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# MONITORING OF ACTIVATED SLUDGE PLANT STREAMS USING ONLINE REFRACTOMETERS AND CONDUCTIVITY ANALYSERS

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## ABSTRACT

This study investigated the possibility of controlling an activated sludge plant by using continuous dissolved dry solids (DDS) measurements and conductivity analysers. In addition, the correlations of the results attained were compared to typical wastewater sum parameters, such as COD or TOC. The tests were performed by installing five (5) refractometers and five (5) conductivity analysers in a wastewater treatment plant (WWTP) and by collecting data and hand samples from a Finnish integrated pulp and paper mill. The results indicate that new precision refractometers can be used in a WWTP for the detection of very small changes in the DDS at low concentrations (about 50 mg/L). The results also indicate a strong correlation between the measured DDS and the COD and TOC values, suggesting great potential for their use in monitoring influent load and the quality of effluent before it is introduced into the local water system. Conductivity measurement also works well, but since the purpose of an activated sludge plant is to remove organic material from wastewater, this measurement method is not very effective in monitoring effluent load in the local water system. However, more research is needed to gain a better understanding of the use of these on-line measurements in monitoring the operation of WWTPs.

**Keywords**: Activated sludge plant, chemical pulping, conductivity, refractometer, wastewater

## INTRODUCTION

Environmental awareness has increased in recent years, particularly in the growing economies of Asia and South America where population and industrial activity are growing rapidly. Concern about the availability of pure fresh water and the condition of local water systems will cause tighter regulation of the quantity and quality of effluents from municipal and industrial systems. This trend has created a need for improved on-line monitoring and control of wastewater treatment plants (WWTP).

A chemical pulp mill alone can be a significant source of effluent load introduced into local water courses. The total load depends on the quality and quantity of the effluent and the efficiency of the effluent purification system. Normally, wastewater is treated using an activated sludge plant (ASP), where easily degradable organic materials are treated in an aeration basin with oxygen. This system also includes a primary clarifier for removing fibres and all heavy particles, such as sand. Before the treated effluent is introduced to the local water course, the sludge that is formed in the aeration basin is removed by a secondary clarifier. The principle of a typical wastewater treatment plant used for kraft pulp mill effluents is shown in **Figure 1**.

The most critical parameters in controlling the operation of an ASP are pH, temperature, nutrient balance, oxygen concentration, sludge age (SA) and hydraulic retention time (HRT). The first three are controlled by the amount of chemicals added (acid/alkaline, urea and phosphorus acid), oxygen concentration by air pumping and temperature by a cooling tower. The HRT is normally set when the ASP system is originally planned. To keep the ASP functioning correctly, conditions in the aeration basin when the effluent from a chemical pulp mill is treated should be as follows **/1/**: pH 6.8–8, temperature 35–37°C and oxygen 1.5–2.0 mg/L. The nutrient amount is typically set by the influent BOD content as follows: $BOD_5$:N:P ratio of 100:5:1. However, when treating kraft pulp mill effluents the need for nutrients, especially phosphorus, is usually lower. In study **/2/** with kraft pulp mill effluents, the optimum ratio between $BOD_5$:N:P was found to be 100:5:0.3.

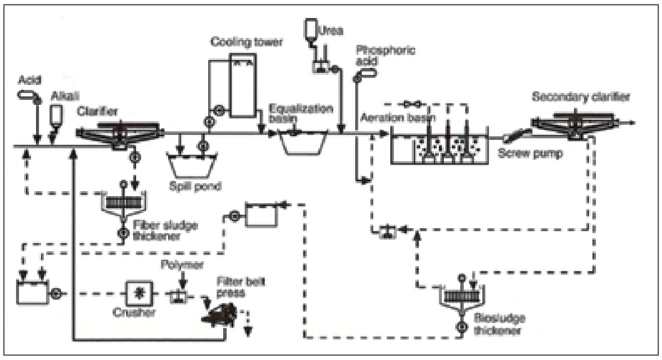


**Figure 1.** Typical wastewater treatment process for kraft pulp mill effluents /1/

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In practice, the efficiency of an ASP depends greatly on the quality and quantity of the influent. If there are unusual changes in influent quality (e.g. leaks from chemical recovery), a spill pond is used to reduce unwanted peaks, using a normal conductivity measurement as a "police measure". The single most important parameter that affects ASP performance is sludge age (SA). The most suitable SA for an ASP depends on many factors, such as the volume of the organic load [kg/d], the quality of the organic load, temperature, pH and the volume [$m^3$] of the aeration basin. If the SA is reduced too much, the mixed liquor suspended solids concentration (MLSS) also decreases too much. The range of the MLSS is wide when treating pulp and paper industry effluents using an activated sludge process, from 2.2 to 9.0 g/L **/3/** depending on the process.

The performance of an ASP is typically estimated by measuring the influent and effluent BOD, COD, TOC, phosphorus, pH and conductivity values. Among these parameters, the BOD, COD and TOC provide some indication of the amount of organic material, and electric conductivity provides an indication of the presence of inorganic salts. The challenge of making estimations for control and efficiency of an ASP is strongly related to measurement of the above-mentioned parameters, since pH and conductivity can currently be measured only on-line and phosphorus can only be measured in line. The delay for COD and TOC is hours, and for BOD it is several days.

The goal of this study was to better understand the operation of mill-scale activated sludge plants using an on-line conductivity analyser and dissolved solids measurement based on the refractive index in different areas of the ASP.

## METHODS

### On-line measurement with refractive index in ASP

#### *Refractive index measurement principle*

The refractometer measures analyte concentrations in solutions based on a measurement of the refractive index. A refractive index measurement is a measurement of the speed of light in a medium. The speed of light in a medium depends on the medium itself, as well as the temperature and wavelength. The refractive index depends on the concentration of dissolved solids. In general, the greater the molecular size of the dissolved solids, the greater the refractive index per concentration unit. The measurement accuracy is not affected by particles, bubbles, fibres, colour or temperature changes in the process medium. The laboratory reference temperature is usually 20°C or 25°C. Due to wavelength dependency, the refractive index is measured with monochromatic light. The measurement principle behind the measurement of dissolved dry solids content through refraction has been presented in detail in our earlier studies **/4,5,6/**.

#### *Measurement arrangement in the ASP of the mill*

Both influent and effluent from the activated sludge plant were monitored by five (5) refractometers to measure dissolved total solids and by five (5) conductivity on-line analysers, as shown in **Figure 2**. Wastewater without fibres consists mainly of alkaline and acidic filtrates from the pulp mill's fibres bleaching process. It also contains save-all from paper machines 2 and 3. Wastewater with fibres consists of screening reject from the pulp mill, filtrates from the collector tank of bleaching, soda precipitates, wastewater from barking, water from the grindery (reject and peroxide bleaching), return from the ground basin, water from the drying machine and sanitary water. Before the trial runs, the refractometers were calibrated in co-operation with the refractometer supplier, and conductivity analysers were calibrated in co-operation with the pulp mill's staff. Calibrations were made by taking water samples from all the installation points. More samples were taken during a trial run to re-check the calibration.

During the mill trials, samples from each point were taken every two hours during the day (8 a.m. to 4 p.m.). In every sample, the dissolved solids (DS), ash content, conductivity, COD and TOC were measured in a laboratory. On-line data (DS, T, conductivity and flow) from sensors were collected and stored in the mill's data collection system.

The physical properties of the activated sludge plant examined in the trial were: The volume of the aeration basin 1 (Aerator 1) was 51,000 $m^3$ and that of the aeration basin 2 (Aerator 2) was 39,000 $m^3$. The average flow to the ASP was about 60,000 $m^3$/d and the total retention time was about 24 h. The total amount of solids in the aeration basins was on average 4–5 g/$dm^3$. The total concentration of solids in return sludge was 8–9 g/L, with a volume of 55,000 $m^3$/d–65,000$m^3$/d. The calculated sludge age was usually around 18–22 d.

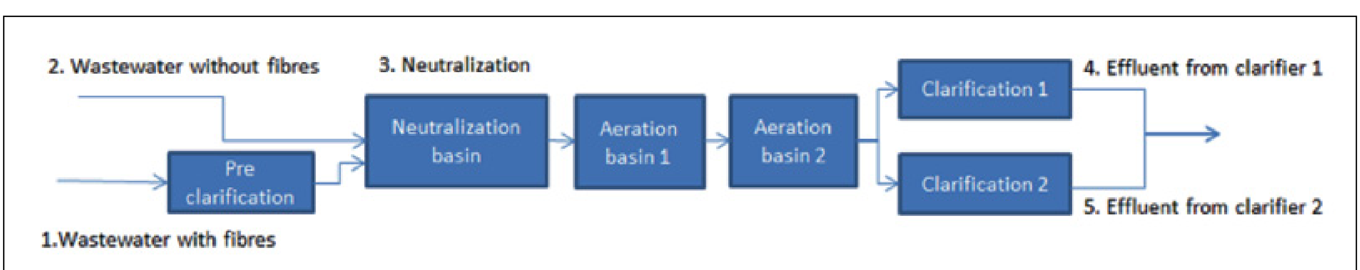


**Figure 2.** Simplified flowchart of the activated sludge plant and refractometer and conductivity analyser installation points (1. to 5.) in an ASP

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### Laboratory analyses

All of the influent and effluent samples in this study were measured in laboratory conditions using the following standards: pH (SFS 3021), conductivity (SFS-EN 27888), $COD_{Cr}$ (SFS 5504), TOC with Shimadzu *TOC-V CPH* analyser (SFS-EN 1484) and dissolved solids (SCAN-N 22:77).

## RESULTS AND DISCUSSION

### On-line and laboratory measurements

#### *Influent to ASP*

The influent dissolved dry solids concentration measured by the refractometer, versus the COD, TOC (laboratory analysis) and on-line conductivity is shown in **Figure 3**. The results indicate that all of the measurements were nearly consistent. This was expected, since laboratory tests showed that the consistency of dissolved material in wastewater without fibres was fairly evenly polarised into organic (40%–45%) and inorganic (55%–60%) matter. Compared to the history data of the mill, the wastewater quality was quite normal with a DDS of 0.3% and a COD of 2,000 mg/dm³. After a steady beginning (24 and 25.1), some problems in the fibre line occurred, causing extra load to the ASP. One diffuser washer was out of service and the pulp and filtrate streams were contaminated, consequently contaminating wastewater without fibres. Also, a small amount of filtrate containing black liquor from oxygen bleaching pressure washers was bypassed to wastewater with fibres.These concentration changes in the influent stream (26.1 and 27.1) were observed in real time using an on-line refractometer and conductivity measurements.

The results of the on-line refractometer DDS and laboratory COD, conductivity analyses and the measured ash content from the influent stream to the ASP are shown in **Figure 4**. Normally, ash content in wastewater is approximately 40%–60%. In the wastewater examined, the DDS consisted of equal amounts of organic and inorganic matter. The results showed an exceptionally high ash content, 76%, at point 6 (25.1.11:59). A momentary spike in the amount of inorganic matter occurred, increasing the conductivity and the refractometer values, while no effect on the COD value was observed. These results support the theory that conductivity is related mainly to inorganic content and the COD is related mainly to organic matter content, while the refractometer measurement is related to both organic and inorganic content, i.e. it measures all dissolved material.

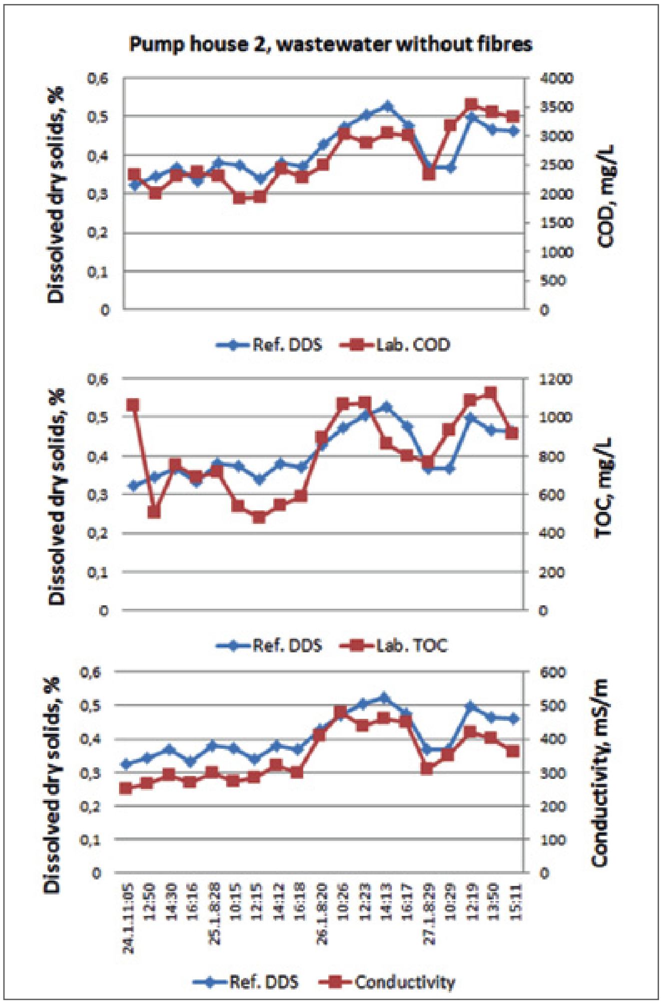


**Figure 3.** Influent DDS content versus the analyses of COD, TOC and conductivity

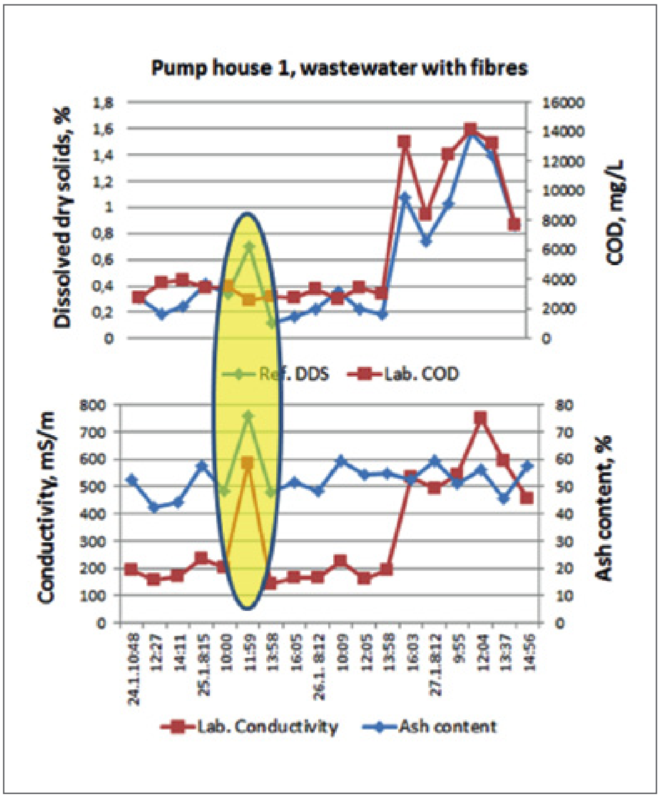


**Figure 4.** Influent DDS, COD, conductivity and ash content

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***Effluent from ASP***

The results of the on-line refractometer measurement and the laboratory analyses of COD and TOC are shown in **Figure 5**. The refractometer results correlated strongly with the mill's COD and TOC analyses in the effluent stream from the ASP. The on-line measurement results indicated that an aeration system can compensate for momentary changes in wastewater load, but larger problems (27.1.8:05) occurred when the concentration of DDS increased. During the monitoring period, the DDS increased from 0.17% to 0.22% and the COD from 500 mg/L to 800 mg/L.

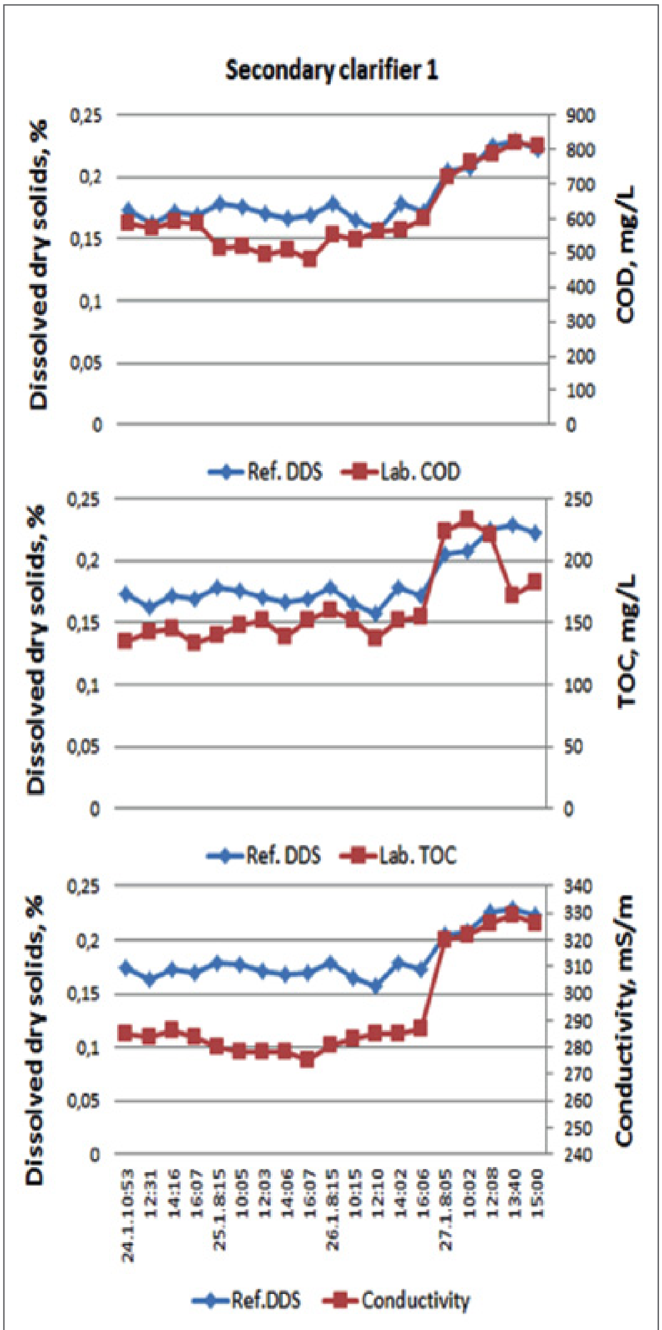


**Figure 5.** Effluent DDS content versus the COD, TOC and conductivity analysis

***Influent to ASP and effluent from ASP***

The dissolved dry solids measured by the refractometer, the COD (laboratory analysis) and on-line conductivity are shown in **Figure 6**. The results indicated that the activated sludge plant where the samples were collected operated normally, reducing the COD by approximately 75%, while there was no significant effect on concentrations of inorganic matter. Therefore, the conductivity measurement, which correlated to the inorganic measurements, was not a very good indicator of the effluent load from the ASP into the local water system. The results also indicated that concentration changes in the effluent with fibres were higher than in the effluent without fibres. **Figure 7** shows that the flow rate of the stream of wastewater with fibres was usually smaller than the flow rate of the wastewater without fibres, which consisted mainly of filtrates from the bleaching process of the pulp mill.

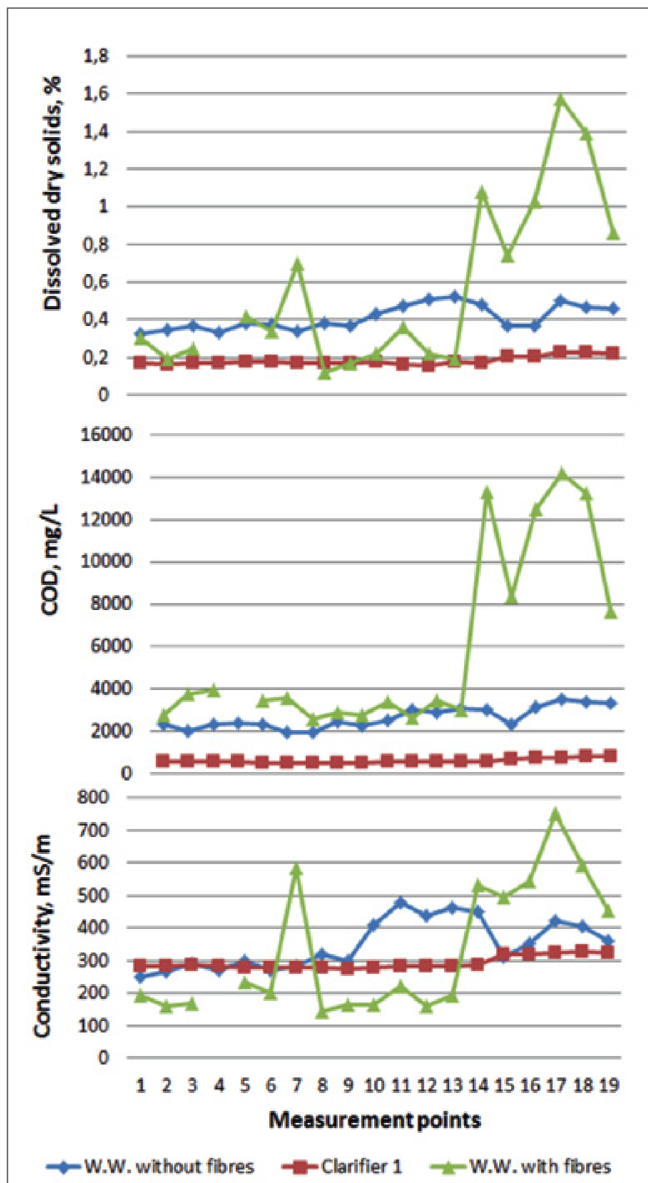


**Figure 6:** Influent and effluent DDS, COD and conductivity analyses

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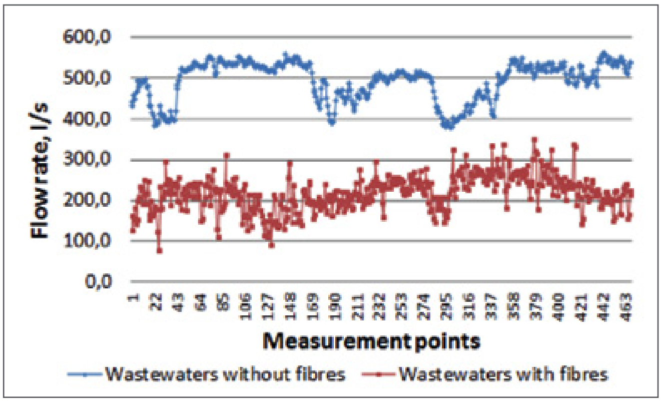


**Figure 7.** Flow rates of the influent streams from pump houses 1 and 2 from 24.1. 10 a.m. to 27.1. 4 p.m.

## CONCLUSIONS

The results indicated that refractometers are suitable for the detection of very small changes in the dissolved dry solids at low concentrations (about 50 mg/L). The results also clearly indicated that real-time refractometer measurements of the ASP influent and effluent streams correlate to the mill's COD and TOC analyses. Conductivity measurement responds well to concentration changes in influent streams. Conductivity measurement alone is not adequate for measuring the performance of the ASP because changes in the concentration of inorganic materials in the WWTP are so small. A reliable DDS measurement combined with a conductivity analyser could provide better possibilities for controlling the performance of an ASP.

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