ICUD-0614 Towards an improved characterisation of suspended solids in sewers using acoustic backscattering

F. Blumensaat[1], P. Weber[2], S. Ibric[2], S. Fischer[3]

1 Swiss Federal Institute of Aquatic Science and Technology- Eawag, Urban Water Management, Dübendorf, Switzerland
2 Swiss Federal Institute of Technology- ETH Zurich- Switzerland, Institute of Environmental Engineering, Zurich, Switzerland
3 UBERTONE, Strasbourg, France

Summary

Particulate matter (PM) conveyed with urban stormwater can have severe ecological impacts on aquatic ecosystems in case of uncontrolled sewer overflows. Despite that occurrence and variability of PM as a lumped parameter have been studied to large extends, the understanding of dynamically changing PM characteristics (e.g. size distribution), is very limited. We report upon dedicated experiments to systematically monitor PM characteristics (sand, municipal wastewater) using a novel multi-frequency acoustic Doppler sensor. Our results show a systematic dependency between acoustic echo (frequency-specific attenuation, backscatter) and PM characteristics (concentration, size distribution).

Keywords

particulate matter, acoustic turbidity, particle size distribution, wastewater characteristics, online monitoring

Introduction

Studying rain-induced variability of size distributions of PM in stormwater is not only relevant because suspended PM itself may considerably affect fish and spawn populations, but also because a wide range of emerging contaminants show a high, particle-size specific affinity to PM (Zhao and Li 2013). Moreover, PM - here also referred to as suspended solids (SS) - is increasingly used as aggregating proxy for urban drainage impact assessment (e.g. Rossi et al. 2009). This trend also reflects efforts to integrate the growing number of micro-pollutants occurring in hardly detectable traces into practical impact assessment schemes. Despite that valuable research has been conducted on SS as *lumped* parameter (various references), the understanding in how solids characteristics (e.g. particle size distribution, composition, structure) change is still very limited. One promising approach to gain further insight is to conduct repeatable in-situ monitorings using the multi-frequency acoustic Doppler technique. Here we report upon experiments dedicated to PM characterisation using a novel acoustic Doppler sensor (UB-Flow 315, Fa. Ubertone, France). With this paper we pursue two main goals: i) discussing the results in the light of the used experimental approach, and ii) sharing experiences on using a novel sensor to enable future research in this field.

Methods and Materials

The key idea of the stepwise analysis approach is based on the hypothesis that the acoustic echo (a combination of signal attenuation and backscattering) is influenced by the frequency of the emitted Doppler signal on the one hand side and by size, concentration, shape and material, i.e. acoustic impedance of the suspended particles on the other hand (see Fig. 1). By fixing two of the influencing factors (shape and material), and systematically varying the others, characteristic echo profiles (turbidity ratio) are recorded, of which the corresponding profile parameters (slope and intercept of regression line – see Fig. 2) are correlated with particle characteristics.

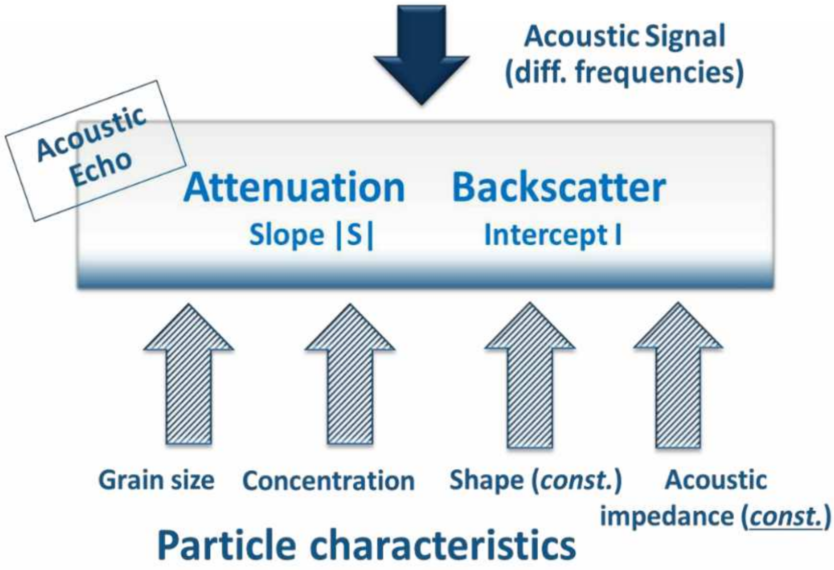

Fig. 1. *Methodological concept for analysing acoustic echoes using sand of different size/concentration.*

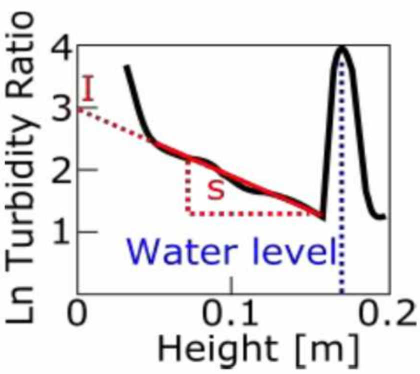

Fig. 2. *schematic principle of characterising the acoustic turbidity ratio profile by extracting regression parameters.*

Different to previous studies, we link research of both, synthetic materials (sand, polyamide) in pilot-scale and combined sewage in quasi full-scale, obtaining reproducible results with a high degree of redundancy and accuracy. The experiments are conducted in two steps:

a) We batch-test different sand slurries to systematically study the influence of concentration, size on the acoustic echo, and so derive parameters relevant for signal interpretation.

b) We compare rain-induced SS concentrations in real sewage (monitored using UV-Vis spectrometry) with turbidity ratios and particle size distributions obtained throuh diffractometric analysis. The correlations found in (a) are used to interpret measurements in (b).

Results and Discussion

1. In batch tests with sand (a) we observe a distinct relationship between particle concentration and the absolute slope *S* of the logarithmic *turbidity ratio* (indicating the degree of attenuation of the acoustic signal - see Fig. 3). Similar trends are observed for the intercept *I* (indicating the degree of backscattering) related to the measured volumetric particle concentration $c_{V,eq}$ (results not shown). This clearly confirms the hypothesis that, with increasing particle concentration, both acoustic backscattering and attenuation grow.

2. We further observe a size class depending influence, particularly for size classes below ~200 µm. The results suggest that for similar volumetric concentrations (e.g. 10^{-2} mL sand L^{-1} water), the influence on the attenuation */S/* (Fig. 3) and backscatter *I* (not shown) decreases with decreasing particle size, irrespective of the emission frequency. For larger size classes (187, 259, 360 µm) however, turbidity ratio characteristics (S, I) are very similar. If this similarity can be attributed to limiting boundary conditions (e.g. through the experimental set-up), sensor limitations (max. f_0 is 3.75 MHz) or other reasons will be clarified in the ongoing research.

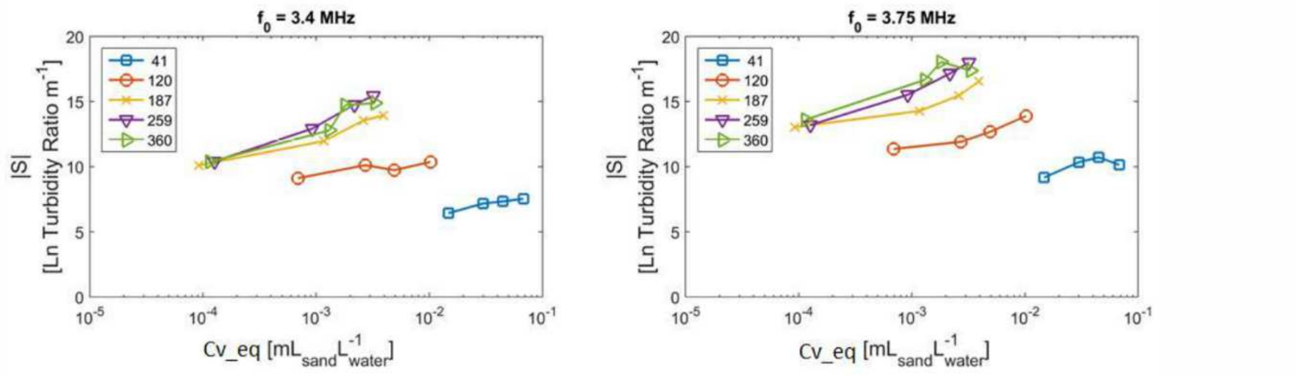

Fig. 3. attenuation of acoustic echo (slope |S|) vs. volumetric sand concentration Cv,eq for two emission frequencies f0. Coloured lines indicate different particle size fractions (in µm).

3. Preliminary analyses of experiments with real sewage (b) show a high correlation between turbidity ratio signals (all f_0) and SS concentration dynamics (parallel-monitored with an UV-Vis spectrometer). An in-depth analysis confirms similar trends but show characteristic deviations for different emission frequencies. Results so far are limited to one single event (depth/duration: 8.7 mm/400 min); further experiments will be conducted.

Conclusions

The particle size of the scatters clearly influences the response of an acoustic Doppler signal. However, the acoustic spectrum (acoustic response depending on f_0) is not directly related to the particle size. A systematic de-convolution of the acoustic spectrum would be required. Further research should focus on the relevance of acoustic turbidity due to air bubbles (clear-water attenuation), the analysis of different synthetic material (e.g. polyamide) and a repeated analysis with higher emission frequencies. Joint efforts on a systematic experimental analysis (different sensors, different experimental conditions) are required to allow generic conclusions for measurements in real-life sewers and beyond.

References

Rossi, L., Chevre, N., Fankhauser, R., and Krejci, V. (2009). "Probabilistic environmental risk assessment of urban wet-weather discharges: an approach developed for Switzerland." *Urban Water Journal*, 6(5), 355-367.

Zhao, H., and Li, X. (2013). "Understanding the relationship between heavy metals in road-deposited sediments and washoff particles in urban stormwater using simulated rainfall." *Journal of Hazardous Materials*, 246–247, 267-276.