Improvement of water quality by sewer network flushing

Amélioration de la qualité des eaux en utilisant des chasses pour nettoyer le réseau

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RESUME
Les dépôts dans les réseaux d’égout ayant des impacts négatifs sur la qualité de l’eau, des opérations sont entreprises pour réduire ces dépôts. La pratique la plus courante est le nettoyage à haute pression effectué à intervalles espacés. Pour assurer une amélioration significative de l’intégralité de réseaux d’égouts, il est nécessaire de nettoyer de manière continue ou quasi-continue certains points difficiles. Des dispositifs automatiques de chasse permettent cela. Cet article traite des exigences et des qualifications nécessaires à l’application d’une stratégie de mise en œuvre de ces chasses ; ces éléments sont tirés d’études sur site et de données de la littérature. Un intérêt particulier est apporté aux réseaux combinés avec capacité de stockage.

ABSTRACT
Deposits in sewers cause several negative impacts on water quality. Therefore sewers are operated to reduce deposit. Most common practise is high pressure cleaning which is carried through in large intervals of time. If significant improvements of cleaning entire sewer networks are pursued, at least hot spots must be cleaned continuously or quasi-continuously. Automated flushing devices are able to encounter this. This paper deals with requirements and qualifications to implement a strategy to realize sewer network flushing. They are driven from field studies and literature values. Special interest is also given to combined sewers with storage capacity.

KEYWORDS
Flushing, Sewer Cleaning, Sewer Management, Sewer Network Flushing, Water Quality.
1 INTRODUCTION
Emissions from sewer networks and waste water treatment plants have substantial influence on water quality. A main part of the yearly load discharging into receiving waters is attributed to the remobilisation of deposit by storm water events (ASHLEY et al., 2004; CRABTREE, 1988; BROMBACH, 1984). Therefore operation and maintenance of a sewer system should aim at lower-emissions by supplementing a deposit managing system. Usually deposit cannot be avoided completely by planning measures thus cleaning of sewers and structures within the sewage system has to be carried out regularly. Nowadays the most common procedure of high pressure cleaning (jetting) is not feasible to maintain clean sewers enduringly. Jetting is used with cleaning intervals form several months to even years to keep maintenance costs on an economical reasonable level. Taking into account that deposit build up in sewers quasi-continuously and over the entire sewer system punctually, an area-wide and regular cleaning has to take place in short intervals.

However, first objective for a preventive cleaning strategy is still reducing emissions from sewer systems.

Nowadays, for the use of storage volume activating devices (SVAD) methods are available to dimensioning flushing in sewers with circular cross-section as well as straight directions (CAMPISANO AND MODICA, 2003; CAMPISANO et al., 2005; DETTMAR, 2005; DETTMAR AND STAUFER, 2005a). These were based upon one-dimensional numerical studies in connection with either laboratory or field data. Further suggestions for dimensioning and operating of SVAD within combined sewers with storage capacity are contributed by DETTMAR (2005) and DETTMAR AND STAUFER (2005b). This paper deals with results form measuring campaigns as well as literature values to indicate a method to asses a sustainable cleaning strategy that is really able to reduce emissions to the water body.

2 OBJECTIVE
After determining effects on the receiving water if a cleaning strategy is applied to an entire network to reduce pollution loads from CSOs, aspects of implementing such a method are driven from field studies and literature.

3 METHODS
3.1 Approach
Emissions from sediments arise mostly during storm water events (RISTENPART, 1995). Quickly increasing discharges in combined sewers remobilize sediments containing organic material and to some extend heavy metals. If storm water discharges succeed the hydraulic capacity of the connected waste water treatment plant (wwtp) combined sewage is released into the receiving water. With it eroded sediments from the entire sewer network contribute to emitted loads from CSOs.

Storage capacity protecting the environment against further pollution will be reduced, if extended amounts of deposits form in storage devices for combined sewage, such as combined sewers with storage capacity. Also, sediments increase emissions from wwtp by the phenomenon called first flush which refers to increasing loads entering a wwtp at the beginning of a storm water event (KREBS et al., 1999; MANNINA et al., 2003). If organic material, nutrients or heavy metals wash off of particles, increasing
loads may not be decomposed completely by activated sludge processes and thus enter the environment.

The flushing offers the possibility to remove deposit promptly after sedimentation (DETTMAR, 2005, FAN, 2004, LAPLACE, 2002) or to prevent their formation at the entire sewer network. Then suitable flushing devices have to be installed at all relevant deposit-critical points in the sewage and need to be operated automatically. During the last years developed flushing devices are able to activate several flushing waves per day and consequently they can keep sewers free of deposit enduringly (BERTRAND-KRAJEWSKI, 2005, KIRCHHEIM, 2005, SCHAFFNER, 2007). However, different local circumstances of sewers and guidelines of application of flushing devices need to be obeyed. For instance, waste water flow has to be sufficient to create the flushing volume in time without risking any anaerobic conditions in the sewage.

3.2 Field Investigations

Field investigations were carried through to show the efficiency of big sized flushing devices in a combined sewer with storage capacity. The results in respect to the relevance and success of cleaning may be transferred to sewer sections which are used for storing waste water within a real-time-control strategy. Figure 1 shows a scheme of combined sewer with storage capacity and bottom end overflow (csscbo). It is about 400 m long and has a diameter between 2,500 mm and 3,400 mm. At the bottom end of this csscbo overflow structure and throttle having a maximum discharge of about 500 l/s are placed. An automatic flushing device, driven by a pneumatic engine, was installed dividing the sewer into two sections. A more detailed description may be found in DETTMAR AND STAUFER (2005). The flushing section is about 300 m long where as the storage section extends to 100 m.

If big storm water events cause discharges that exceed the throttle’s outflow, the storage capacity is activated. During impoundage and especially during the time the csscbo needs to empty, suspended solids settle on the bottom. After an impoundage measurements of the height of deposit were documented. Sediments grew up to 5 cm in height. The deposit’s constitution is similar to sludge. The sludge had a volatile loss of 63.8 % and contained about 28.6 g/l COD which was mostly formed by particles (>97 %).
In case of a following storm water event this material may be carried out by the CSO. An automatic flushing device is able to clean the bottom of a sewer by generating flushing waves eroding sediments and taking it towards a waste water treatment facility. TSS-loads with in an flushing wave have been determined by measuring discharge continuously and TSS-Concentration in intervals of 30 s right behind the throttle, see Figure 2. The flushing wave had a storage height of 1.0 m and corresponding flushing volume of 117 m³. The maximum TSS-Load rises up to 1.5 kg/s. The discharge reaches the limit of the throttle for about 20 sec and is then declining. The total mass carried by this wave sums up to 137.6 kg. After run a second wave, the bottom of the sewer was basically free of deposit.

![Figure 2](image-url) Documented concentration and load of total suspended solids (TSS) as well as discharge of a flushing wave

### 3.3 Solids in ordinary combined sewers

At the time being knowledge is incomplete about processes forming deposits in sewer networks (ASHLEY et al., 2004). Detailed models determining accurately sediment height and composition of sediments in sewers are missing as well. Therefore German guidelines for dimensioning structures for storing combined sewage (DWA, 1992), such as storing tanks and combined sewers with storage capacity, consider sediments by a factor \( a_a \) to determine the necessary volume. The factor \( a_a \) depends on average slope of a given catchment and the variation between maximum flow and averaged daily flow. These characteristics are considered to influence the occurrence of sediments strongly. If an entire network is kept free of deposit, this value may be set to \( a_a = 0 \). Figure 3 shows results of calculations to determine the necessary storage volume for the treatment of combined sewage following DWA (1992). If, by any means, a combined sewer system is kept free from deposit, necessary storage volume for the treatment of combined sewage decreases. For example, the specific volume decreases of about 40 % if the factor for sediments for this sewer system is lowered from 0.3 to zero. The difference of the total number of installed volume for the treatment of combined sewage and the necessary volume if an entire sewer...
network is kept free of sediments indicates the benefits for the water body. This way possible benefits are able to be estimated regarding emissions into the water body. Numerical investigations using pollution models can advance conclusions whether keeping an entire sewer system free of deposit is sensible.

![Figure 3: Behaviour of necessary specific volume, which relates to impervious area, in respect to the factor for sediments (a_a) for a given catchment following German guideline DWA A 128](image)

Most often decisions have to be made for existing sewer systems. In this case monitoring of sediments is mandatory in order to identify either hotspots or non-critical passages within the network. After having evaluated the occurrence of deposits, the most promising cleaning measure has to be chosen. This includes high pressure jetting as well as mechanical cleaning devices or flushing devices. For storage volume activating devices requirements will be discussed further.

4 DISCUSSION AND RECOMMENDATION

4.1 Implementing a concept of sewer network flushing

An integral management system taking care of sediments will become important, if, along with others,

- existing sewer systems are confronted with changes in water consumption which leads to smaller dry weather flow with higher risk of sedimentation or
- changes in regulations prompt operators to achieve more knowledge about the condition of their sewers.

Any cause should aim at lower emissions and an easy operation of sewer networks.

4.2 Applying flushing devices in combined sewer systems

In sewer section of the combined system where deposit forms regularly flushing devices can be a powerful tool to keep the bottom free of deposit. This is caused by insufficient velocities of the dry weather flow. To overcome sewer sections between two sections which are self cleaning flushing is a tool to remove deposit. Figure 4 illustrates the necessary local circumstances to apply storage volume activating flushing devices in sewer networks. Depending on the storage volume, height of the stored water body, slopes of the sewer and its diameter it is possible to clean flushing length of several hundreds of meters (BERTRAND-KRAJEWSKI, 2005, CAMPISANO et al. 2005, DETTMAR UND STAUFER, 2005a).
The large parts of the storing section and especially those at the beginning need favourable conditions. The velocity of dry weather flow must create self cleansing power to assure that no sediments remain which built up during storing up flushing volume. Also, the section following the cleaning length need fair transport capacities during dry weather times. Such remobilized solids do not settle again. If remobilized solids reach another section with risk of sedimentation, the most promising cleaning alternative has to be elected again. At special points of interest, e.g. inverted siphons, sediment traps may be placed to take out the material.

4.3 Combined sewers with storage capacities and reservoir sewers

Whether a flushing device is needed in combined sewers with storage capacity or reservoir sewers should depend on the risk that higher loads are emitted to the receiving water body. On the one hand this may be a result of reduced storage volume because sediments occupy a significant volume. At a first glance loosing more than 3 % of the storage volume seems to be a significant lost. This value is subject to many discussions and may be chosen differently. One the other hand sewers operated offline need to be cleaned after impoundage if any sediment is found after emptying. This is the case in any sewer if self-cleaning capabilities are not sufficient. Figure 4 shows a flow-chart to determine whether demand for flushing exists.

As for storage tanks, which are commonly cleaned by flushing after storm water events, combined sewers with storage capacity aligned offline a demand for flushing devices is evident, because there is hardly found any self cleansing effect.
CONCLUSIONS

As seen cleaning entire sewer systems can have significant impact on water quality. If cleaning intervals reduce to days instead of years, automated cleaning devices as well as a transparent sediment managing system is necessary. The cleaning strategy has to base on thoroughly collected data to identify hotspots and all sections with risk of sedimentation. A sustainable sewer management has to focus on sections where deposits build up instead of cleaning clean unsoiled sewers. The set of measures must not solely consist of flushing devices. If storage volume activating devices are included into the sewer network flushing the following requirements need to be fulfilled.

- Self cleansing properties are established in storage section and the following section.
- A sufficient dry weather flow must exist to create the flushing volume in time.
- Anaerobic conditions in the sewage must be prevented.
- If compacted solids are present, basic cleaning has to be carried through in advance.
- Downstream elements such as pumping stations, siphons have to be considered.
- Safety instructions for personnel have to be obeyed strictly.

AKNOWLEDGMENT

We like to acknowledge the support of the study by the Ministry of environment and conservation, agriculture and consumers protection (MUNLV) of Northrhine-Westfalia.
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