REPORT

Performance and potential of Cerlic CBX

An optical sludge blanket meter

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Summary

The settling of sludge is one of the most crucial parameter in the operation of wastewater treatment plants (WWTP). Not only is the whole purification process affected by sludge settling both prior and after the biological treatment step but also the quality of the final effluent, the operation of further treatment units and the whole line of sludge handling. Especially, controlling sedimentation characteristics of the sludge in the post-sedimentation can be named as one of the most important parameters for WWTP operation. Here accurate measurements of sludge levels can be utilised for effective and optimal treatment control.

This report provides an evaluation of an optical sludge blanket meter. This includes its performance in measuring and control of sludge levels in WWTP and the potential for better treatment control. The Cerlic CBX has been tested in both laboratory and pilot-scale and at a WWTP. The conclusion is that it can provide automatic and reliable measurements of the sludge blanket. The Cerlic CBX can be used as supplied but it also provides extensive configuration options for demanding applications. The ability to measure actual suspended solid concentrations at various depths reduces the need for compensations or interpretation as necessary when using indirect measurements.

The application of the optical sludge blanket meter should therefore facilitate a better control of WWTP operation and buffer variations in incoming sewage flows and loads. It can further provide a continuous process monitoring and thus increase the robustness and reliability of the treatment process. The control of the sludge content in the biological stage, detection of operations problems such as disturbances due to storm water events etc. can be detected more easily.

The report further includes other potential advantages for WWTP operation using sludge level measurement sensors like the Cerlic CBX.

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Contents

1 Abstract

The settling of sludge is one of the most crucial parameter in the operation of wastewater treatment plants (WWTP). Not only is the whole purification process affected by sludge settling both prior and after the biological treatment step but also the quality of the final effluent, the operation of further treatment units and the whole line of sludge handling. Especially, controlling sedimentation characteristics of the sludge in the post-sedimentation can be named as one of the most important parameters for WWTP operation. Here accurate measurements of sludge levels can be utilised for effective and optimal treatment control.

This report provides an evaluation of an optical sludge blanket meter. This includes its performance in measuring and control of sludge levels in WWTP and the potential for better treatment control. The Cerlic CBX has been tested in both laboratory and pilot-scale and at a WWTP. The conclusion is that it can provide automatic and reliable measurements of the sludge blanket. The Cerlic CBX can be used as supplied but it also provides extensive configuration options for demanding applications. The ability to measure actual suspended solid concentrations at various depths reduces the need for compensations or interpretation as necessary when using indirect measurements.

The application of the optical sludge blanket meter should therefore facilitate a better control of WWTP operation and buffer variations in incoming sewage flows and loads. It can further provide a continuous process monitoring and thus increase the robustness and reliability of the treatment process. The control of the sludge content in the biological stage, detection of operations problems such as disturbances due to storm water events etc. can be detected more easily.

The report further includes other potential advantages for WWTP operation using sludge level measurement sensors like the Cerlic CBX.

2 Background

2.1 Cerlic CBX

Cerlic Controls has developed and produced a stationary sludge level indicator (CBX) that, as stated by the manufacturer, detects sedimented or thickened sludge in different positions in a treatment plant. By measuring the sludge content with an optical transmitting method, the Cerlic CBX obtains an actual value of the sludge level as a function of the concentration by sending down the probe, which differs from conventional methods where the sludge level is predicted based on the measurement of the different absorbance of an ultrasonic signal.

This implies that the Cerlic CBX would find the sludge level regardless of the existence and amount of fluff sludge as the sludge level is defined as the level at which a certain predetermined sludge content (concentration of suspended matter) occurs. According to Cerlic, the CBX can simultaneously measure profile, fluff and sludge level, sonar can only measure the sludge level and this measurement is disturbed by fluff. For more information about the technology, see Cerlic (www.cerlic.se).

2.2 General about sludge sedimentation problems

Sludge settling in post-sedimentation basins is an important step in wastewater treatment. Under normal conditions, flocks (bacteria) settle in the basin and are then returned to the biological treatment step or to further sludge handling (excess sludge used e.g. for biogas production) and flocks that do not settle will be removed with the effluent water. This implies a self-regulation that preserves the bacteria with good settling characteristics. However, at low flows even sludge of worse quality can settle as the retention time increases. At high flows at the other hand, sludge is drained with the effluent, which causes problems in following sand filters. There are a number of different sedimentation problems caused by various reasons (see e.g. Röttorp *et al.*, 1999). One of the most important parameter for WWTP operation, however, is controlling sedimentation characteristics of the sludge in the post-sedimentation. The sludge level provides direct information about the sludge sedimentation characteristics and its sensitivity to disturbances in flows. By keeping sludge levels low the plant sensitivity to changes in incoming water is reduced. If measurements even include data on various sludge layers, a good picture of the sludge characteristics is available for optimal treatment control.

Floating/fluff sludge or the drainage of sludge is a problem that has a direct negative impact on the treatment efficiency. In addition, it increases the risk to fail effluent quality requirements significantly. Most problematic would be meeting the limits for phosphorous removal for WWTPs without sand filter as the final step. However, even if sand filters are present that may be able to hold back the floating sludge from reaching the recipient, an increased backwash and thus overflow of unfiltered water would be the consequence. Floating sludge moreover may imply many practical problems with sludge overflowing and contaminating various areas in the plant. The problem of floating/fluff sludge various much between different plants. Often it is caused by temporal overloading of the plant or due to operation failures or a combination of both and it varies a lot between different treatment plants. Röttorp et al. (1999) observed the problem regularly in a number of plants while other plants rarely had the problem or only during periods when temperature changes occurred, i.e. spring and autumn.

3 Aim

The aim of this study is to test and verify Cerlic's CBX sludge level indicator. This means more specifically, to examine how the sludge level meter is able to measure the sludge profile, fluff and sludge level. The tests should further identify technical difficulties, advantages and disadvantages of using the Cerlic CBX, and limitations and reliability. Therefore, the study includes various tests in lab and pilot scale of the Cerlic CBX sludge level meter. In order to cover all potential problems, the company was only permitted to supply the standard support and configuration. If relevant, the test should also indicate new fields of application and suggest improvements if such are identified during the test period.

Cerlic Controls wants to illustrate that the CBX sludge level indicator has advantages over other methods (e.g. ultrasonic sonar) and contacted IVL Swedish Environmental Research Institute, for an independent evaluation of the CBX carried out with the support of the development project Environmental Technology for Growth, which accounts for 50% of the costs while Cerlic stands for the other 50%. This project has thus been initiated with help of the Swedish Agency for Economic and Regional Growth – Tillväxtverket and the European Regional Development Fund (ERDF).

4 Methodology

A validation of the Cerlic CBX technology measuring sludge profiles is obtained by separately verifying the concentration measurement and level measurement since they are independent of each other.

This and the overall evaluation of the unit performance was done on different scales at the R&D-facility Hammarby Sjöstadsverk (www.hammarbysjostadsverk.se) in special designed test columns and the after-sedimentation basin in one of the pilot train at the facility representing conventional active sludge municipal wastewater treatment.

The study included three stages divided in lab, pilot and full-scale:

- Laboratory experiments: Three sludges with different concentrations were evaluated. A defined amount of the different slurries were filled into columns and mixed, then allowed to settle for a predetermined time. Then the sludge level and sludge concentration were documented at various levels by standard analyses of suspended solids and photography. Concentrations and sludge levels were simultaneously measured with portable version of the Cerlic CBX.

- Pilot Scale: Line 1 at Hammarby Sjöstadsverk was used as a replicate of a traditional active sludge process as commonly used in Wastewater treatment plants in most part of the world. The Cerlic CBX was operated during several months to check general operational characteristics and to detect potential problems. Manual analyses of sludge concentrations at various depths were performed to verify measurements by the Cerlic CBX. Various operational problems, i.e. pump failures, stormwater events etc. were simulated in that treatment train in order to test the response and reliability and use of the Cerlic CBX.

- Full Scale: The Cerlic CBX was earlier evaluated within a Master thesis at the wastewater treatment plant Käppala, Stockholm. This study also included two common ultrasonic sonars. The results of that study were summarized and discussed in the study.

4.1 Laboratory experiments

The test cylinder, provided by Cerlic, was placed inside the R&D-facility Sjöstadsverket. A Cerlic CBX unit was mounted above the cylinder and connected to a central unit BB1 (see Figure 1). From the BB1 unit a logger was connected for data collection of depth profiles, fluff and sludge level during the measuring campaigns. The cylinder was filled with different types of sludge from process lines at Sjöstadsverket that represents a common wastewater treatment process.

4.1.1 Test characteristics

The different sludges have been selected to simulate common sludge but also sludge that is the result of operational problems such as storm water events, pump failures etc. that may lead to e.g. spontaneous nitrification in the basin process and thus disturb the sedimentation process. Six sludges were provided from various treatment lines at Sjöstadsverket. Sludges II-VI simulate various problems in the sedimentation basin, either caused by pump failures, storm water events or other disturbances resulting in non-optimal operation.

Figure 1. Laboratory test setup (available at the R&D-facility).

Sludge I: The first sludge to be tested in the pilot cylinder was from the post-sedimentation at line 1 at Sjöstadsverket at normal operation consisting of common operation configuration including recirculation of sludge and withdrawal of excess sludge. The sludge was left for about 2 hours for settling. After 2 hours, a profile measurement was initialized.

Sludge II: The next measuring was using a mixture of old settled sludge and return sludge. About 50% of the sludge from the previous test was removed and replaced with the same amount of fresh return sludge was added. The mixture was left for one hour of settling.

Sludge III: The third sludge consisted of 100% return sludge without time for sedimentation.

Sludge IV: This was the same sludge as sludge II but after sedimentation of about 30 minutes.
Sludge V: Consisted of 100% sludge from the post-sedimentation with a sedimentation time of about 18 hours.

Sludge VI: The final test was with 25 % of sludge V and 75% activated sludge. This mixture was left for settling in 3 hours and 40 minutes before measurement.

After each test, the cylinder was emptied and cleaned before filling with new sludge.

The test cylinder had five openings at different depths for manual sample collection. Manual samples were taken during each profile measuring campaign when the CBX sensor was at the same depth of the sampling outlets. The manual samples were then analysed onsite in the laboratory at Sjöstadsverket with respect to sludge concentration. Each result presented in this report consists of triplicate analyses. Suspended material/sludge content is determined gravimetrically after filtration though weighted 1.2 µm glass fibre-filters. This is in accordance to the standard SS EN 872:2005 and the uncertainty is estimated to ± 20 % in the present sludge.

A portable version of the Cerlic CBX was used to check readings at certain depths of the cylinder. Photos of the different sludges have been made to document the sludge characteristics visually. The main two parameters that can be predefined and that represent the simplest output from the Ceric CBX are the desired concentration that defines the blanket concentration and the concentration that will define the fluff layer. These parameters were in the laboratory test defined as 3000 mg/l and 500 mg/l, respectively. Note that the standard configuration of the Cerlic CBX has values of 5000 mg/l and 1000 mg/l, respectively, for these parameters. The latter is an average and should be a good initial configuration for WWTP. However, each installation requires an adaptation of this to represent the sludge characteristic of the sludge at the site. That is also the standard recommendation by Cerlic.

4.1.2 Limitations and observations

Because of the cylinder dimensions, it was very difficult to get a complete mixing of the sludge column after filling. Further, the five openings for manual sampling stuck almost half through the cylinder and had a diameter that was about 1/10 of the cylinder diameter. Consequently, these sample openings influenced the settling of the sludge column. Taking manual samples was also influencing the settling, as a certain volume of sludge had to be removed. The effect of this was however tried to minimize by sampling from the uppermost to the lowest sampling point. Moreover, collecting representative samples for analyses is difficult as opening the manual sampling valves implied that sludge and water in the direct vicinity of the opening was forced out and due to turbulences mixing occurred. At the same time, the sludge located near the manual valves was already influenced by the valves itself as mentioned above. The operation of the manual sampling points and their impact on sedimentation is illustrated in the figure below.

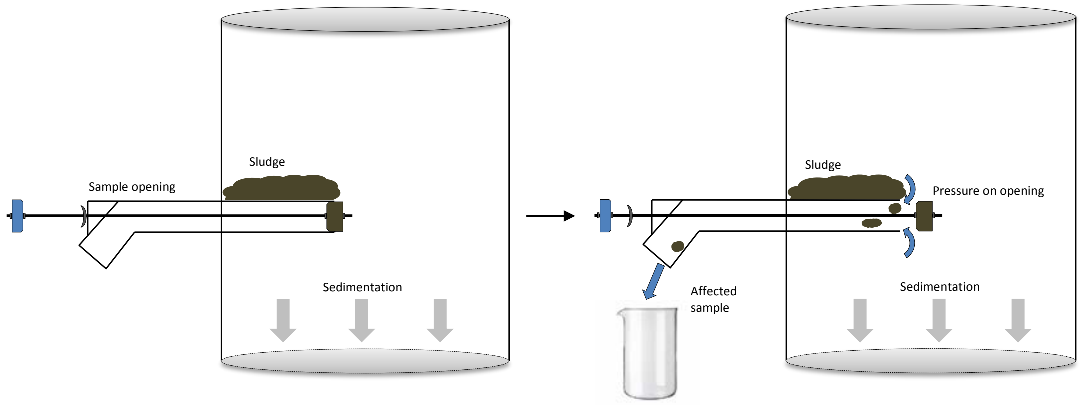

Figure 2. Manual sampling openings and their impact on settling and sampling.

For the visual documentation, it is important to realize that only sludge and settling characteristics from the front view could be documented.

4.2 Pilot-scale test in Process Line 1 at Hammarby Sjöstadsverk

Hammarby Sjöstadsverk houses several different lines of which Process Line 1 was used in the test to evaluate the Cerlic CBX performance. Line 1 (see figure below), is designed as a conventional Swedish plant with the following steps: pre-precipitation, sedimentation, six stages of biological treatment, secondary sedimentation, and also sand filtration that offers the possibility of post-precipitation. Line 1 is a copy of the nearby Henriksdal treatment plant.

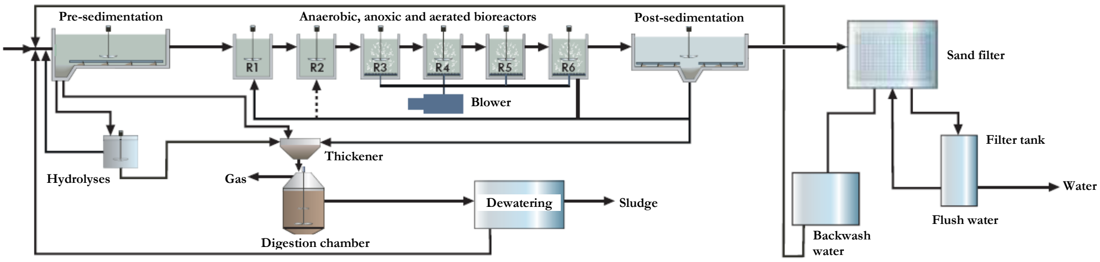

Figure 3. Line 1 at Hammarby Sjöstadsverk: Aerobic treatment with activated sludge and biological nitrogen (and optional phosphorous) removal.

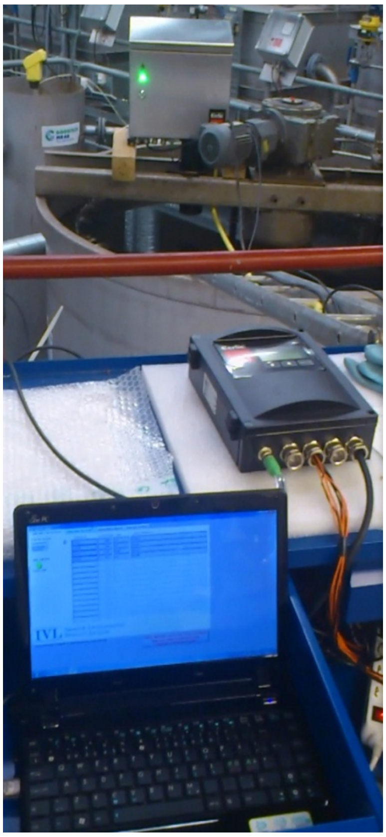

Figure 4. Cerlic CBX test setup in Line 1.

4.2.1 Test characteristics

The final sedimentation tank of Line 1 is a circular tank with a cone in the bottom and a total depth of about 3.5 m and a diameter of about 2.5 m. A scraper is frequently started to mix the sediment at a very slow seed. The scraper has a horizontal stabilisation at a depth of 2.8m, which is important for the Cerlic CBX to be harmonized with. Excess (about 0.4 m^3/day) and return sludge (ratio 0.8 of inflow) is pumped from the bottom of the tank cone. Water from the biological treatment is released in the centre of the tank. The Cerlic CBX was installed as close to the centre of the tank as possible. Automatic water cleaning was connected and the sensor was run with various average frequencies of about 6, 30 and 60 minutes. The Cerlic CBX was again connected to a data logger. This test was performed during April – June 2012. After that, the sensor has been in operation for another 6 month for long-term operation tests.

5 Results

The following sections provide main results from the laboratory and pilot-scale tests. Further, main conclusions from full-scale tests at one of Stockholm's WWTP are included.

5.1 Pilot tests

5.1.1 Sludge I

2 hours after filling the cylinder a profile measurement was initialized. A clear phase of a couple of centimetres was observed at the surface. Sludge concentration was almost constant at about 8700 to 8900 mg/l. The portable blanket tracker showed similar concentrations.

5.1.2 Sludge II

The next measuring was with a mixture of old settled sludge and return sludge. The mixture was left for one hour of settling. A clear phase was observed approximately between 0.5 and 1 meter depth. All different measured values; sludge profile, fluff and sludge blanket level, sludge concentrations from the portable blanket tracker and manual samples are presented in Figure 5, including a picture of the test cylinder.

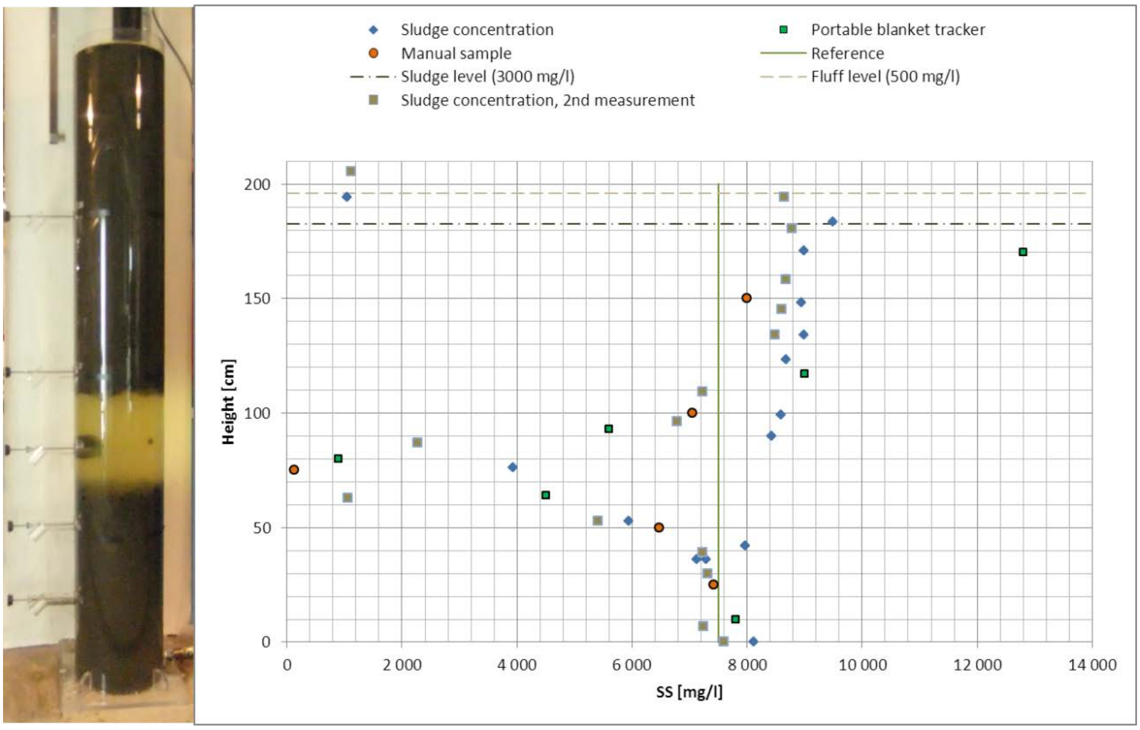

Figure 5. Results from measurements with old settled sludge and return sludge.

Both, the automatic Cerlic CBX and the portable sensor observe the clear phase in the lower part of the column, which is visible on the photograph. Note that using only the two values for sludge blanket and fluff level will fail to provide information about the clear phase. However, using the option of profiles will provide that information. In addition, indirect measurements like ultrasonic devises may have problems to detect such characteristics or they may be filtered out as signal errors by the data processing step of the instrument. This was for instance observed during comparison of different measuring approaches in the test at Käppala Treatment plant (see section 5.3).

5.1.3 Sludge III

After the above test the cylinder were emptied and filed with return sludge. The measurements started after the cylinder was filled with sludge, hence no sedimentation time. In Figure 6, a photo of test cylinder and results from measurements are presented. It is noticed that the sludge looks were homogenous.

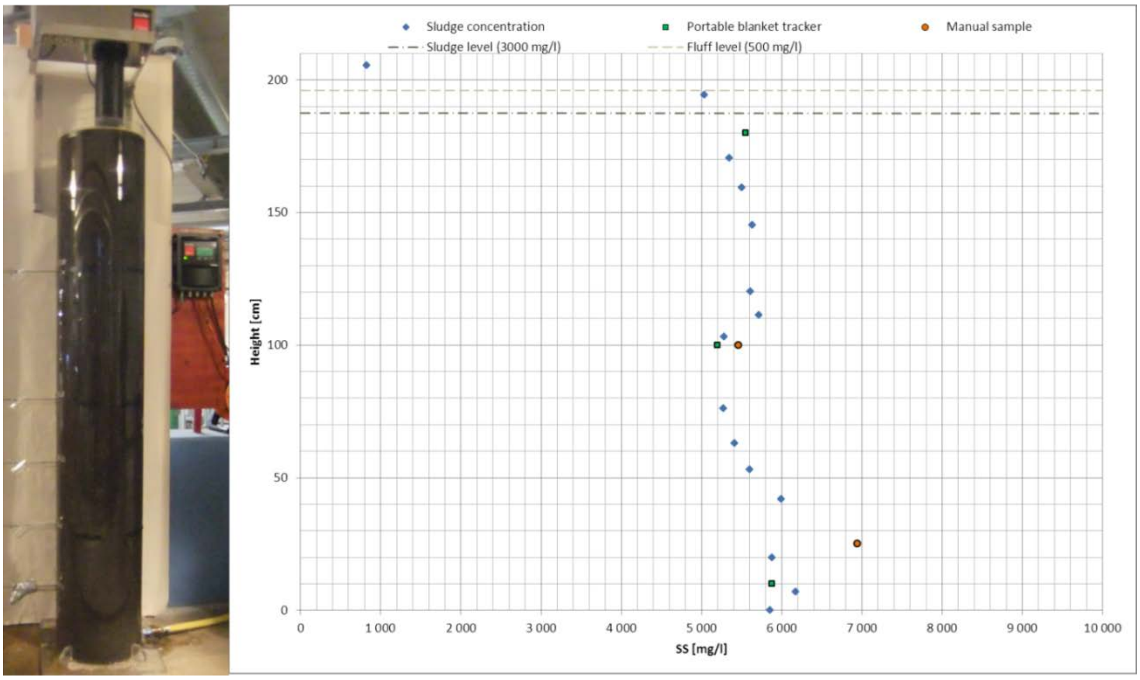

Figure 6. Results from measurements with return sludge.

The manual and automatic measurements with the Cerlic CBX confirm that homogeneous sludge. Even this type of sludge may pose a challenge for sludge level blanket meter based on e.g. ultrasonic as they are working with filters that interpret the reflection/absorbance of the ultrasonic signal. If that is constant throughout the depth of the sedimentation tank, the suggested sludge blanket level may be wrong (see section 5.3).

5.1.4 Sludge IV

Then the sludge was set for settling in 30 minutes, note that the total height of the sludge was lower since manual samples were taken out from the test cylinder. The results can be viewed in Figure 7. A clear face is observed at the top.

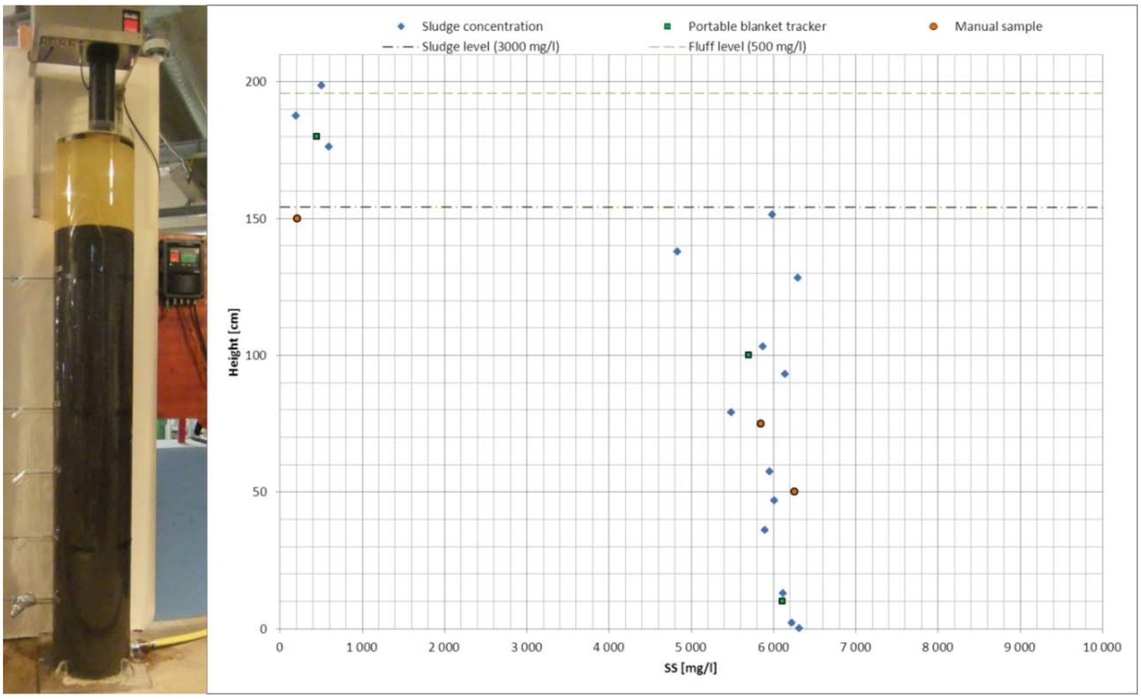

Figure 7. Results of measurements with return sludge after 30 minutes sedimentation.

This measurement illustrates difficulties in collecting undisturbed and completely representative manual sludge samples. Data and visuals indicate that the sludge blanket is located at a level of about 154 cm while the analysis of the manual sample indicates a lower sludge concentration. The reason for this is illustrated in Figure 2; opening the manual valves that is approximately at that height of the sludge blanket level results in that water can easier exist than sludge and as the manual sample will be "contaminated" by clear water and thus show a lower result.

5.1.5 Sludge V

The test-column was thereafter emptied and sludge from the final sedimentation was filled into the cylinder. The sludge was left for sedimentation overnight and the measurements were performed after approximately 18 hours. Results are shown in Figure 8. The sludge is stratified with clear phases in between at the same levels as the outlets for the manual samples. Partly nitrification in the sludge is also observed. This example illustrates the difficulty of detecting layers with lower concentration without using a complete profile measurement. The use of levels of sludge blanket and fluff sludge only would, as seen in the figure below, not indicate levels of significant different sludge characteristics.

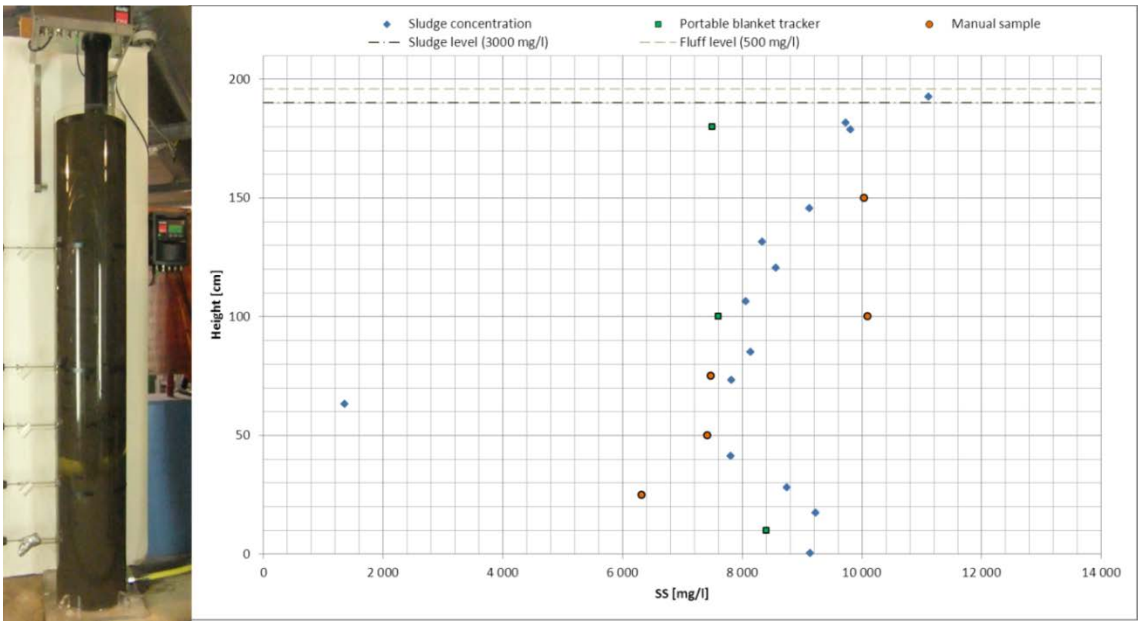

Figure 8. Results of measurements at sludge from final sedimentation and after 18 hours of settling.

5.1.6 Sludge VI

The final measurement was with 0.5 meter of previous sludge and 1.5 meter of activated sludge. This mixture was left for settling in 3 hours and 40 minutes. Results are shown in Figure 9. A clear phase of 20 cm is observed at the top.

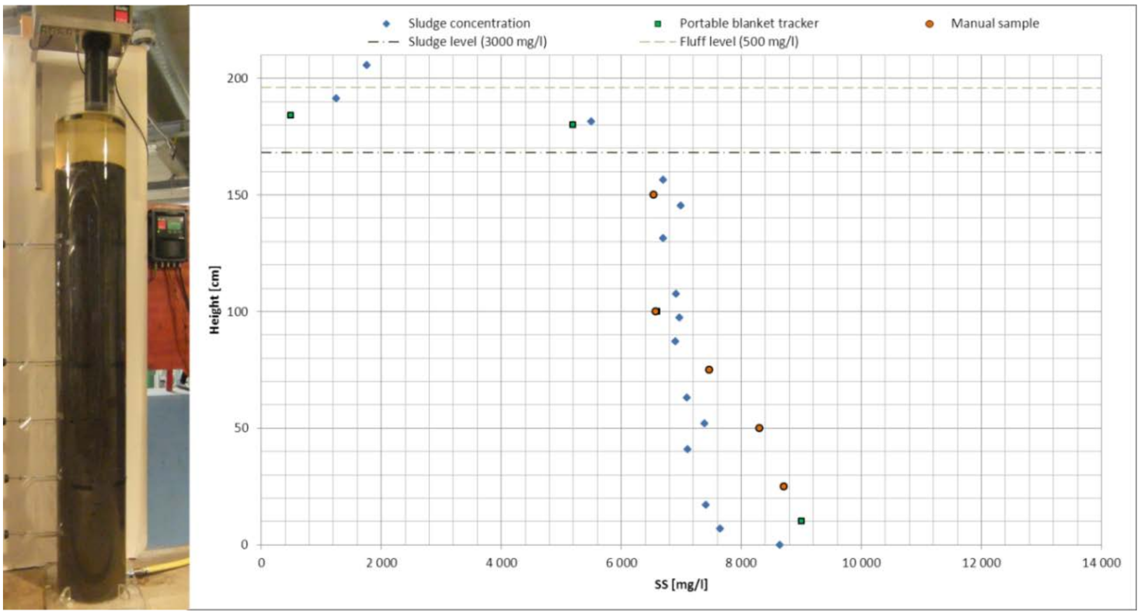

Figure 9. Results from measurements with sludge mixture and settling for about 3 hrs and 40 min.

5.1.7 Summation

Overall, the various tests indicated a good performance of the Cerlic CBX as it is able to measure the sludge profile, fluff and sludge level. While the accuracy of manual sampling highly depends on the sludge characteristics and stratification and it further is influenced by the sampling process itself, the Cerlic-CBX can accurately detect all different kind of sludge characteristics; homogenous or heterogeneous. Both visuals and grab samples confirm the readings of the automatic measurements. However, in reality visuals would not be possible and grab samples would not provide reliable results as that sampling obvious affects the results and difficulties arise if samples are taken at e.g. interfaces were sludge characteristics change significantly.

An important reflection from the test is that the option of profile measurements should be the preferred alternative if more information than just the sludge blanket level and the fluff sludge level is necessary. Using the profile measurements even layers with significant deviating characteristics, i.e. non desired changes in the sludge cause by overload, process failure etc., are reported and may thus be part of the mitigation strategy.

5.2 Pilot-scale test in Line 1 at Hammarby Sjöstadsverk

The active sludge process of Line 1 (Figure 10) with its post-sedimentation basin was used for the pilot-scale studies.

Figure 10. Line 1 of Hammarby Sjöstadsverk that was used in this test. Line 1 was operated as a conventional WWTP with chemical phosphorous removal.

The test aimed to check the ability of the Cerlic CBX to measure and indicate process failures and changes in order to judge possibilities to implement for better control using the online measurements. The verification of the correct monitoring of the sludge concentration in various sludges has been provided in the previous presented tests and is not part of this test. This is partly because collecting sludge samples from different depth is not an easy task and more or less impossible without disturbing the profile. Even so, sampling test were performed as carefully as possible with downwards direction of sampling, inserting the sampler in the sludge destroys the layers and interfaces. Opening the sampler and the following inflow may further induce a bias in the sludge sample. In the real sedimentation tank, there is further no possibility for visual verification.

The correct reading of the Cerlic CBX was regular verified with clean water or a known sludge. Both methods worked well and were easily performed on site. The Cerlic CBX was operated in Line 1 during a period of several months. To verify the reliability of the Cerlic CBX, the portable Cerlic Sludge Blanket Tracker was used on a regular basis for checking the measurements.

5.2.1 Monitoring discontinuous operation conditions and failures

The Cerlic CBX was due to physical limitations in the sedimentation tank, i.e. scraper and supporting fastenings, installed such that the sensor reached a maximum depth of 2.80 m below water level (same as overflow level). The figures presented in the following sections relate to that maximum depth as the zero-level. Figure 11 shows an example of continuous measurements only considering the two defined sludge levels of 500 mg/l and 5000 mg/l, respectively. The measurement frequency was set to 30 minutes and this is the interval when information about the two sludge levels is updated, which is clearly visible in the figure below.

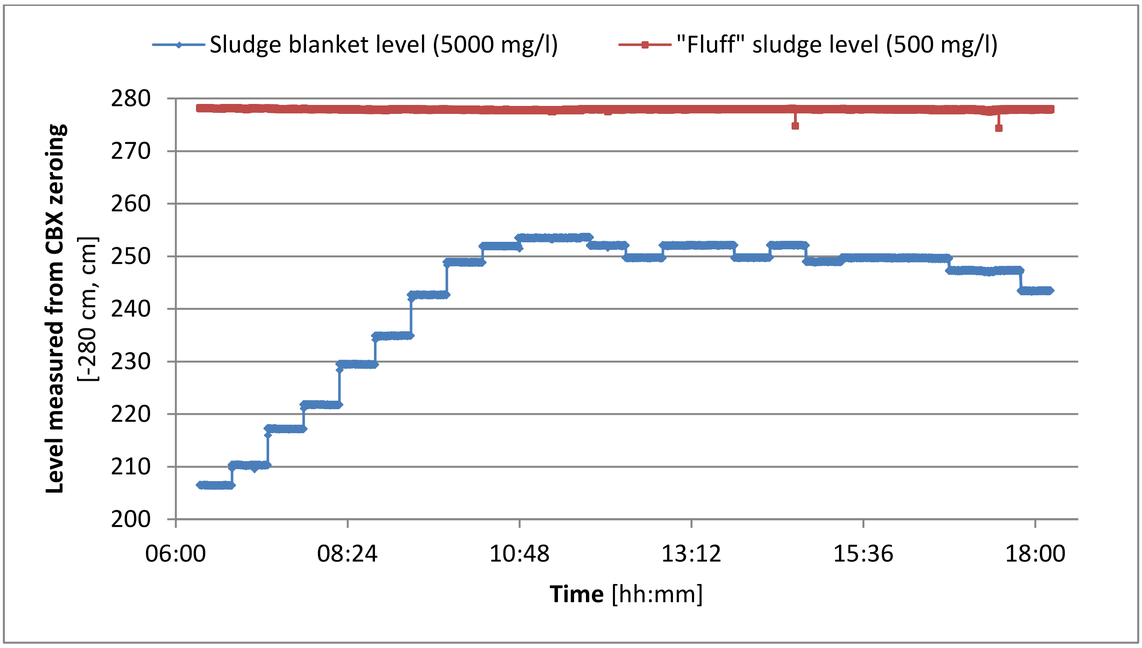

Figure 11. Selected period of some hours that illustrate the typical pattern of a Cerlic CBX measurements defined by the frequency of the performed measurements.

The level of fluff sludge was reported at a very constant level of 278 cm (corresponding to 1-3 cm below water surface), which was throughout the whole period of the pilot-scale tests. Manual tests showed that the predefined concentration for the fluff sludge was too low and therefore the sensor reported the first point of measurement as the fluff level. That this level is not the surface water level but a few centimetres below is explained by a short delay in the Cerlic-CBX measurement exactly when hitting the water surface.

The fluff sludge level, however, can easily be adjusted to sludge characteristics at each site. In the following, only the sludge blanket level is considered. In section 5.3 the experiences from the full-scale test at Käppala WWTP are presented including fluff sludge observation.

Testing the Cerlic CBX to monitor changes in the sludge settling caused by discontinuous operation conditions and failures included a number of different manually simulated operation conditions. Following modifications were done in Line 1 to imitate real scenarios:

1. Increased inflow

   Between May 22 6 am and May 24 7:30 am, the inflow to Line 1 was doubled by increasing the amount of wastewater inflow as well as adding flushing water to simulated stormwater event during peak flows, which often represents a critical operations period. In addition, during shorter periods on May 27 the inflow was temporally increases by just adding more than double the inflow of flushing water to Line 1.

2. Increase of excess sludge withdrawal

   On May 25 the excess sludge withdraw was doubled during a period of 3 hours to simulate a controller failure.

3. Stop of excess sludge withdrawal

   Between April 20 -25, all pumping of excess sludge out from the post-sedimentation was stopped to simulate pump failure.

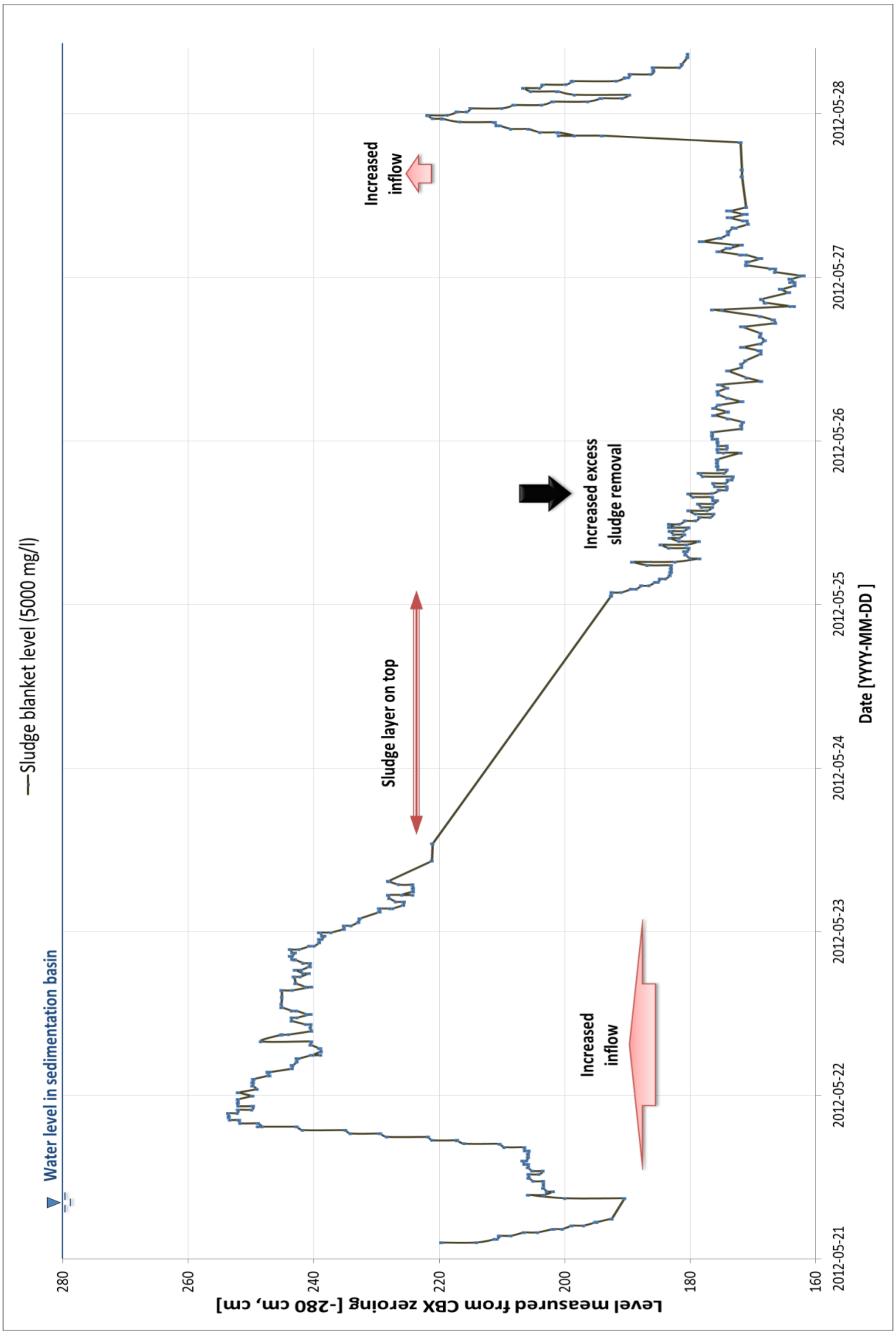

Figure 12. Measured sludge levels by the Cerlic CBX during May 21 –May 28. The graph further indicates periods of increased inflow to Line 1 and floating sludge layers disturbing the measurements.

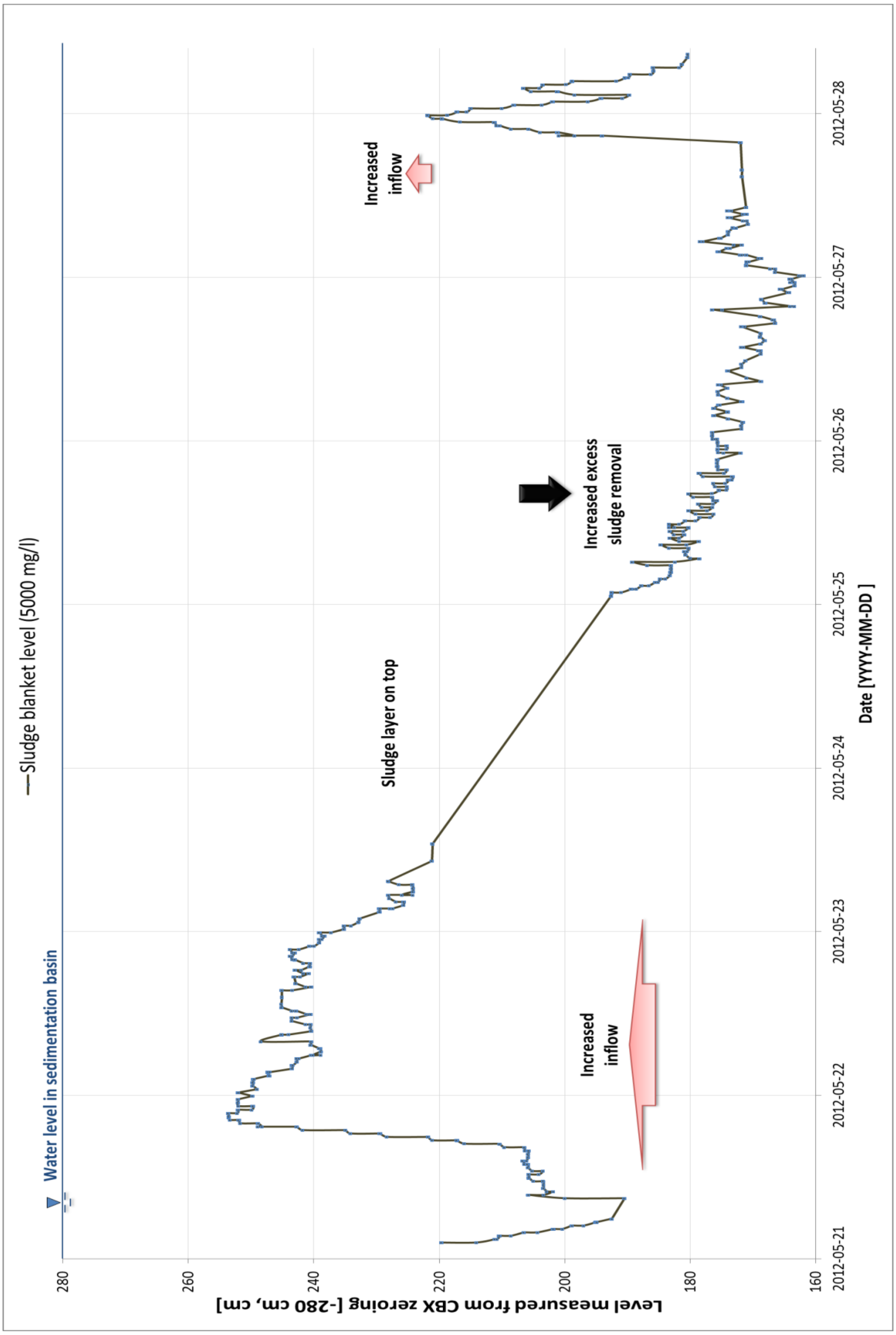

Figure 12 shows how the sudden increase of the inflow has a direct and instantaneous impact on the sludge blanket in the post-sedimentation. The time it takes for water from the point of inflow to the treatment line to the sedimentation tank is about 15 hours for normal flow and 6-8 hours for peak flows as the one simulated. However, an increase in the inflow to the treatment line will results in an almost direct hydraulic response in the system with an increased flow to the post-sedimentation. However, the characteristics of the water reaching the post-sedimentation are at that time still the same as prior to the increase of water inflow, which results in a shorter retention time but also an increased number of particles that can sediment. This leads, as can be seen from the observations, to an increase of the sludge blanket level as return and excess sludge flows are not controlled towards a constant sludge blanket but according to the nominal inflow to the treatment line, i.e. they remain the same.

After several hours, when the treated diluted stormwater has reached the post sedimentation and the treatment line has adapted to the new inflow conditions, the composition of the water in the post-sedimentation has stabilised. It can be observed that the sludge blanket level decreases again as less sludge, i.e. particles, per flow unit is formed in the bioreactors due to more diluted wastewater while the retention time in the sedimentation basin remains the same as at the beginning of the stormwater event.

The same pattern is observed during shorter periods of flow increase.

Further, the figure illustrates that measurements are disturbed when the top sludge layer becomes too thick and sludge concentration exceeds the measure range of the sensor. Measurements during this period have been cleared from the figure. In full-scale applications, the removal of such sludge layers is necessary for practical reasons. The Cerlic CBX also provides the option to increase the blind zone, which would start the measurements first after that the sensor has passed though the disturbing sludge layer.

The increased removal of excess sludge on the other hand has more or less no impact on the sludge blanket level as shown in Figure 12. Even if this may be partly explained by the still relatively low quantity of this flow compared to the total load to the post-sedimentation and the return sludge flow, this illustrates that the shorter technical problems may not disturb the overall operation of the sedimentation.

The figure below shows the sludge levels and measured during the whole May. The pattern indicates high dynamics in the sludge levels even when no controlled operational changes were performed. However, the two most significant impacts (except for operational changes) are related to natural stormwater events that results in the same flow to Line 1 (constant side stream from main inflow) but lower concentrations in the wastewater. Similar effects on the sedimentation are observed as for the artificial induced changes of the inflow to Line 1.

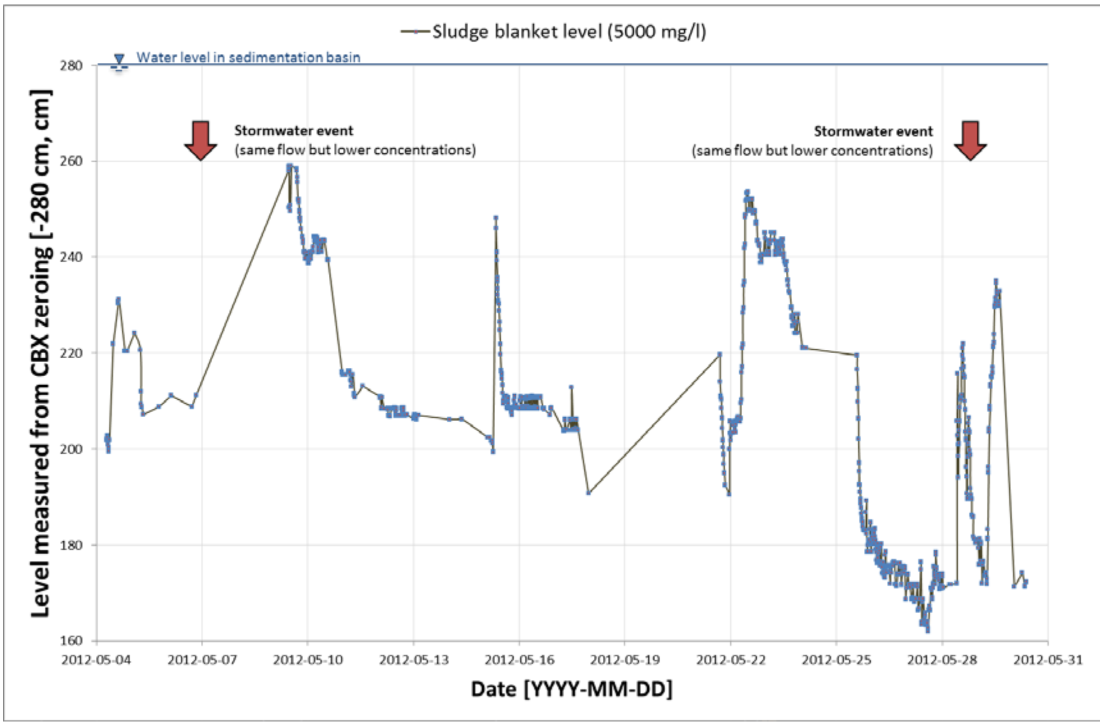

Figure 13. Measured sludge levels by the Cerlic CBX during May 04 –May 31 with indication of natural stormwater events (diluted wastewater).

During the period of 5 days when no sludge was removed from the post-sedimentation only slight changes in the sludge levels could be observed. This again may be explained by the relatively low magnitude of this flow. At normal operating conditions, the excess sludge removal only corresponds to about 1/100 of the incoming water flow whereas the return sludge flow is in the some quantity as the incoming water flow. The latter is therefore dominating the post-sedimentation basin. Pump failures in that flow will be more significant and observed in shorter time. They will also alter the treatment process in a significant way.

5.2.2 General handling and operation

The installation of the Cerlic CBX was performed without the assistance of the company even so this is generally offered to costumers. All connections are easily understandable and with help of the provided manual, the installation is managed in an easy way. The configuration of the Cerlic CBX to the post-sedimentation of Line 1 at Sjöstadsverket with a scraper at the bottom was performed without problems. Test with changing blind zones, scraper high etc. were initially done to investigate the flexibility. The configuration menu is intuitive and clear designed. Both automatic and manual measurements are easily configurable and performed.

Generally, the handling and operation of the Cerlic CBX was very straightforward. The sensor never had to be cleaned as the automatic cleaning was connected. Opening the device after de-installation showed no water, dirt or other depositions inside the housing of the sensor, which indicates that the automatic cleaning is proper constructed. The housing is further waterproof and cleaning the post-sedimentation tank from surface sludge layers was not a problem concerning the sensitivity of the equipment to water.

5.2.3 Restrictions in operation and recommendations

The standard configuration of the Cerlic CBX includes the detection of two interface levels; the fluff sludge and the sludge blanket. However, as tests in this study show, only the first level of detection is reported by the instrument. In case sludge layers include a clear water phase, such as in the test-sludge II (see Figure 5), the sludge blanket indicated may be misleading and operation of sludge flows based on this information may result in undesired sludge characteristics of the sludge that is either returned to the bioreactor or the following sludge handling. Therefore, the main recommendation is that the complete concentration profile of the measurement should be used as basis for operation. As the Cerlic CBX has the option for this, only the two main levels may be reported but profile information may always be available to process engineers.

Alternatively, the Cerlic CBX configuration could be extended by the producer to send a notification to the operator in case more than one level with the predefined sludge concentration is detected. Then, the operator can choose to check the complete profile in order to get a better understanding of the sludge characteristics. This of course would require an interaction by the plant operator. However, such sludge characteristics should only occur under extreme load situations such as high flows when special operational attention is provided anyhow and when a proper control of sludge flows is outermost crucial for an optimal treatment efficiency.

As the Cerlic CBX is measuring the sludge content by a sensor moving though the various layers of the sedimentation basin, any hinder on this pathway has to be avoided in order not to damage the sensor. In the present sedimentation basin of Line 1, a scraper that was located at the basin bottom had a supporting beam 1 meter above the bottom. The latter rotates together with the scraper around the tank in order to prevent accumulation of material. Scrapers are standard installation in many treatment facilities and do not pose any limitation to the operation of the Cerlic CBX The easiest way would be to configure the sensor with the scraper movement (e.g. by connecting the sensor to the overall control system). An important aspect is the timing as experiences (see e.g. section 5.3) show that the scraper influences the measurement by pushing a “sludge wave” in front of it. However, the installation of each sensor is accompanied by adjustments on site in order to trim the timing for most appropriate measurements.

A minor aspect that may have to be considered in some cases when using the Cerlic CBX is the dilution of the sludge at the top layer of the sedimentation basin due to the automatic cleaning feature. Especially when measuring with close intervals and at the presence of thick sludge layers (see Figure 14) the flush water will influence the measurements by decreasing the sludge concentration in the top layer and direct vicinity of the sensor. This situation, however, is not a standard operational state and both should and can easily be solved by cleaning/removing the top sludge layer or by increasing the blind zone in the Cerlic CBX configuration.

Figure 14. Sedimentation basin with thick top sludge layer and visible dilution near the sensor that is generated by the automatic cleaning of the CBX sensor.

5.3 Full scale tests at Käppala WWTP

Käppala WWTP in Stockholm evaluated three different brands of sludge level indicator in the post-sedimentation; the Cerlic CBX and two different ultrasonic meters. The aim was to find a reliable online measurement of the sludge level that completely or partly could replace the manual sampling and analyses that is performed approximately once per week. Of particular interest was to get a better characterization of the sludge characteristics at various sludge removals and at various flow situations. To measure the "fluff level" was also of interest as high levels of fine dispersed sludge can easily disturb the operation of sand filter and degrade the plant's hydraulic capacity. During colder periods of the year when high sludge ages are required for complete nitrification, situations with poor sludge settling characteristics occur frequently. This often implies sludge drains from the post-sedimentation at high flows, which in turn can overload the following sand filters.

Tests at Käppala WWTP were performed during a period of 7 weeks in summer of 2010 (Nordenborg 2010) and included three different sludge blanket sensors of which one was the Cerlic CBX sludge level indicator. The comparison between the three sensors suggested that the Cerlic CBX performed best during this period, which however has been characterized by overall low sludge levels and good sedimentation characteristics.

Compared to the two other sensors testes following advantages of the Cerlic CBX were named:

- Actual sludge concentrations are measured at each level instead of interpreting an ultrasonic echo. This provides more information as e.g. sludge blanket and fluff sludge.
- Measurements were not disturbed by scrapers as for the other sensors.

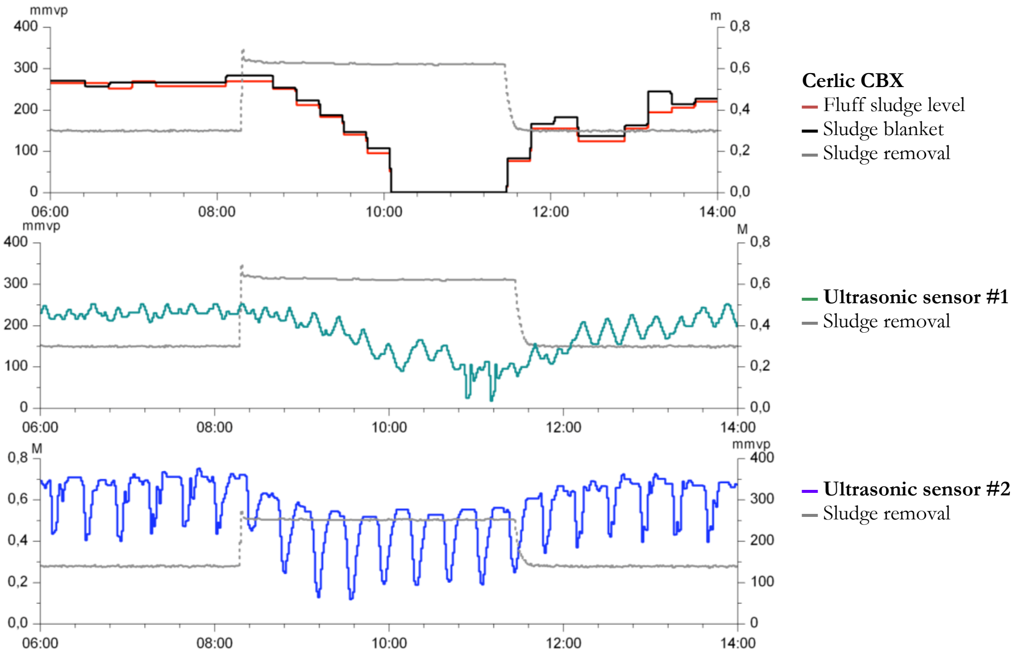

Figure 15. Measured sludge blanket levels (and fluff in the case of Cerlic CBX; minutes average) by the three tested sensors (modified from Nordenborg 2010).

Figure 15 shows that all sensors identify constant sludge levels during normal operational conditions even so it is clearly visible that the ultrasonic sensors are disturbed by the scraper in the sedimentation basin. All sensors did further indicate a sludge level decrease during increased sludge removal rates; however, only the Cerlic CBX did inform the operator about that the increased sludge disposal actually was so high that all sludge was removed from the tank. Indirect measurements did still indicate sludge levels despite the actual situation. This disinformation may cause operational problems. Thus, from an operational perspective, the outputs from the ultrasonic sensors would always need further processing (i.e. filtering) before they are usable in operational control.

In general, the Cerlic CBX did provide more reliable and consistent measurements than the other sensors tested. At very low sludge blanket levels in the sedimentation basin, ultrasonic sensors indicated instead unrealistic sludge blanket levels of several meter and varied very much from measurement to measurement. Both the scraper and bottom of the tank had a disturbing effect on the readings.

A longer test period including various operating conditions as well as exceptional events was proposed in order to obtain enough data to evaluate the real performance of the various sensors under such conditions. Without such tests is was difficult to conclude how the different sensors would perform and what disadvantages and advantages each sensor would provide during different operation conditions.

6 Conclusions

The present study examined how the sludge level meter is able to measure the sludge profile, fluff and sludge level. The tests further identified technical difficulties, advantages and disadvantages of using the Cerlic CBX, and limitations and reliability. Therefore, the study includes various tests in lab and pilot scale of the Cerlic CBX sludge level meter.

Both laboratory and pilot-scale test indicate that the Cerlic CBX is an optical sludge blanket meter that provides automatic and reliable measurements of the sludge blanket. It is easily handled and does not need any special configuration or start-up phase in order to be operative. At the same time as it has all the basic features such as two different predefined sludge levels and visual control, it also provides extensive configuration options for demanding applications. This includes for instance freely configurable measuring intervals, measurements of the whole profile and individual configuration possibilities to adjust for local basin characteristics. The ability to measure actual suspended solid concentrations at various depths avoids the need for compensations or interpretation as necessary when using indirect measurements.

The ability to configure the Cerlic CBX individually to each application e.g. post-sedimentation basins as just in this study provides several options of using the information provided by the sensor for various uses. These include controlling excess and return sludge flows in order to keep an average, minimum and maximum sludge blanket in order to provide good operation and buffer variations in incoming sewage flows and loads. It can further provide a continuous process monitoring and thus increase the robustness and reliability of the treatment process. The control of the sludge content in the biological stage, detection of operations problems such as disturbances due to storm water events etc. can be detected more easily.

The next section provides a brief discussion of which possibilities the use of the Cerlic CBX in post-sedimentation provides to a better control of WWTP operation for various aspects. It is worth to mention that the sensor may also be used in other treatment steps of a WWTP as e.g. the primary clarifier.

7 Perspective

Manually calculating the sludge age for a given load and temperature in order to determine the necessary SS concentration in active sludge process are common practice in many WWTPs. The operation is manually adjusting the excess sludge flow and sludge return flow to the bioreactor so that there proper sludge content is achieved. Control of sludge flows from post-sedimentation are thus largely manual, and removal of sludge from settling basins is not synchronized with one of the plant's main control parameters, the sludge age.

Low TS content of the extracted sludge causes increased pumping costs but also reduced the efficiency of following sludge handling steps such as decanters etc. Further, a lower TS content in the extracted sludge also entails an increase of heating costs of the digesters. Sludge settling in the post-sedimentation basins could also be used to buffer fluctuations in the incoming flow to the WWTP as well as to indicate and remediate disturbances in the biological treatment.

Overall, a goal for all sewage treatment plants should thus be the automatic (alternatively partly automatically) control of both excess sludge and return sludge flows is controlled automatically to a set point of sludge age (or sludge content). This would imply that finding and controlling towards an optimum (and for each WWTP unique) sludge level for post-sedimentation basins would facilitate a uniform TS content in return and excess sludge flows.

Practically enhanced sludge level measurement using sensors like the Cerlic CBX could imply following improvements in WWTPs:

- Energy savings through reduced pumping of sludges with low TS
- General savings in operation due to better monitoring and control
- Better monitoring and information about processes with malfunctions
- Savings through less backwashing sand filters if sludges washouts are prevented
- Fewer overflows at high flows due to maintained hydraulic capacity
- Improved sludge handling through increased TS in dewatered sludge
- Improved and more stable biology
- Improved digestion process due to higher TS
- Reduced return sludge flow
- Control of polymer dosing in post-sedimentation

8 References

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