SLUDGE SETTLING CHARACTERISATION WITH AN AUTOMATED SETTLOMETER

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ABSTRACT

An automated sensor for measuring sludge settling properties is presented. In this sensor the evolution of the sludge water interface is followed during a 35 minutes batch settling experiment. This sensor can be used for lab research as well as for on-line monitoring of the settling characteristics of activated sludge on a full scale waste water treatment plant.

By means of lab experiments the effect of different concentrations of additives on the sludge settling properties are evaluated. In addition to the evaluation of the direct positive effect of the additive, a method is proposed to study the stability of the beneficial effect of the additive. The information obtained can be a useful tool when one is looking for the economically most interesting additive to use in a specific case of sludge settling problems.

For full-scale applications the sensor can be used to screen for operational parameters that have an effect on the settling characteristics of the sludge. Thus the waste water treatment plant can be tuned towards operating conditions that ameliorate the settling characteristics of the sludge

INTRODUCTION

It is generally accepted that within the activated sludge process the final clarification is a crucial unit process (Albertson, 1992). Wanner (1994) estimates that 50 to 80 % of the COD in the effluent is caused by the wash out of sludge. The presence of sludge flocs in the effluent contributes further to its total nitrogen and phosphorus content. The efficiency of the sedimentation process is dependent on the sludge sedimentation properties, the sludge concentration and the hydraulic conditions in the settler. The hydraulic conditions in a settler can change quite rapid e. g. when a rain event reaches a WWTP. In addition, changes in the settling characteristics of the sludge flocs are possible. For instance, population dynamics brought on by changes in operational conditions can influence the sedimentation characteristics. These shifts occur rather slow and have time constants in the order of weeks. The waste water composition can also change the sludge settling properties. For instance the wastewater conductivity influences the floc formation (Zita & Hermansson, 1994). Reid and Nason (1993) furthermore suggested the dependency of sludge settling characteristics on the pollutant concentration remaining in the mixed liquor entering the final clarifier. As the wastewater composition can change quite fast (Verbanck, 1995), the subsequent changes in sludge sedimentation properties are expected to be fast.

Sedimentation characteristics are normally determined manually with a low frequency using batch settling tests generating data as the SVI, SSVI or DSVI. The experimental conditions in such experiments can differ significantly from the ones in the full scale sedimentation tank: in small settling columns, bridging can become a problem and sludge settling characteristics are often evaluated at reduced sludge concentrations. Moreover, such experiments yield data that can't be directly used in the solid flux theory but that have to be transformed by empirical relationships (Ozinsky & Ekama

1995) or that have to be plot in empirical secondary clarifier charts (Keinath, 1990) in order to fit this theory. Such an additional step hampers the use of such data in clarifier control strategies designed to assure optimal clarifier performance.

MATERIALS AND METHODES

The sensor

At the University of Gent (Belgium) a settlometer was developed (commercially available from AppliTek nv, Belgium) in which sludge settling characteristics are determined in a very simple way (Fig. 1) (Vanrolleghem *et al*., 1996). The core of this apparatus is formed by a 10 l downscaled Pyrex decanter equipped with a stirrer (1 rpm) in order to reduce bridging and wall effects. Grijspeerdt *et al*. (1996) have demonstrated that the evolution of the sludge blanket height in this decanter is representative to the sludge blanket movements in a full scale circular settler when the flow to and from the downscaled version were proportionally reduced to its surface. Within the sensor, this decanter is operated in batch mode: the decanter is filled with sludge, the sludge is mixed with air and then the sludge is allowed to settle.

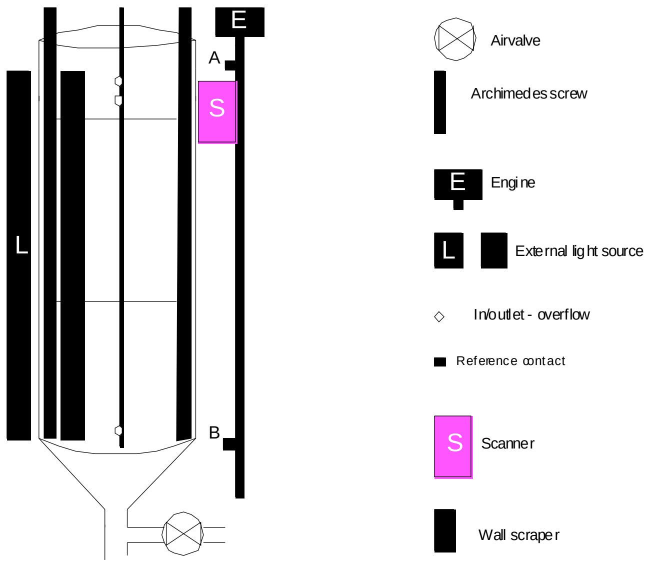

Fig. 1. Schematic diagram of the settlometer

During the settling tests the height of the sludge water interface is monitored by a moving scanner. Opposite to the scanner background light is provided. The scanner moves downward from the upper reference point. When it reaches the sludge blanket, it detects a decrease in light intensity. The distance covered by the scanner and the time elapsed since the start of the settling experiment yield a first data point of the settling curve. Once the sludge blanket detected, the scanner moves back up to the reference point and comes down again, looking for the decrease in light intensity. This cycle is repeated until the difference between the beginning of the experiment and the actual time exceeds an operator predetermined value (typically 35 minutes). This procedure results in a sedimentation curve (Fig. 2). From this curve the zone settling velocity (Vs) is obtained as the maximum downward slope by moving regression analysis. The obtained Vs should be easily implementable in the clarification criterion as proposed by Pagilla (1996). The sedimentation curves can be used as input for the estimation of parameters of sedimentation models. As the operation of the sensor is computer controlled the procedure can be easily customized to specific experimental needs. Modes with appropriate fill routines are available for use of the sensor in the lab and for on-line use at a full scale plant.

The experimental setup

Experiments with additives were done with two different kinds of sludge: one industrial (Janssen Pharmaceutica, Geel, Belgium) and one domestic (Ossemeersen, Gent, Belgium). Sludge samples were collected and transported to the lab within one hour. In the lab, sludge samples were stored aerated at room temperature. This storage mode was chosen as it keeps the sedimentation characteristics rather stable (data not shown).

Sedimentation curves were recorded in the settlometer with the stirring mechanism on. The sludge volume index (SVI) was determined independently using Imhoff cones and a sedimentation period of 30 minutes. The suspended solids concentrations were determined by centrifugation (NBN 366.01).

Two sedimentation additives were used: fine talc powder (PE 8418) with an average particle size of 6 µm (provided by Luzenac Europe) and Zetag 88n, a cationic polyacrylamide polymer (Allied Colloids).

RESULTS AND DISCUSSION

Addition of talc

The effect of cumulative additions of talc powder on the sedimentation curves of the industrial sludge was evaluated. A 10 l sample (SS=6.72 g/l) was brought from the storage vessels into the settlometer. Subsequently, two consecutive reference sedimentation curves were recorded. After dosing 0.5 g of talc/l a new sedimentation curve was recorded. Then consecutively 1, 1, 2, 2 and 2 g/l of talc were added to the sample. Each addition of talc was separated from the other by the recording of a sedimentation curve. Advantages of such a consecutive addition are fact that only one sludge sample is needed and that the additive can be tested with a constant concentration of suspended solids. The latter is important as the Vs is influenced by the sludge concentration. Nevertheless this modus operandi demands that the sedimentation characteristics of the sludge as such remain constant for the duration of the experiment. Preliminary experiments with untreated sludge revealed that the sedimentation velocity was constant when the sludge was subjected for repeated cycles of 10 minutes of aeration followed by 35 minutes of sedimentation for more than a day (data not shown). Continuous cycles of aeration and sedimentation without the addition of additives will further on be referred to as duration tests.

The result of the experiment with talc addition is shown in Fig. 2. It can be seen that an increase of the talc dose corresponds with a decrease of the initial lag faze and an increase of the settlingvelocity. In Fig. 3 the resulting initial settling velocities are compiled. A linear trend in the effect can be detected. Experimental experience (data not shown) has learned that an increase in the initial settling velocity caused by the dosage of additives or even by a reduction of the sludge concentration is associated with a reduction in the lag faze.

After the addition of the last aliquot of talc, the sample was kept in the setllometer and subjected to a duration test. This was done to get an idea of the stability of the positive effect obtained by the additive. This experiment resulted in a small initial decrease in the sedimentation velocity

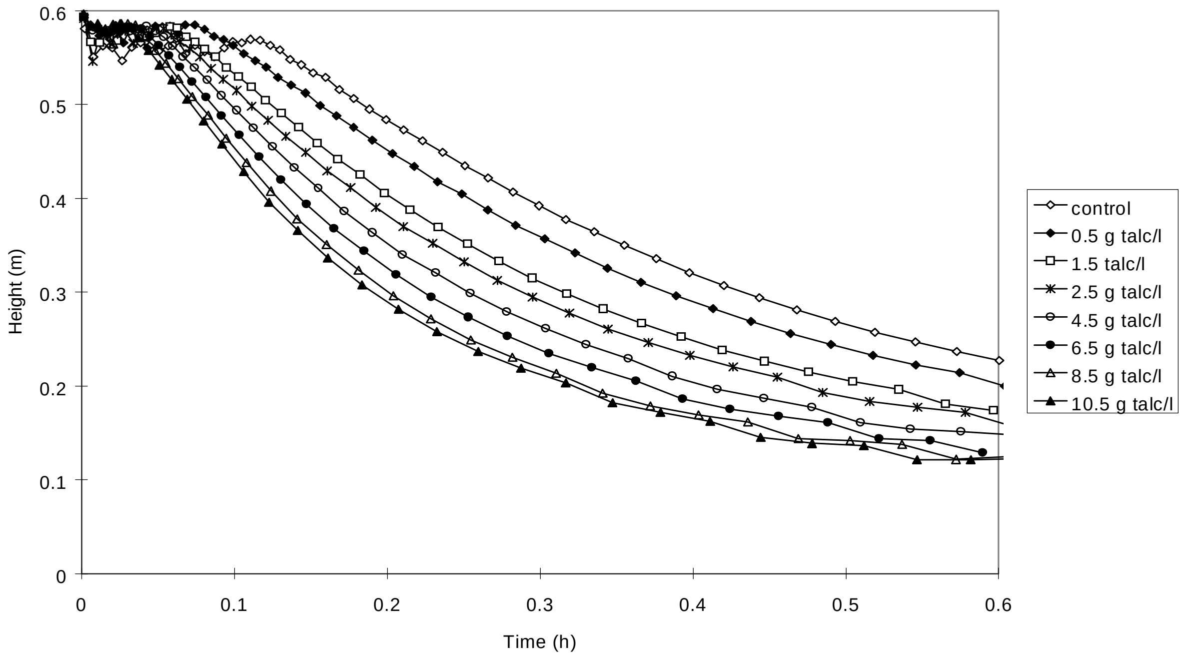

Fig. 2. Sludge sedimentation curves for different talc dosages added to sludge from an industrial WWTP, (SS=7.2 g/l, the talc dosages are cumulative)

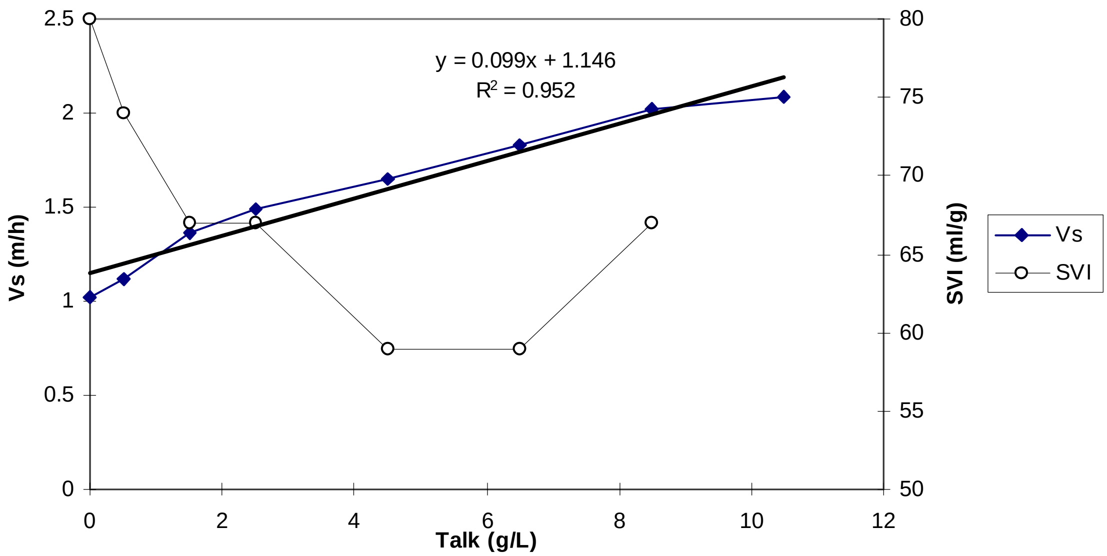

Fig. 3. Evolution of the initial settling velocity and SVI in function of the talc concentration for sludge from an industrial WWTP (SS=7.2 g/l)

during the first 3 hours from 2.1 m/h to 1.8 m/h. Subsequently the sedimentation velocity remained at a stable level. It can be concluded that the effect of the talc powder is rather stable. The initial decrease could be explained by the release of talc particles from the sludge surface.

In parallel with the settlometer experiments the effect of talc on the SVI was evaluated. The result of this experiment is summarized in Fig. 3. Talc has a beneficial effect on the SVI. Nevertheless this effect is reduced at higher concentrations: above 4.5 g/l of talc no further reduction of the SVI can be noticed. At 8.5 g/l there is even an increase in the SVI. This is in contrast with the settlometer data where in the range of 4.5 to 8.5 g/l still an increase in the settling velocity could be detected. This shows clearly the potential of the sensor to detect differences in sedimentation characteristics other then the ones obtained in the classic SVI measurement.

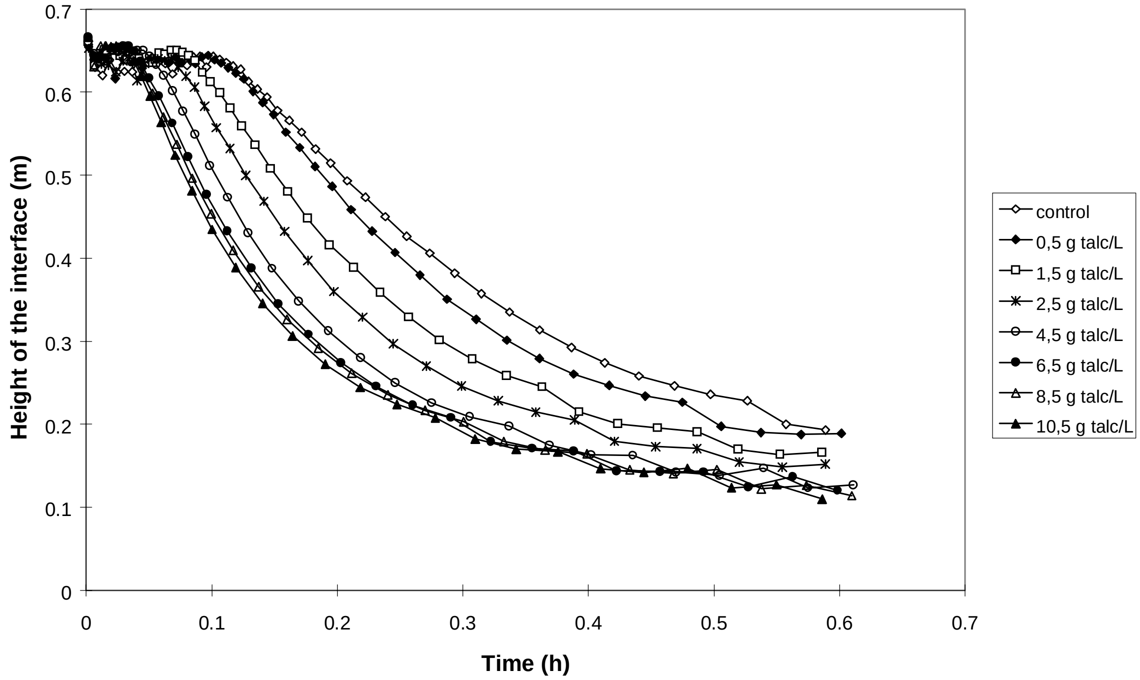

Fig. 4. Sludge sedimentation curves for different talc dosages added to sludge from a domestic WWTP, (SS= 5.8 g/l, the talc dosages are cumulative)

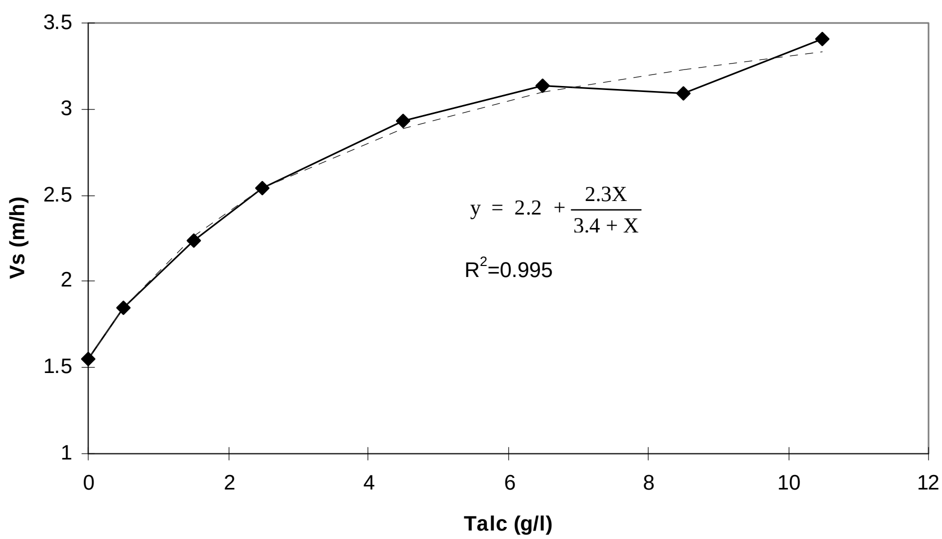

Fig. 5. Evolution of the initial settling velocity in function of the talc concentration, domestic sludge (SS=5.8 g/l)

Analogous experiments were set up with the domestic sludge (Fig. 4 and 5). In this case not a linear but a hyperbolic relation can be detected between the sedimentation velocity and the added amount of talc.

As the dosage of talc expressed as weight talc/weight sludge doesn't differ significantly between both sludge's an explanation should be found in the properties of the sludge. Microscopic evaluation revealed that in the domestic sludge filaments could be detected at the outside of flocs, whereas these filaments weren't present in the industrial sludge. A hypothesis can be put forward based on the principle that filaments influence interparticle compression and in this way affect the response of the sedimentation velocity to an increase of the specific weight of the sludge. However at this stage it is difficult to substantiate such hypothesis.

Addition of polymer

With the industrial sludge a cumulative addition experiment was performed with the Zetag 88n polymer. This polymer was chosen as it was also used in the full scale WWTP. A sequence of polymer doses were added: 0, 4, 4, 4, and 8 mg polymer/l. The results of this experiment are given in Fig.6. The positive effect of the polymer is obvious : the sedimentation velocity increases from 1.8 to 6.0 m/h. After addition of the last aliquot of polymer, the mixed liquor was kept in the sensor and submitted to cycles of 35 minutes of sedimentation separated by 10 minutes of aeration. This had a quite drastic effect on the sludge sedimentation velocity. Within 3 hours, the sedimentation velocity was reduced to the level of the sedimentation velocity before the addition of the polymer (Fig. 7). After this initial decrease the sedimentation velocity remained constant at the level equal to the one the sludge had before the addition of the polymer. In the studied case the positive effect of the polymer was quite volatile. This hampers the extraction of a relationship between the dosage of polymer and the settling velocity.

Without any doubts the sludge in the settlometer is subjected to more shear stress and a greater oxygen supply than is the case in a full scale clarifier. Therefore the evolution of the settling velocity has to be seen as a worst case scenario for the stability of the additive. It is therefore difficult to translate the observed reduction of the polymer to the full scale. The point that one should take in account is the fact that part of the effect of the polymer goes lost before the sludge leaves the clarifier.

When comparing both additives for the industrial sludge it is clear that the talc (20 BEF/kg) is far more expensive than the polymer (200 BEF/kg) as the amounts of talc to be added are significantly larger. However if one would be facing sludge settling problems in systems with only a limited amount of waste sludge (Yasui *et al.,* 1996) the addition of talc can be a economically interesting alternative.

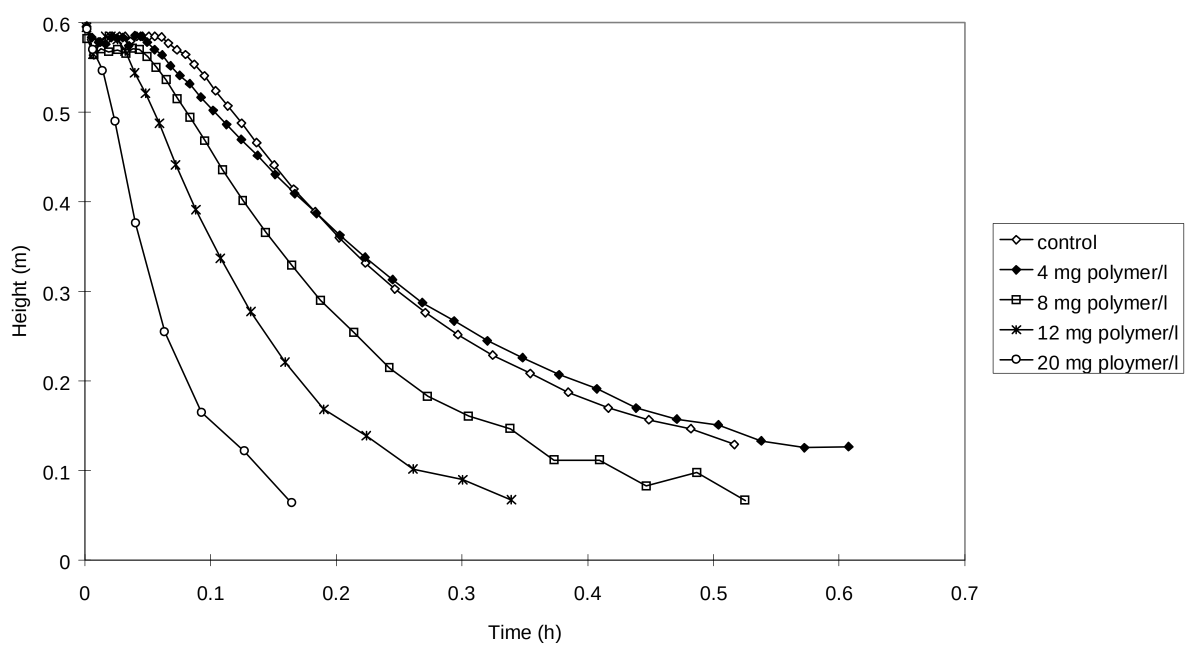

Fig 6. Sludge sedimentation curves for different polymer dosages added to sludge from an industrial WWTP, (SS= 6.1 g/l, the polymer dosages are cumulative)

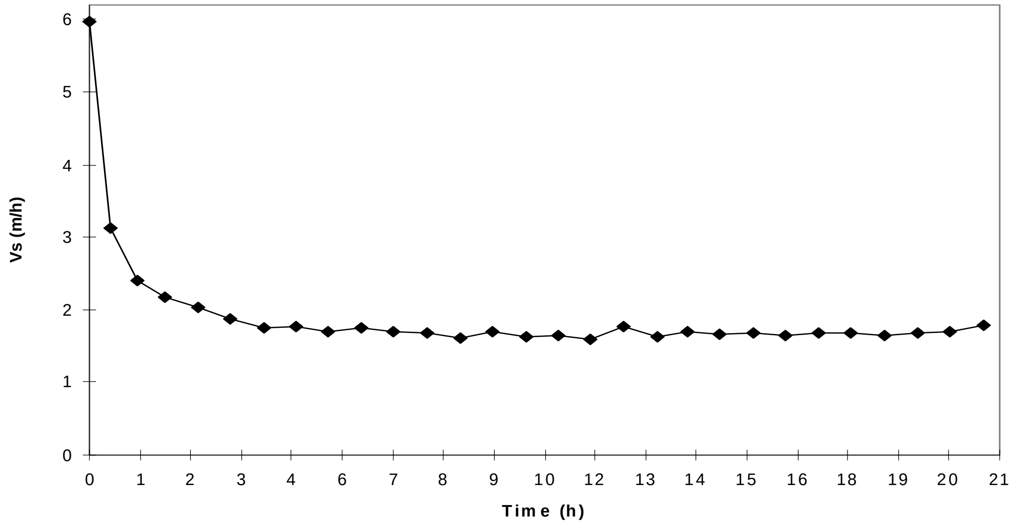

Fig. 7 Evolution of the initial settling velocity of the sludge from an industrial WWTP after the addition of polymer during 35 min. settling, 10 min. aeration cycles (SS=6.1 g/l)

CONCLUSIONS

A settlometer can be efficiently used to evaluate the effect of additives that enhance the sludge settling. The sensor is a good tool to determine the amount of additive needed to reach a certain settling velocity. With an industrial sludge two different additives were tested: talc and Zetag 88n. Both additives had a positive effect on the sedimentation. A linear correlation between the talc concentration and sedimentation velocity was detected. The effect of talc was far more stable than the effect of the polymer. When looking at the economic aspects, the treatment with the polymer is cheaper. The effect of talc was also tested with a domestic sludge. In this case a hyperbolic relation could be detected between the added amount of talc and the settling velocity. The difference in response of both sludge's reflect the differences in the structure of the respective sludge flocs.

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REFERENCES

Albertson, O. E. (1992). Clarifier design. In: Design and retrofit of wastewater treatment plants for biological nutrient removal. Eds. Randall, C. W., Barnard, J. L. & Stensel, H. D. Technomic Publishing, Lancaster, 185-254.

Grijspeerdt, K. Bogaert, H. & Verstraete, W. (1996). Design and verification of a model secondary clarifier for activated sludge. Journal of Chemical Technology and Biotechnology, 67, 404-412.

Keinath, T. M. (1990). Diagrams for designing and operating secondary clarifiers according to the thickening criterion. Research Journal Water Pollution Control Federation, 62, 254-258.

NBN 366.01: 'Wateronderzoek, afvalwaters en verontreinigde waters : zwevende stoffen - Centrifugaalmethode', 1e uitgave, maart 1956.

Ozinsky, A. E. & Ekama, G. A. (1995). Secondary settling tank modeling and design Part 1: Review of theoretical and practical developments. Water SA, 21, 325-332.

Pagilla, K. R. (1995). Optimization of secondary clarification process: Determination of solids mass and clarifier safety factor. Proceedings 68th Annual Conference Water Environment Federation. Miami beach, Florida, 1, 489-501.

Reid, J. M. C. & Nason, R. B. (1993). Automatic monitoring of activated sludge settling characteristics and plant control applications. Journal of the Institution of Water and Environmental Management, 7, 636-645.

Vanrolleghem P.A., Van der Schueren D., Krikilion G., Grijspeerdt K., Willems P. & Verstraete W. (1996). On-line quantification of settling properties with In-Sensor-Experiments in an automated settlometer. Wat. Sci. Tech., 33(1), 37-51.

Verbanck, M. (1995). Variabilité des charges solides en suspension à l'exutoire des réseau de collecte. Journée d'étude IAWQ, 31/05/1995 Fonctionnement du traitement des eaux usées en cas de fortes variations de débit, Liège, 1-12.

Wanner, J. (1994). Activated sludge bulking and foaming control. Technomic Publishing, Basel, 327p.

Yasui, H., Nakamura, K., Sakurma, S., Iwasaki, M.and Sakai, Y. (1996). A full-scale operation of a novel activated sludge process without excess sludge production. Wat. Sci. Tech., 34(3-4), 395-404.

Zita, A. & Hermansson, M. (1994). Effects of ionic strength on bacterial adhesion and stability of flocs in wastewater activated sludge system. Applied and Environmental Microbiology, sept. 1994, 3041-3048.