Determining fine suspended solids in combined sewer systems: Consequences for laboratory analysis

Déterminer les fines matières solides en suspension dans un système d’assainissement unitaire : conséquences pour l’analyse en laboratoire

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RÉSUMÉ
Les eaux usées provenant de surverses d’orage sont connues comme étant une source importante de pollution de l’eau en milieu urbain. Une grande partie de ces polluants sont adsorbés en particules fines de matières solides en suspension, en particulier à la fraction < 63 µm. Par conséquent, la possibilité de retirer ces particules des déversoirs d’orage avant qu’elles ne parviennent dans les eaux de surface présente un intérêt considérable. C’est pourquoi les particules fines de matières solides en suspension < 63 µm (SS$_{63}$) suscitent un grand intérêt dans la communauté de l’assainissement urbain. Il n’existe cependant aucune procédure d’analyse standardisée permettant de mesurer les SS$_{63}$. Les méthodes normalisées existantes ne concernent que l’ensemble des matières en suspension, et ne tiennent compte d’aucune répartition en fonction de leur calibre. En particulier, l’analyse des particules SS$_{63}$ dans les déversoirs d’orage présente plusieurs difficultés, telles que le faible volume des échantillons ou la flocculation des particules pendant le prélèvement d’échantillons et l’analyse en laboratoire. Il est nécessaire d’en tenir compte lors de l’élaboration d’une méthode praticable d’analyse en laboratoire. Il est cependant primordial de mettre au point une méthode de laboratoire cohérente afin d’établir des programmes de suivi en vue de déterminer les quantités de SS$_{63}$ dans les déversoirs d’orage. Nous avons donc comparé les méthodes pour l’analyse des concentrations de SS$_{63}$ dans les déversoirs d’orage en incluant des paramètres tels que le type de filtre, le processus d’homogénéisation, le criblage en utilisant la solution de référence et souligné les conséquences pour les technologies actuelles de traitement des déversoirs d’orage.

ABSTRACT
Wastewater from combined sewer overflows is known as a major source of urban water pollution. A large part of these pollutants are sorbed to fine suspended solids, especially to the fraction < 63 µm. Thus, removing these fine particles from CSOs before they enter surface waters is of major interest. Therefore, fine suspended solids < 63 µm (SS$_{63}$) have gained wide interest in the urban drainage community. However, there is no standardized analytic procedure for measuring the SS$_{63}$. Existing standard methods only refer to total suspended solids, not considering particle size distributions. Especially the analysis of SS$_{63}$ in combined sewage comes with several challenges, such as small sample volumes or flocculation of particles during sample taking and lab analysis. They must be taken into account for a practicable standard laboratory method. However, it is crucial to develop a consistent lab procedure in order to set up monitoring programs to determine SS$_{63}$ in CSOs. We therefore compared methods for analysing SS$_{63}$ concentrations in combined sewage by including parameters such as type of filter, homogenisation process, screening using standard solution, and pointed out consequences for current combined sewer overflow treatment technologies.

KEYWORDS
Combined sewer overflow, fine suspended solids, laboratory method, SS$_{63}$
1 DEFINITION OF FINE SUSPENDED SOLIDS

1.1 Distinction between fine suspended solids and total suspended solids

Discharges from combined sewer overflows (CSOs) are known as a major source of urban surface water pollution (Tondera et al., 2015). Therefore, storage tanks are constructed to catch the first flush and primary clarify the discharged combined wastewater. In the German urban drainage system, most of these standard treatment technologies such as stormwater tanks are designed to purify the wastewater by sedimentation. The effectiveness of this treatment process mostly depends on the hydraulic residence time. Solids can only be separated from the wastewater, if their settling velocity is higher than the flow rate. According to Stokes’ Law, the settling velocity depends on the particle size, whereas small particles have a lower settling velocity and therefore are more difficult to remove (Gibbs et al., 1971).

There are several studies on fine suspended solids from separate sewer systems (e.g. Viklander, 1998; Boogard et al., 2015), but hardly for those from combined sewer system. In the German urban drainage system, there is an ongoing vivid discussion on transferring design guidelines depending on fine suspended solids < 63 µm (SS$_{63}$) from separate sewer system. However, one of the major gaps at the moment is the lack of a standardized analytic procedure to determine this fraction.

1.2 Potential risks of SS$_{63}$ discharges

Small particles have a larger specific surface than bigger fractions (Michelbach & Wöhrle, 1994). This leads to an increased adsorption potential and therefore pollutants such as heavy metals or aromatic hydrocarbons (PAHs) tend to adsorb to fine suspended solids (Dierschke, 2014; Lau & Stenstrom, 2005; Faram et al., 2007). Considering the pollutant loads of different particle sizes, it is noticeable that the biggest proportion of heavy metals is bound to particles < 60 µm. Figure 1 shows this characteristic for the heavy metals lead (Pb), cadmium (Cd), zinc (Zn), copper (Cu) and nickel (Ni). Thus, SS$_{63}$ can be identified as a carrier for heavy metals. In addition, similar observations were made for PAHs (Xanthopoulos, 1990).

![Fig. 1: Heavy metal load of different particle sizes (Xanthopoulos, 1990)](image)

With regard to impacts on receiving waters and requirements of the EU Water Framework Directive (EU WFD, 2000), removing fine suspended solids from CSOs before they are discharged into receiving waters is of major interest. Bilotta and Brazier (2008) already pointed out that an adequate method is lacking which includes geochemical composition and particle size of suspended solids. Thus, we try to develop a reliable laboratory method to determine SS$_{63}$ in order monitor treatment effectiveness of existing CSO treatment systems.

2 LABORATORY METHOD FOR MEASURING FINE SUSPENDED SOLIDS

2.1 Approaches to measure SS$_{63}$ concentration

To ensure reliable and comparable results, a standardized analytical procedure for measuring the fraction < 63 µm is needed. Currently, there are different approaches to measure SS$_{63}$.

One way to determine the concentration of SS$_{63}$ is using wet screening. In this process, the sample is
fractionated first with a screen (pore size of 63 µm). The next step is the sedimentation of the through fraction. The supernatant is withdrawn and the residue dried at 105 °C (Eyckmanns-Wolters et al., 2013).

However, by using this method the fine particles also include dissolved ingredients (e.g., salts). In contrast, “classic” total suspended solids (TSS) according to DIN EN 872 (2005) only comprise undissolved substances that can be separated by filtration. Thus, this method is not comparable with classic TSS and SS$_{63}$ cannot be given as a fraction [%] of the total amount of TSS.

Hence, the analysis of the fine suspended solids should in general follow the existing German standard methods to analyse TSS, DIN EN 872 (2005). However, there are some additional steps that need to be implemented. The following instructions are intended to provide a rough overview over the general steps in analysing SS$_{63}$. Figure 2 summarises the key steps screening and filtration:

- thoroughly homogenize the sample using magnetic stir bar
- divide sample into two aliquots
- one aliquot is analysed as described in DIN EN 872 (2005) using glass fibre filter
- the other aliquot is fractionized, using a screen with a pore size of 63 µm
- the through fraction is analysed as described in DIN EN 872 (2005) using glass fibre filter

![Fig. 2: Schematic representation of the work steps filtration and screening](image)

The division into two aliquots provides the possibility to measure TSS as well as SS$_{63}$ concentration. Thus, the proportion of SS$_{63}$ from TSS can be determined. Backwashing solids from the screen appeared to be impractical in laboratory routine.

### 2.2 Filter material

One important difference in determining SS$_{63}$ concentration results from the use of different filter materials. According to DIN EN 872 (2005), the sample should be filtered by glass fibre filters. These filters do not have a unique or defined pore size. Depending on the manufacturer, the pore size ranges from 0.3 µm – 1 µm. In contrast, the German DIN 38409 part 2 (1987) also refers to membrane filters as applicable filters. These filters have a defined pore size of 0.45 µm. Therefor, the particle size spectrum differs depending on the used filter material.

![Fig. 3: Comparison between different filter materials](image)
A comparison between the two filter materials is given in Figure 3. The diagram shows the measured concentration of TSS > 63 µm and SS$_{63}$ concentration using different filter materials. TSS > 63 µm was calculated as the difference between TSS and SS$_{63}$. For this purpose, samples of artificial wastewater were divided into two aliquots. One was analysed as described above with glass fibre filter, the other was analysed with membrane filter. The results demonstrate that both filter material achieve similar results. Mean concentration of SS$_{63}$ in the samples analysed by glass fibre filter were not considerably different from the results achieved by membrane filter.

Especially when considering the matrix combined wastewater, the use of a glass fibre filter is more practicable. If the solids content in the sample to be analysed is particularly low, large sample volumes have to be filtered to achieve the limit of determination. This process took very long when using a membrane filter due to the low filtration velocity. As a result, we recommend the use of glass fibre filter.

3 CONCLUSION

In order to meet the standards of the EU Water Framework Directive, the parameter SS$_{63}$ should be taken into account, yet there are no comprehensive studies for wastewater from combined sewer systems. Measurement results gained from wastewater from separate sewer systems as well as used laboratory methods could not be transferred to CSOs. The listed instructions should help to achieve reliable and comparable laboratory data for CSOs. It also provides important input for planning technologies for a sustainable urban water management.

LIST OF REFERENCES


