ICUD-0155 SSC characterization with acoustic turbidity using linear regression tools

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Summary

The use of ultrasonic velocity profilers for characterization of suspended solid concentration in sewer systems is currently under study and can already provide qualitative information. These instruments are less susceptible to biological fouling than optical instruments and can measure sediment property over a cross-section which is an advantage over optical turbidity. We describe a quantitative method modeling suspended solid concentration as a linear function of acoustic turbidity profile's slope and intercept, and compare it to a similar model with optical turbidity. We discuss the influence of weather conditions and highlight the limitations of our analysis.

Keywords

acoustics, linear regression, suspended solid concentration, turbidity, ultrasonic velocity profiler

Introduction

Continuous measurement of SSC (Suspended Solid Concentration) is of crucial importance in regard to their impact on water quality. Especially in wastewater, strong regulations concerning the SSC bring the need of constant monitoring.

The most common detector in the wastewater industry is the optical turbidity. Adequately calibrated by the correlation with wastewater samples analysis, it is known as a good SSC indicator.

SSC determination with ultrasound measurements is still under study. Classic data analysis of the acoustic turbidity gives encouraging results. With in mind a possible data treatment automation, we tried a new statistical approach of data analysis.

Methods and Materials

To test the method, we used available data from a long term measurement campaign in the entry chamber of the wastewater treatment plant of Grand Nancy, close to one of the inflows.

An Ultrasonic Velocity Profiler (UVP ; model UB-Flow, Ubertone, Strasbourg, France) gave the acoustic turbidity profile information thanks to the signal processing of the acoustic backscattered echo. Optical turbidity was recorded by a Solitax-ts-line sc device (Hach-Lange, Lognes, France). Punctual SSC measurements were also performed for some days: the water analysis was done according to the usual procedure NF EN872- 2005.

In this article, we analyse the data of 3 days corresponding to different weather conditions: dry weather (19/06/14), after heavy rain (08/07/14), storm weather (21/07/14). For these days, we used acoustic turbidity (1.0 MHz, every 6'), optical turbidity (every 5'), SSC (every 15') and water height measurements.

According to Pallarès (2017), referring to Thorne (2002), and given the definition of the acoustic turbidity in (Ubertone, 2016), following can be said: assuming the homogeneity of particle size and density distribution, an acoustic turbidity profile can theoretically be written as:

$$T = K_1 \cdot M \cdot exp((K_2 + K_3 \cdot M) \cdot r) \quad (1)$$

$$\ln(T) = \ln(M \cdot K_1) + (K_2 + K_3 \cdot M) \cdot r = I + S \cdot r \quad (2)$$

where T is the turbidity $[m^{-1}]$, r the distance from the transducer $[m]$, M the particle concentration $[g/m^3]$, and $K_1\ [m^2/g]$, $K_2\ [m^{-1}]$, $K_3\ [m^2/g]$ are constants depending on the measuring system and particle characteristics.

As $\ln(T)$ depends linearly on r, we determine the intercept $I\ [1]$ and slope $S\ [m^{-1}]$ by linear regression. Then we see how well these coefficients can predict the concentration M.

Unnecessary information was eliminated from the acoustic profile:

Bottom echo,

Near field,

Points influencing I and S too much statistically, in order to correct imprecisions on bottom and near field truncation.

On the remaining points (Fig. 1), we compute I and S using least squares regression.

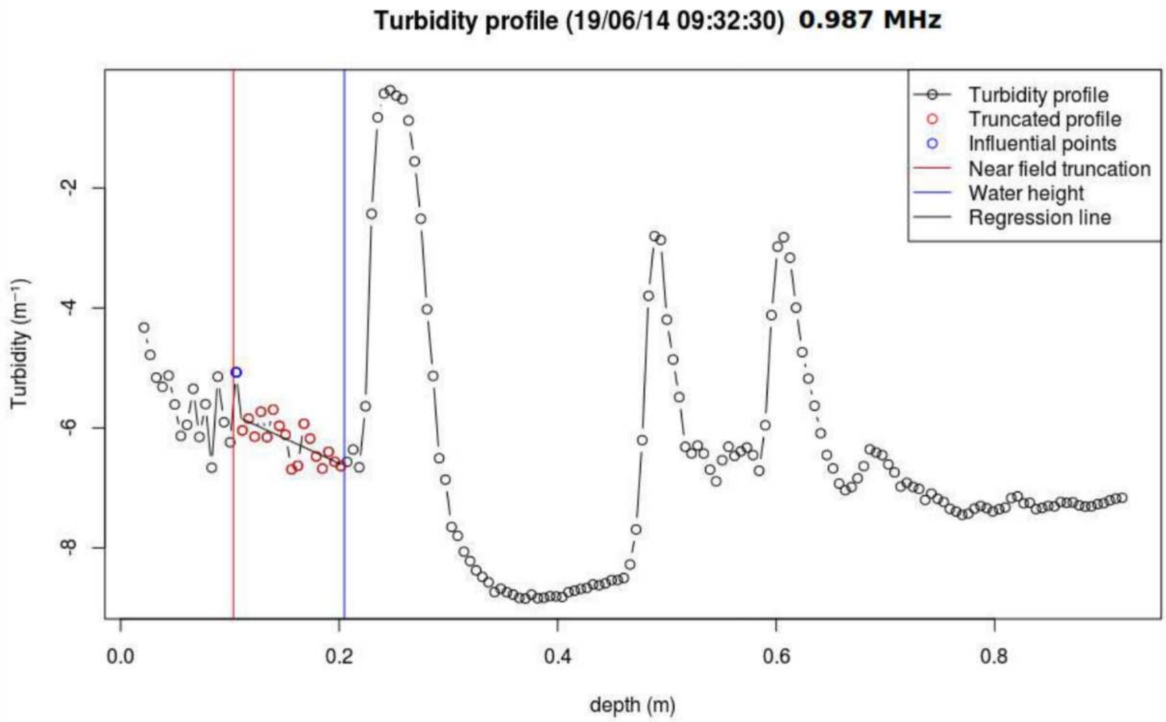

Fig. 2. *Turbidity profile.*

Results and Discussion

Optical turbidity measurements are consistent with results presented in other articles Lacour (2009): a linear relationship between SSC and optical turbidity exists with coefficients depending on the weather (Fig. 2.a).

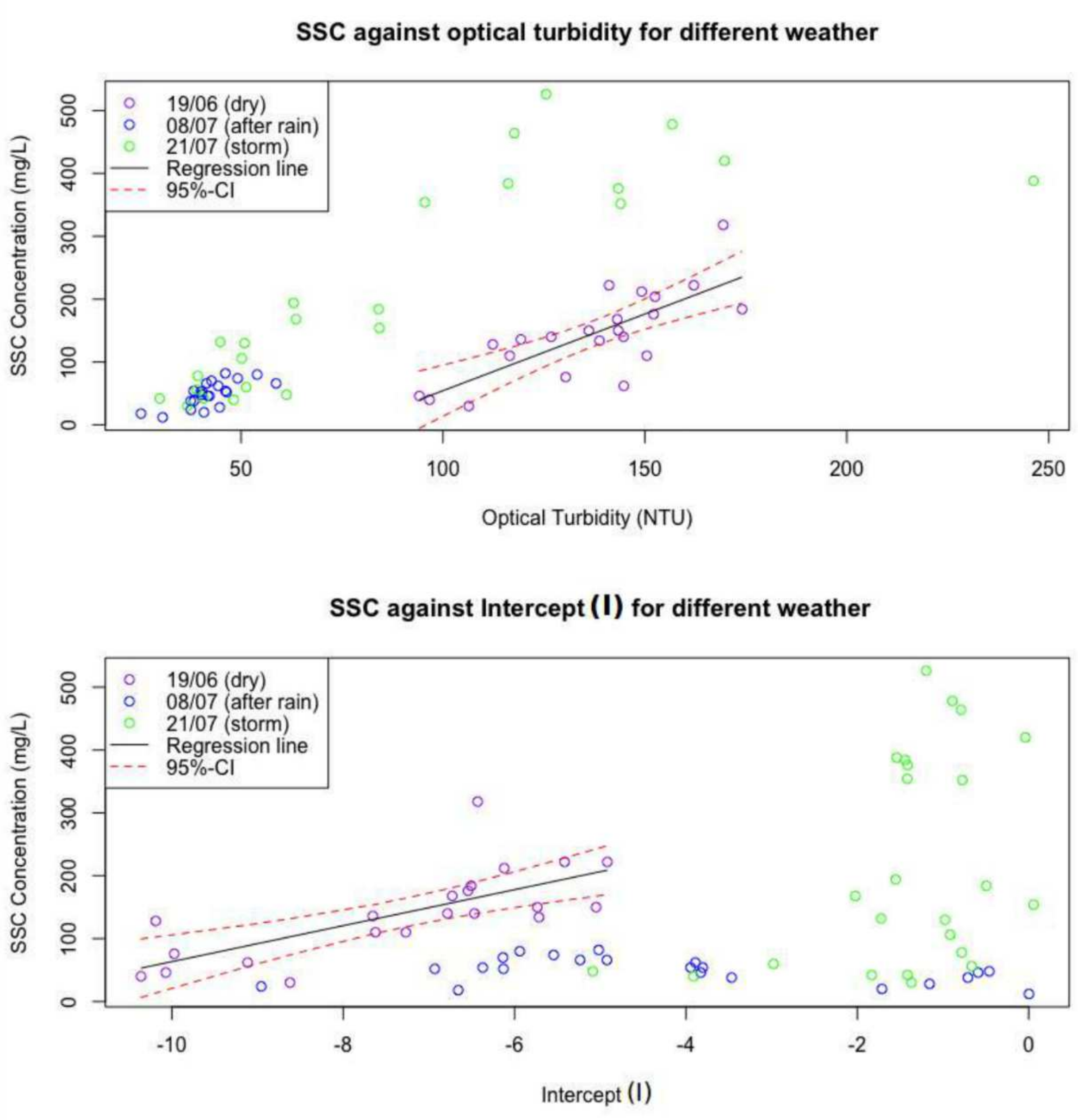

Fig. 3. *SSC against optical turbidity and Intercept*

Concerning acoustic turbidity the points behave in 3 different ways (Fig. 2.b). These behaviours seem to depend on weather conditions. Since the coefficients K_i vary according to particle characteristics, it comes as no surprise to see different behaviours from one weather condition to another. However it is disappointing not to see any relationship between SSC and the Intercept values for rain weather. It may be linked to the presence of bigger particles at rain events, which leads to an increase of the acoustical turbidity (Pallarès, 2017). Indeed there is some inconsistency between acoustic measurements and SSC during these days. Even the color plot of acoustic profile evolution shows no sign of link with SSC evolution. We do not know for sure what went wrong here (Fig. 3).

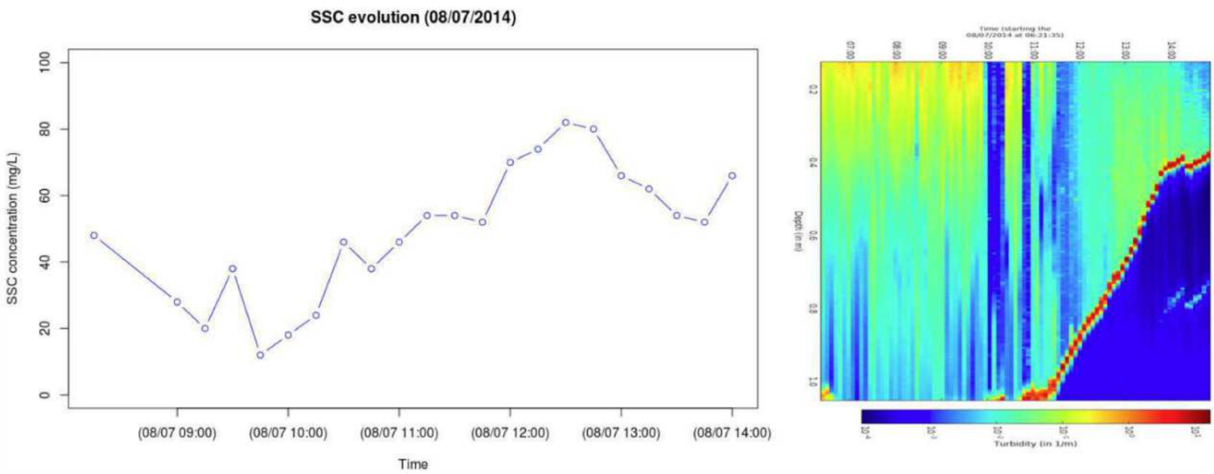

***Fig. 4**. Evolution 08/07 (after rain)*

When SSC is orthogonal or parallel to I (Fig. 2.b), the variables aren't correlated. Thus at rain weather, I is a bad linear predictor for SSC. For dry weather on the contrary, there is some correlation between I and SSC.

We can quantify that correlation and compare its predictive power to the optical performance. Least squares fitting of formula $SSC = a * Opt + b$, where Opt is the optical turbidity [NTU], leads to (Fig. 4) (std=46mg/L). Since I and S are complementary, we can try fitting $SSC = a * I + b * S + c$, which leads to a better result (Fig. 4) (std=35mg/L).

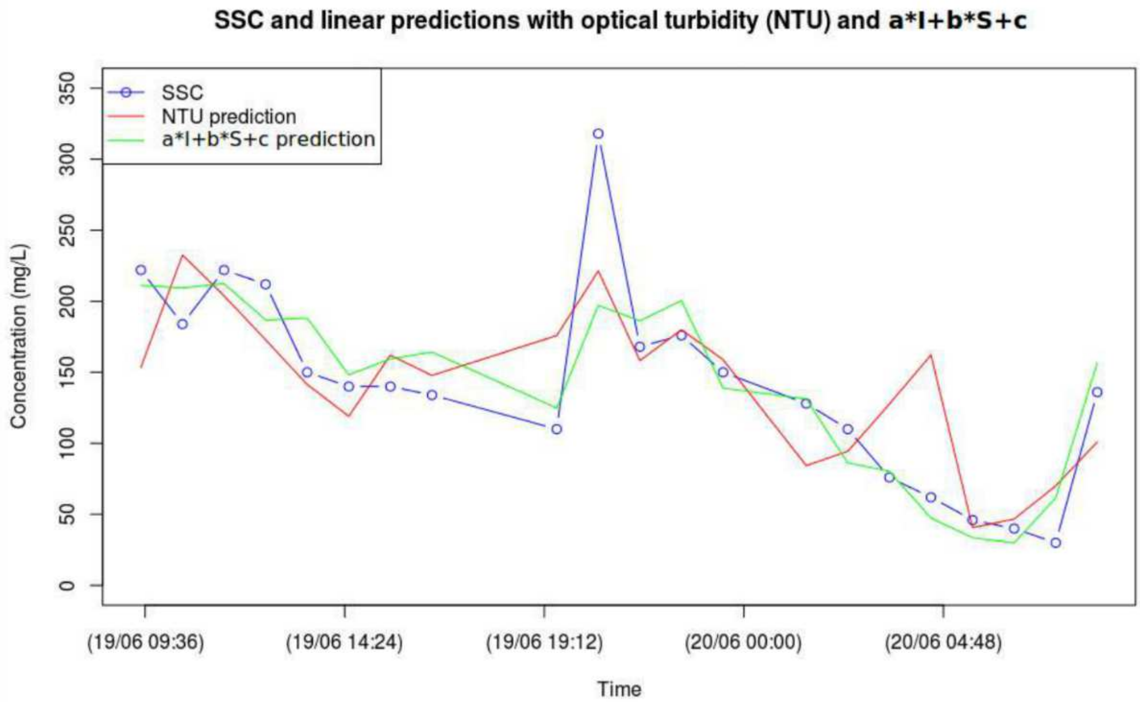

***Fig. 5.** SSC and estimations over time*

Conclusions

After adequate treatment, dry weather acoustic turbidity profiles can be used for SSC prediction in wastewater, with better precision than optical turbidity, at least for this dataset. For rain weather however, not even a qualitative link can be found between acoustic profiles and SSC.

These models have been built with only 21 data points and have not been tested on new data; this is not sufficient to draw any solid conclusion. Furthermore the models are specific to the measuring instruments, to the wastewater treatment site, to the weather and to the particle characteristics on that day (shape, size).

Still, the results are encouraging and underline the potential of acoustic turbidity measurements for SSC characterization.

Acknowledgement

The authors want to thank M.N. Pons (Laboratoire Réactions et Génie des Procédés – UMR CNRS 7274, Université de Lorraine) and X. France (GEMCEA) for their precious help in the collection of the experimental data. This research was partly funded by the french ANR and DGA agencies through the project ANR-MESURE (ANR-16-ASMA-0005-01).

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