. However, grab samples provide only random indications of loads from farm lands at a local scale, due to rather variable concentrations and highly variable discharges of drainage water. To determine the contribution of different sources of nutrients to surface water we would like to measure loads instead of concentrations.

Flowcap and SorbiCells

Since 2010 the LMM has taken part in the development of a measuring system (Flowcap) for discharge average concentrations, based on the SorbiCell[3], a passive sampler. The SorbiCell is a porous cartridge filled with sorbents, to retain specific chemicals, e.g. nitrate. It also contains tracer salt, dissolving proportionally when water transits the cartridge. The ratio of the mass of the adsorbed chemicals and the sampled volume results in a time average concentration.

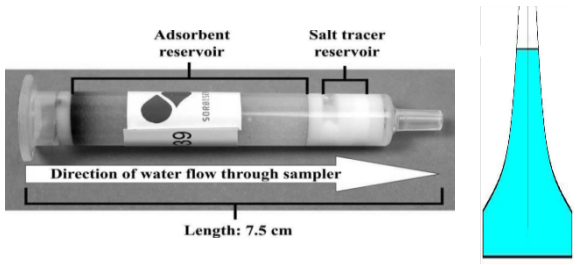

Figure 1: *SorbiCell and Flowcap outlet (Sutro Weir-profile)*

The Flowcap[4] is based on the relation between the water pressure and the flow rate through the SorbiCell. The Flowcap is placed at the end of a drainage tube, holding one or more SorbiCells. The outlet of the Flowcap has the shape of the Eiffel tower (Sutro Weir-profile, Figure 1), ensuring a profound linear relation between the tube discharge and the sampling rate in the SorbiCell[4]. Thus, the SorbiCell in the Flowcap generates a discharge average concentration and its sampled volume is a measure for the discharge of the tube : with these data loads can be assessed.

In the past years prototypes of the Flowcap have been tested under field conditions in the LMM, resulting in some practical adjustments and a newly designed Flowcap. In the winter of 2014/2015 this new Flowcap has been tested on three farms in the LMM.

Field experiment

On 3 farms, respectively in the Peat, Clay and Sand region, Flowcaps have been placed on the outlets of 4 subsurface drainage tubes. Each Flowcap held two SorbiCells, one with low flow resistance (NiP90) and one with high flow resistance (NiP92), to cover a wide range of effluent discharge. The SorbiCells have been replaced approximately once a month. In total 48 trials have been executed and 96 SorbiCells have been analysed on nitrate. When SorbiCells were replaced, regular grab samples have been taken and flow rates have been assessed.

Table 1: *four sampling periods on four tubes at the Clay farm*

Clay farm		Sampled volume (ml)		Flow rate	Average concentration NO_3 (mg/l)		
Tube	Period	NiP90	NiP92	(l/min)	NiP90	NiP92	Grab samples
8	1	50	61	*	-	5.3	179
	2	32	36	*	163	161	136
	3	30	31	*	71	76	90
	4	78	45	1.9	-	-	57
9	1	50	116	1.4	12	145	115
	2	356	36	1.2	74	135	78
	3	236	32	1.8	8.9	-	36
	4	165	60	3.1	-	-	19
14	1	50	50	0.96	-	-	5.2
	2	25	22	0.96	-	-	<5
	3	64	32	1	-	-	8.9
	4	42	43	1.3	-	-	10
15	1	44	58	*	-	8.4	5.7
	2	49	52	1.2	11.1	-	5.3
	3	65	53	1.2	-	-	5.8
	4	59	55	*	-	-	6.8

Table 2: *four sampling periods on four tubes at the Sand farm*

Sand farm		Sampled volume (ml)		Flow rate	Average concentration NO_3 (mg/l)		
Tube	Period	NiP90	NiP92	(l/min)	NiP90	NiP92	Grab samples
10	1	59	68	6	-	7.1	67
	2	39	49	4.4	51	23	56
	3	26	18	2.6	17	-	47
	4	96	43	4.2	24	-	44
11	1	169	50	*	-	-	81
	2	24	30	5.4	22	22	75
	3	41	31	1.5	19	-	67
	4	18	30	3.1	-	-	56
12	1	332	403	*	36	37	27
	2	554	27	12	7.5	31	25
	3	539	317	9	1.3	24	24
	4	496	335	9	1.3	17	23
13	1	64	59	4	8.9	5.3	38
	2	64	44	3.3	33	49	25
	3	107	37	1.7	-	-	13
	4	82	72	1.9	-	-	16

Table 3: *four sampling periods on four tubes at the Peat farm*

Peat farm		Sampled volume (ml)		Flow rate	Average concentration NO_3 (mg/l)		
Tube	Period	NiP90	NiP92	(l/min)	NiP90	NiP92	Grab samples
5	1	70	75	*	-	-	5.2
	2	*	49	6	-	-	<5
	3	61	68	6	-	-	10.3
	4	50	60	1.2	-	-	11.7
6	1	142	125	*	-	-	<5
	2	41	53	4.2	-	-	<5
	3	61	87	6	-	-	5.5
	4	61	52	6	-	-	<5
7	1	48	83	*	-	-	5.2
	2	62	44	4	-	-	<5
	3	101	89	4	-	-	8.9
	4	41	56	*	-	-	10
12	1	44	58	*	-	8.4	5.7
	2	49	52	1.2	11	-	5.3
	3	65	53	1.2	-	-	5.8
	4	59	55	*	-	-	6.8

** not available, tubes were not running*
- under detection limit

Results

Unfortunately, sampled volumes in de Sorbicells were very low, in 37 of 48 trials sampled volumes were below 100 ml. In a previous LMM field test, at a different farm, the smallest volume was 241 ml. In this Flowcap test design, 100 ml was the minimum for reliable determination of average concentrations and discharge calculations.

Furthermore, as the NiP90-SorbiCell has less flow resistance than the NiP92, we expected higher sampled volumes in the NiP90 . However, in 22 of 48 trials less water passed the NiP90 than the NiP92 (Tables 1, 2 and 3, results in red), indicating hampered functioning of the Flowcap and the SorbiCells.

Still, tube 9 at the Clay farm shows some consistent results: more water passed the NiP90 than NiP92 (Table 2, results in green). At the Sand farm, in tube 12 (Table 3, green results) the discharges exceeded the capacity of the low resistant NiP90 (500 ml), but were within the capacity of NiP92 with high resistance. In these cases the NiP92 provided a more reliable nitrate concentration.

Figure 2: *A: Flowcap with SorbiCells (blue arrow) and outlet (red arrow). B: Flowcap partially under water.*

During field visits it was observed for all tubes that the SorbiCells and the Flowcap outlet were partially or completely under water. This may have disturbed the pressure within the Flowcap and the water transport through the SorbiCells, resulting in low and inconsistent sampled volumes.

Conclusions

The Flowcap outlet being under the water surface from time to time seemed to have a large effect on the functioning of the Flowcap and the water transport through the SorbiCells. These effects should be further examined.

Due to the low and inconsistent sampled volumes in most of the periods, there was no use to interpret concentrations, or calculate drainage discharges and loads.

The field conditions at the test farms were representative for the Dutch drained farms: flat farmlands with drainage tubes at approximately 15-50 cm above water surface. The currently developed Flowcap, with its outlet at risk for flooding, is not fit for LMM-farms.

References

[1] e.g. Lukács et al. 2015. Agricultural practice and water quality at grassland farms registered for derogation in 2013. RIVM report 2015-0072. Bilthoven

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[3] www.sorbisense.com

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