Reduction of pollution load from street-runoff by an inlet-filtration-system filled with adsorptive material

Réduction de la pollution des eaux de ruissellement de chaussées avec un système de filtration aux avaloirs utilisant un matériau absorbant

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RESUME

La pollution des eaux de surface par les ruissellements de chaussées devient un problème crucial comme le montrent plusieurs études nationales et internationales. Il existe différentes stratégies de réduction des ruissellements urbains. L'une consiste à réduire la charge polluante vers les cours d'eau et les lacs par le biais de retenues centralisées, de bassins de purification et de zones humides artificielles centralisées.

Le contrôle à la source est une stratégie alternative. Cet article présente une solution pour les milliers d'avaloirs des voies urbaines qui drainent les ruissellements pollués des rues et des routes. Il s'agit d'une cartouche qui peut être insérée dans les avaloirs. Le flux entrant est traité en deux étapes de filtration - décantation et filtration.

ABSTRACT

Pollution of surface waters by runoff from sealed areas is coming more into focus. As shown by several national and international studies, this part of wastewater cannot be neglegted. There are different strategies to reduce emission from urban runoff. One is to reduce the pollution load to rivers and lakes by centralised retention, purification tanks and centralised constructed wetlands.

An alternative strategy is source control. The presented solution in this paper concerns the thousands of inlets in urban areas draining highly polluted runoff from roads and highways. This solution consists of a cartridge that can be inserted into standard inlets. Within 2 filtration steps, a settling volume and an adsorptive filtration, the inflowing runoff is treated.

The results of the quality measurements are :

- a mixture of special filter sand with an adsorptive material is suitable for different inorganic and organic compounds.
- a high retention for suspended solids was found
- a significant reduction for heavy metals (zinc and copper), o-phosphate, and PAC was observed.

KEYWORDS

Heavy Metal, Pilot Plant, Stormwater, Surface Runoff, Treatment, Urban drainage.

1 INTRODUCTION

Pollution of surface waters by runoff from sealed areas is coming more into focus. As shown by several national and international studies, this part of wastewater cannot be neglegted. In Germany, it is estimated that around 50% of the total pollution load emitted to rivers is discharged by separated sewers and overflows from combined sewers. In the case of separated sewer systems, there is usually no treatment provided.

Until now stormwater treatment in separated sewer systems is usually done by end-of-the-pipe solutions. These are mostly stormwater clarification tanks, some soil filters or chemical treatment plants (sedimentation after flocculation). The principles, based only on the sedimentation process, are to be seen critically, because the effect on reduction of heavy metals and nutritions is too low. Soil filters are preferred.

However, these end-of-pipe-technologies have several disadvantages:

- The level of a sewer system is usually 2-4 m below ground level. Therefore, the inlet to the central treatment facility (i.e. soil filter) must be as deep as the sewer system, which is not possible in mostly flat regions like the northern part of Germany. This means that the amount of water which is treated has to be pumped to a higher level or this type of plant cannot be realized.
- Because of the position at the end of the sewer system, only a mixture of polluted stormwater can be treated. There is no separate treatment for highly polluted runoff from streets and highways and low polluted runoff from other areas (i.e. roofs) possible.
- At the end of the pipe, the amount of water to be treated is mostly so high that only a part can be handled by the centralized plants.

An alternative strategy is source control. The presented solution in this paper concerns the thousands of inlets in urban areas draining highly polluted runoff from roads and highways.

Therefore, a new on-site system of stormwater runoff treatment was developed which purifies the highly polluted runoff on-site. This method uses the difference in height from ground level to sewer level. This system is called INNOLET® and can be integrated into newly built inlets or installed into existing ones.

Projects in USA and Denmark have shown, that runoff filters have been developed (Claytor, 1996) and suitable adsorptive filter materials are available (Möller et.al., 2002). In a project in Switzerland adsorptive filter material was used for reduction of copper in the runoff from a roof covered with copper. (Frenzel et al., 2001)

2 POLLUTION FROM RUNOFF IN URBAN AREAS

There are a number of pollutants from runoff in urban areas which have an impact on the receiving water. However, there is a certain difference between runoff from streets and from roofs. Runoff from streets generally has a higher content of pollutants.

	unit	Streets				roofs			
	unit	Count	Medium	Minimum	Maximum	count	Medium	min	max
PH		4	7.0	6.4	7.6	3	6.1	5.9	6.3
Cond.	mS/cm	8	136.6	69.2	342.5	3	91.7	66.0	129.0
TSS	mg/l	11	210.2	37.5	980.0	2	51.6	43.2	60.0
TOC	mg/l	2	17.2	6.6	27.8	0	n.v.	n.v.	n.v.
COD	mgO2/l	17	88.1	13.2	260.0	3	30.8	22.0	37.0
AOX	mg/l	6	136.5	12.8	600.0	0	n.v.	n.v.	n.v.
P_{tot}	mg/l	8	0.9	0.1	3.0	1	0.1	0.1	0.1
PO4-P	mg/l	6	0.1	0.0	0.2	0	n.v.	n.v.	n.v.
N_{tot}	mg/l	3	2.8	1.8	4.1	1	9.0	9.0	9.0
NO3-N	mg/l	11	0.8	0.4	1.5	1	0.2	0.2	0.2
NH4-N	mg/l	11	1.0	0.2	2.4	1	4.0	4.0	4.0
HC	mg/l	8	0.3	0.0	0.7	0	n.v.	n.v.	n.v.
BOD5	mg/l	11	15.0	1.1	28.0	0	n.v.	n.v.	n.v.
PAH	mg/l	5	1.9	0.6	3.1	1	0.5	0.5	0.5
Cd	mg/l	10	5.2	0.0	20.0	1	1.0	1.0	1.0
Zn	mg/l	14	687.9	80.0	1950.0	1	24.0	24.0	24.0
Cu	mg/l	11	76.0	6.0	380.0	1	35.0	35.0	35.0
Pb	mg/l	14	180.2	9.4	980.0	1	104.0	104.0	104.0

n.v. = no value, cond. = conductivity, TSS = total suspended solids, HC = Hydrocarbon

Table 1 : Contents of different compounds in runoff from streets in comparison with runoff from roofs (Förster and Herrmann, 1996; Göttle, 1978; Grottker, 1987; Hahn and Xanthopoulos, 1995; Heinzmann 1993; Paulsen 1987; Sommer et.al., 2002; Xanthopoulos, 1990)

In the table it can be seen, that compared to roofs, the values for heavy metals, HC, AOX and COD are higher in runoff in particular from streets. Nutritions like Phosphorus are responsible for euthrofication of the receiving waters. In the literature it is acknowledged that high concentrations can be found in runoff from highly travelled roads. (Grottker, 1987) remarks that different pollution loads of heavy metals are obtained from different road types.

Another problem is that several compounds and heavy metals are adsorbed at different grain sizes. 60-90% of the heavy metals in the runoff are adsorbed to the smallest fraction of grain in the runoff, which means that it must be in the suspended fraction and will not settle in a settling tank. (Xanthopoulos, 1990)

3 PURIFICATION METHOD : INNOLET®-SYSTEM

The idea of the INNOLET® Filtration-System is to reduce the high pollution in runoff from heavily travelled streets and highways. Two systems have been developed. The first system is the INNOLET® gutter. It is an implementation of a filter in a standard gutter that is suitable for renewal of streets and new built roads.

The INNOLET® filter cartridge instead can be easily applied into the existing inlets, built according to the German DIN, without any change of the inlet. (Sommer, 2003),(Sommer and Sieker, 2004)

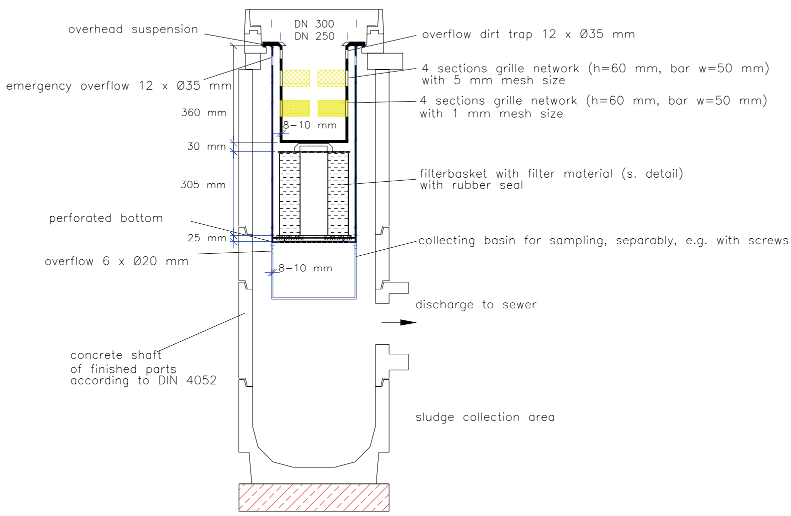

Figure 1 : Drawing of the INNOLET®-filter cartridge placed in a standard German inlet

The INNOLET® filter cartridge is a 2 step filter unit. The first step is a sedimentation and filtration of bigger particles like sand or leaves. In the second step an adsorptive material is reduced to reduce soluble compounds. The adsorptive material is an granulated iron hydroxide which is capable to remove heavy metals and phosphate. Both parts are inserted into a containing cartridge.

For evaluating the hydraulic behaviour of runoff in the system, a model inlet was built. The results from these pre-measurements were the basis for changing and optimizing the design of the system.

If the filter is not able to handle the amount of runoff to the inlet, overflows directly to the sewer assure that the environment is not flooded.

The studies showed that the proposed flow rate could be reached with a special selection of filtration material. The best results were with a filtration sand with a steep distribution curve. The sieve curve of dust from streets is much smoother, because the quota of small particles that will be suspended in the runoff is higher.

4 RESULTS

4.1 Hydraulic aspects

The aim was to treat a runoff rate of 7-15 l/(s*ha) (2.5-5.4 mm/h) in the filtration area according to the the dimensioning of conventional rain water tanks. The first task was to optimise the flow rate and the filtration time. Table 2 shows the filtration speed and filtration time for the 2 systems.

	Filter speed		Filtration time
	(m/s)	(m/s)	(s)
INNOLET gutter	0.001	1.0E-03	100
INNOLET filter cartridge	0.005	5.0E-03	20

Table 2 : Filtration speed

With these operating conditions is was possible to filtrate 3 quarter of the runoff as shown in the water balance in table 3.

	Inflow	overflow	treated	treated	not treated	overflows
	(m³/a)	(m³/a)	(m³/a)	(%)	(%)	(N/a)
INNOLET® gutter	114.78	26.5	88.22	77	23	67
INNOLET® filter cartridge	114.66	25.17	89.48	78	22	71

Table 3 : water balance for an area of 320 m² per INNOLET®-Element

4.2 Quality Aspects

Preliminary tests with potential adsorption material showed that some compounds have a higher concentration in the outflow than in the artificial storm water. For further tests it was decided to use iron oxide and zeolithe. Following filtration materials were selected and tested.

FerroSorb Plus (Ironoxide)
FerroSorb RWR (Ironoxide plus Zeolithe)

Table 4 : Selected material for adsorption of different compounds in runoff

The main aim was to reduce heavy metals and phosphorous compounds in the outflow of the filter. Other target parameters were hydrocarbons and polyaromatic hydrocarbons (PAH).

name	Unit	Load	Load	load	Total outflow	load
		Input	overflow	filtrate	Purified	reduction
Artificial rainwater	(m³/a)	114.66	25.17	89.48		
TSS	(kg/a)	196.30	43.09	61.28	104.37	47%
Cu	(g/a)	2.19	0.48	1.20	1.68	23%
Zn	(g/a)	17.82	3.91	5.56	9.48	47%
PAH	(g/a)	15.73	3.45	6.14	9.59	39%
o-PO_4-P	(g/a)	45.23	9.93	14.12	24.05	47%

Table 5 : pollution load balance, results of adsorption experiments with artificial runoff stormwater

The results of the load balance of the runoff showed a reduction from around 20% (Cu) up to nearly 50% (TSS, ZN, o-PO_4-P). The base of these calculations were the experiments with artificial runoff stormwater which offer the opportunity to measure in differents stages of usage.

5 PILOT SITE HAMBURG

Within the Urban Water Cycle project, an EU Interreg IIIb North Sea Region project, the City of Hamburg and the Hamburg Sewage Service is partner of the project.

One of the aims of the Hamburg UWC projects is the purification of storm water before running into the receiving water. One possibility is the treatment of the runoff at the source. Therefore, the innovative filtration system INNOLET®, which can be applied to standard inlets, was selected for treatment in a road with high daily traffic load (more than 35.000 veh/d) in the project catchment of "Mittlere Bille". The road is one of the main through roads of the suburb of Hamburg Bergedorf. It is swept once a week by the public cleaning company.

Figure 2 : INNOLET® filter cartridges were implemented in "Mittlere Bille" catchment area, parts from the left: cartridge, filter filled with adsorptive material, retainment of larger particles like sand and leaves

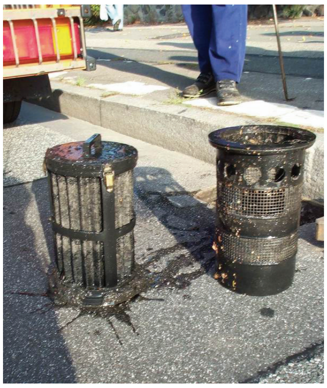

Figure 3 and 4 : INNOLET® filter cartridges after one month inserted in the gully, right pictures shows the retention of leaves

19 pilot cartridges of the INNOLET® system were inserted into inserted existing inlets. Therefore the existing inlets were rebuilt. These inlets are monitored monthly for maintenance. No quality measurements are made in this period.

The first results are:

1. The street has high TSS-load with app. 1000 mg/l
2. The INNOLET filters retain a large amount of TSS (Sand and leaves) in the bucket .
3. The INNOLET filter also retains a large part of the small grain size fraction on the filter surface.
4. Less than one day per week street sweeping is not efficient enough to reduce the high amount of TSS from the street. In a corresponding project in a similar road (NORIS, Hanover) the frequency is 3 times a week. The TSS load which is flushed the inlets in rainfall events is far lower.
5. The maintenance frequency of the buckets is considered to be once a month at the moment. This includes the cleaning the buckets. The maintenance frequency of the filter considered to be half a year. After one year the filter material shall be replaced.

6 CONCLUSION

With INNOLET®, a new way of reducing pollutants from street runoff was presented. In hydraulic experiments on the pilot plant, the usability of the system was verified. There were several optimisations on retention and the adsorptive material. Finally a sufficient flow rate and a good retention of particles could be achieved. The flow rate is highly dependent on the distribution of corn fractions in the filtration material.

The system was then tested for 2 years on-site in inlets of a road in an industrial area. The practical hydraulic tests showed good results. A problem hereby is to prevent the filter from clogging with small suspended particles. An exchange time of 0.5-1 year for the filter can be expected.

The results of the quality measurements are:

- a mixture of special filter sand with an adsorptive material is suitable for the reduction of different inorganic and organic compounds.
- a high retention for suspended solids was found
- a significant reduction for heavy metals (zinc and copper), o-phosphate, and PAC was observed. The results for other parameters were insignificant.

The System INNOLET® is a suitable treatment method for catchment areas with highly polluted roads or spatial restrictions for centralised treatment plants. It can be applied in existing gullies.

First results in a Urban Water Cycle pilot catchment, located in Hamburg in a road with high daily traffic, show, that INNOLET can retain the most of TSS in the run off. The second filter step retains also the smaller grain size fraction which is meant to keep the highest amount of heavy metals. In roads with high TSS load the maintenance frequency should be adjusted to more than once a week.

The results will be integrated into a catchment-wide simulation with the source & flux model STORM-SEWSYS with different scenarios.

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