Innovative alternatives for the treatment of storm water in separate system catchments

Alternatives innovantes pour le traitement des eaux pluviales dans les zones à systèmes séparatifs

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RESUME

En Allemagne, des discussions controverses sont menées actuellement sur les critères pointus exigés pour le traitement des eaux pluviales dans les zones de drainage à système séparatif. Le procédé de traitement des eaux pluviales le plus répandu est celui à effet de décantation dans des bassins décanteurs. A cause des nouvelles directives en Rhénanie du Nord Westphalie (Allemagne), les surfaces pavées sont maintenant à examiner du point de vue de leur potentiel de pollution et de nouveaux procédés de traitements exhaustifs sont à mettre en place. Le procédé d’examen complexe des surfaces à drainer a été opérationnalisé par le Cabinet Dr. Pecher AG pour le compte de la municipalité de Wuppertal (16,800 ha). Actuellement d’autres procédés sont en train de faire l’objet d’études afin de déboucher sur des solutions de drainage et de traitement des eaux pluviales plus décentralisées et plus économiques du point de vue du coût et de l’espace.

ABSTRACT

In Germany, more stringent requirements for the treatment of storm water in catchments using separate sewage systems are prompting controversial discussions. Storm water treatment based on sedimentation in tanks is widespread. New regulations in North Rhine-Westphalia (Germany) necessitate both the examination of sealed surfaces with regard to their pollution potential and the execution of more far-reaching treatment measures. For the City of Wuppertal (16,840 ha), the catchment analysis process, which requires considerable effort, has been carried out by Dr. Pecher AG. In addition, processes that permit space-saving, cost-effective decentralized solutions are also currently being examined.

KEYWORDS

Decentralized storm water treatment, filtration, heavy metals, rainfall-runoff, sedimentation
1 INTRODUCTION

In North Rhine-Westphalia (Germany) with a population of more than 18 million, since 2004 more stringent requirements for the treatment of storm water in separate sewage systems have been prompting a controversial discussion. The corresponding ordinance relating to this takes various findings into account that were obtained via a survey carried out as provided for in the EU Water Framework Directive. Previously, treatment applied only to runoff from industrial, small business, and mixed catchment areas. For runoff from streets and roads there were no clear-cut provisions. Now, all types of surfaces have to be registered and categorized.

- Category I: non polluted storm water (e.g. surfaces in residential areas, paths, roof-top surfaces)
- Category II: low-polluted storm water (e.g. areas with low-density motor-vehicle traffic, residential streets, car parks, industrial areas not using water pollutants)
- Category III: highly-polluted storm water (e.g. areas with high-density motor-vehicle traffic, industrial and small business areas).

Category I storm water does not require treatment. In the case of low-pollution areas with Category II storm water, treatment is compulsory; but some exemptions can be allowed here. Runoff from Category III areas requires treatment.

The government order confronts municipalities with the following tasks and problems:

- All surfaces have to be re-registered and re-evaluated.
- Additional storm water treatment measures have to be carried out. In densely-populated areas, there is often no room for these.
- Cost-effective, space-saving alternatives to storm water treatment have not yet been approved since they have not yet been adequately examined.
- An increase in the specific cost of storm water treatment to the population is difficult to put through politically.

2 MATERIALS AND METHODS

2.1 Surface analysis - an example

Dr. Pecher AG has carried out an appropriate surface evaluation for the entire area of the city of Wuppertal (approx. 16,840 ha) and has also developed a storm water treatment concept (Grüning and Hoppe, 2006).

In Wuppertal, attention is being focused on this problem. The city with its population of more than 300,000 extends along the bottom of a valley traversed by the river Wupper. The area is densely populated, sewage from about 90% of it being removed in a separate system. More than 60 separation structures channel the storm water requiring treatment into a big collecting sewer 2.40 m in diameter and nearly 10 km long. This collecting sewer runs alongside the Wupper, right through the Wuppertal urban area, and channels the runoff that needs treatment into the treatment plant. Due to the more stringent requirements, this system is associated with hydraulic bottlenecks.

About 25.5% (4,300 ha) of the urban area as a whole consists of sealed surfaces. The digital sealed surface register contains details of 562,000 individual surfaces used for a variety of purposes (e.g. road surfaces, roofs, paved areas, etc.). The main reason for the elaborate survey was, in particular, the fact that there were some circulation areas to which no clear provision applied. In these cases, a classification based on traffic density was used. In the case of roads without any data from traffic
surveys, estimates had to be made. All in all, categories had to be assigned to 10,300 sections of the city’s streets.

All these surfaces were evaluated and assessed by means of a Geographical Information System (GIS); the work also included evaluating aerial data, the zoning plan, and cadastral data provided by the City of Wuppertal.

2.2 Problems relating to storm water treatment and some solutions

Depending on the degree of potential pollution, the storm water can be treated in storm water sedimentation tanks or in retention basins with soil filters. In addition, when the 15 l/(s·ha) portion subject to treatment has been exceeded, it is also possible to use storm water overflows to discharge the diluted storm flow into the receiving water. The most common and widespread method, however, is treatment in sedimentation tanks. These tanks can be divided up into two types. Tanks that are constantly filled are designed to be purely sedimentation tanks. Tanks that are not constantly filled and that have their contents passed into the treatment plant. Incidentally, such tanks may well cost sums in the region of EUR 300,000. The minimum volume is 10 m³/ha.

Processes differing from the above-mentioned ones require proof of efficacy. On behalf of the Wuppertal municipal utilities, Dr. Pecher AG is currently examining an alternative process involving filter systems. The system is described in Dierkes et al. (2005). The filter systems can be integrated into the sewage system. Figure 1 shows the principal mechanisms on which the system works.
The filter system enables the storm water to be cleaned by the basic hydraulic engineering processes of sedimentation, adsorption, filtration and chemical precipitation. In the filter pits, the effluent is introduced into the bottom section of the shaft via a cyclone-type separator. The tangential direction of flow causes the particulates to be separated from the effluent and sedimented in a collecting tank. The stilling basin inhibits remobilization of the solids during strong incoming surges. The effluent, thus largely freed of its solids, is then channelled in a countercurrent fashion, based on equalization of hydrostatic pressure, through a concrete air diffuser. Due to the countercurrent process and the position of the filter element below the water line, the filter element silts up only at a very slow rate. After a rainfall event, particles fall out of the filter element into the separation hopper, from whence they subsequently enter the sludge collector. The water thus treated can then be discharged directly into a body of receiving water or, alternatively, be allowed to seep directly into the ground. However, to date the process has not yet been approved by the authorities. A temporary approval is issued in exceptional cases, subject to provisos. Table 1 presents a comparison between the action of this system and that of storm water sedimentation tanks.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Sedimentation tank</th>
<th>Filter shaft</th>
</tr>
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<tbody>
<tr>
<td>Efficacy</td>
<td>Limited - retention via sedimentation</td>
<td>Retention of solids and dissolved substances</td>
</tr>
<tr>
<td>Retention in the event of accidents</td>
<td>Advantageous if the gate valve is closed in good time</td>
<td>Not possible – system efficacy is the only factor</td>
</tr>
<tr>
<td>Operating effort</td>
<td>Sludge removal: about 2-3 times a year</td>
<td>Sludge removal: about twice a year</td>
</tr>
<tr>
<td>Space required</td>
<td>10 m³/ha</td>
<td>Shaft diameter: 1.5 m</td>
</tr>
</tbody>
</table>

Table 1: Storm water sedimentation tanks versus filter system

2.3 Research projects for the purpose of testing the filter systems

Dr. Pecher AG is testing this system of filtration in Wuppertal. The results of the research project presented here are meant to demonstrate the efficacy of the filter systems and the maintenance effort required. The system differs from a conventional rainfall tank in that polluted surface water is admitted to two different filter drop structures in the by-pass. So far, the performance capabilities of the filter system have not yet been validated in comparison with conventional processes. The conventional processes in question are, first and foremost, storm water sedimentation tanks, but retention basins with soil filters or the channeling of the polluted surface water into the sanitary sewage system or combined sewage system are also feasible.

The cleansing action of the filter systems is examined by means of online measuring instruments and the analysis of samples. The inflows and outflows are measured so as to establish load balances. The main parameter used to indicate the degree of storm water pollution is solids content. A large number of heavy metals are adsorbed onto the particulates. To assure continuous monitoring, turbidity values are measured by photometer probes in the storm water sedimentation tanks and filter systems. In addition, pH values, electrical conductivity and temperature are recorded online. The photometer probes ensure that purification performance can be observed.
permanently, especially in precipitation-related and consequently highly-dynamic inflows. The use of photometer probes for the efficient characterization of storm water pollution levels also forms part of the investigations (Grüning and Orth, 2002).

Samples are taken to record the substances that can be filtered off (and also to calibrate the probes), total organic carbon (TOC) values, the organic nitrogen content, a number of heavy metals (including lead, cadmium, copper, and zinc), and hydrocarbons.

3 FIRST RESULTS

3.1 Percentage of Wuppertal catchments requiring treatment

About 4,300 ha of the total urban area consists of sealed surfaces. Depending on how these catchments requiring treatment are assessed, about 40-50% of these surfaces have to be connected up to a treatment plant. A particularly controversial issue currently still under discussion is the assessment of the circulation areas. In this respect, two recommendations applicable in Germany are being adduced:

- Relatively stringent requirements: categorization based on the ATV-DVWK-M 153 guidelines (ATV, 2000); here, road surface runoff is already classifiable as “requiring treatment” if the traffic density is 300 vehicles per day or higher.
- Less stringent requirements: categorization based on the “Richtlinien für bautechnische Maßnahmen an Straßen in Wasserschutzgebieten (RistWag)” (FGSV, 2002) (Guidelines for civil engineering projects on roads in water conservancy areas); here, treatment is not required until traffic density is 2,000 vehicles per day or higher.

The results are charted in Figure 2. If assessment is based on the relatively stringent requirements, the total circulation area requiring treatment increases from 362 to 662 ha.

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Figure 2: Assessment of areas requiring treatment and the impact of different traffic density ratings.
3.2 Measurements based on photometer probes

In the trial phase, the efficiency of the different systems (storm water sedimentation tanks and filter systems) is being continuously monitored by means of photometer probes. The main parameter used in this respect is suspended solids (TS). The basic feasibility of this technology has already been put to the test in Wuppertal. Figure 3 shows the characteristic curve of readings taken from a storm water sewer in Wuppertal. The water from a stream flows continuously through this sewer. If it rains, contaminated storm water is additionally channelled into it. So far, this entire runoff has been discharged into the river Wupper. In future, up to 15 l/(s·ha) of the storm water runoff will have to be treated. The plot below demonstrates that clear-cut TS concentration peaks occur when rainfall commences. In Wuppertal, there are plans to use these probes to control runoff based on the degree of wastewater pollution (Grüning and Hoppe, 2006).

![Figure 3: Reading resulting from online-measurement of suspended solids (TS) in a cased stream sewer in Wuppertal](image-url)
3.3 Efficacy of the filter shaft systems - results obtained to date

The trial stage for comparative mensuration of storm water sedimentation tanks and filter pits is scheduled for the period from December 2006 to July 2008. Efficiency values are now available for the cleansing power of the filter pits in respect of runoff from metal roofs and road surfaces (Athanasiadis et al., 2005).

In laboratory tests performed by Dierkes et al. (2005), the system was investigated in a real-scale facility. Performance of the system in assisting the infiltration of road runoff is presented in Table 2. Two years of operation were simulated in the facility, with artificial runoff being used over a period of several weeks. Removal efficiency was found to be more than 96 % for lead (Pb) and copper (Cu) and 84 % for zinc (Zn). Over 99 % of mineral oils (MOTHs) were trapped, no concentrations being detectable in the effluent. The retention of suspended solids (TS) was greater than 99 %.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pb</th>
<th>Cu</th>
<th>Zn</th>
<th>MOTHs</th>
<th>TSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal efficiency (%)</td>
<td>96</td>
<td>99</td>
<td>84</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

Table 2: Removal efficiency under near natural conditions

When scaling up the implementation of the system, some of the next steps should consist of examining the maximum inflows to which the filter pits can be subjected without their efficiency being greatly affected and what operating conditions prevail over a relatively long term (e.g. sludge removal, cleaning of filter components).

4 CONCLUSIONS

Making greater demands on storm water treatment also necessitates more far-reaching treatment options. The implementation of the necessary development measures presented here can be broken down into three main steps, each built on the preceding one.

• The registration, assessment, and categorization of areas producing runoff and the degree of surface pollution involved. The area registration procedures presented here from a bottom-up angle form the basis of a storm water treatment concept to be implemented later on.

• The preparation of storm water treatment measures that are both effective and cost-effective especially in densely built-up urban areas, but also in relatively small areas. The filter systems now developed are to be validated for widespread use under practical conditions. At the same time, any operational factors that may be necessary are to be optimized. The assumption is warranted that the efficiency of these systems will lie considerably above the performance of a storm water sedimentation tank.

• Development and use of measurement techniques for monitoring and even controlling storm water treatment. Use of the photometer probes tested and utilized here enables highly-dynamic substance concentrations (especially TS) to be recorded continuously.

One thing is certain: the necessary expenditure on storm water treatment has to be subjected to constant, self-critical scrutiny in a pan-European context.
LIST OF REFERENCES