How to use TDS measurements to evaluate the performance of diffuser washers – mill study

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ABSTRACT

Various types of pulp washing equipment are available. Each washing device has a unique mechanical construction, and the washing principle is often a combination of dilution thickening and displacement washing. In this work, the performance of the pressure diffuser, the washing operation of which is based on liquor displacement, is studied.

Diffuser washing occurs normally at a medium consistency (10-12%). In the stepwise trials, the effect of the feed and discharge consistencies on the performance of diffuser was studied. The effect of the downward velocity of the screen on the pressure diffuser's washing efficiency was also studied. The measurement of total dissolved solids (TDS) by a process refractometer was used as the wash loss measurement unit and the refractometer's results were used in the E-value calculations. The COD and conductivity were also measured and their results compared to the TDS results.

The results indicated that feed consistency has a significant effect on the performance and effectiveness of the diffusers in the experimental mill. It can also be stated that when the downward velocity of the screen is adjusted to too high a level, the washing efficiency of the pressure diffuser weakens. As a conclusion from the mill test, it can be stated that even small process parameter changes can provide enhanced diffuser washing at the beginning of the washing line, and this has a direct effect on the performance of the post-oxygen washing.

INTRODUCTION

The performance of brown stock washing has an effect on many sub-processes such as evaporation, oxygen delignification, bleaching and waste water treatment, and hence it has a direct impact on the profitability of the fiberline performance. Thus, brown stock washing and post-oxygen washing should be sufficiently effective. For softwood pulp applications, typical washing efficiency requirements are approximately 15-16 before and 7-9 after oxygen delignification when the dilution factor is 2.5 m^3/adt (Tervola and Råmark 2017). In an optimum situation, the operation of the washing line is monitored by on-line measurements which measure all dissolved washable materials, with on-line effectiveness calculations performed using these measurement results. However, this is not very common. The performance of the washing is mainly monitored via the variations in the levels of the conductivity measurements and by measuring and controlling the wash water amount. Closer monitoring with samples is done mainly in optimization and troubleshooting situations and in connection with guarantee runs.

The brown stock washing system is always mill-dependent. It starts with cooking (Hi-Heat) and is followed, mainly in series, by various pieces of equipment such as a drum displacer (DD), a vacuum filter, a diffuser, a press filter, which use either dilution/thickening or displacement washing principles or their combination. The target is to connect these different pieces of washing equipment in a series and attain as good a washing result as possible with a minimum amount of wash water (Crotogino et al 1987).

There are two types of diffuser: atmospheric and pressure. The pressure diffuser in Figure 1 was developed as an application of atmospheric diffusers. It is built to operate at digester pressure and is most commonly positioned directly after a digester or an oxygen delignification tower. There are two types of pressure diffusers: the pulp flow direction is downward or upward. In the upward flow design, pulp of 10% to 12% enters the bottom inlet of the pressure diffuser. The pulp passes up through the annulus between the screen and the baffles on the inside of the shell, forming a uniform 150 mm-thick bed of pulp. A rotating discharge scraper at the top outlet ensures uniform pulp flow through the unit. Since this is a pump-through device, the pulp is discharged with sufficient pressure to flow to the next process. The slightly conical screen causes an automatic back-flush during the rapid downward stroke of each cycle. Washing is performed as a result of the lateral displacement of wash filtrate through the pulp bed. The wash filtrate enters through a series of wash baffles inside the shell. Liquor is displaced through the pulp bed and the extraction screen into the central collection chamber (Tervola et al. 2011).

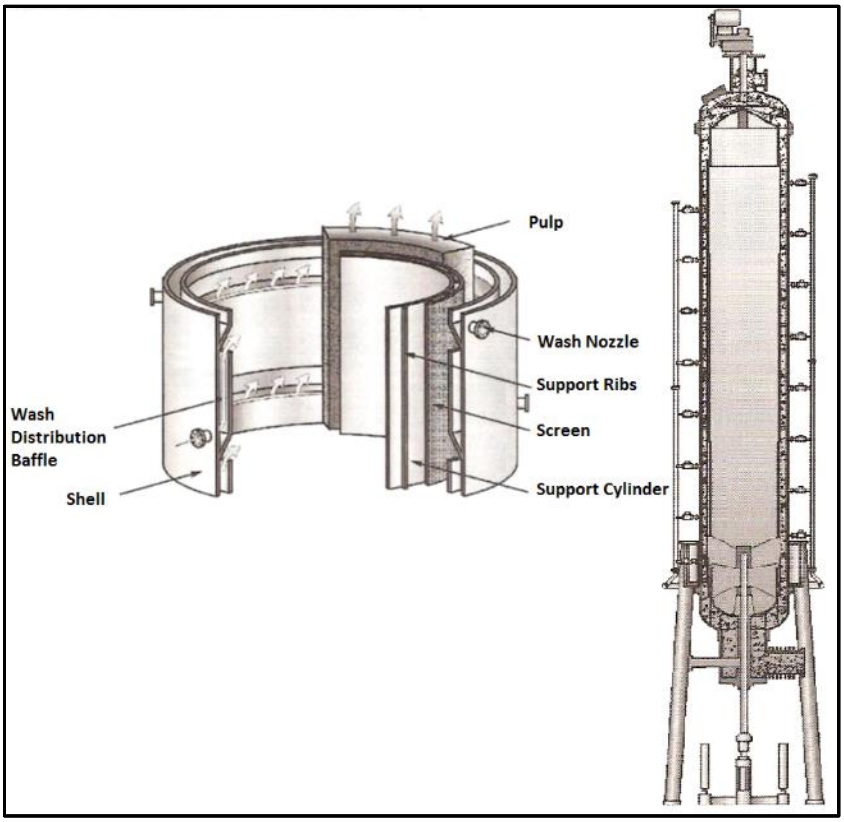

Figure 1 Construction of a pressure diffuser and pulp and filtrate flows in a diffuser (Tervola et al. 2011, Turner et al 1996)

MATERIALS AND METHODS

The experiments for this study were carried out on a Scandinavian pulp mill's softwood line (SW) diffuser's washing. Stepwise trials were conducted, where the effect of feed and discharge consistencies on the performance of diffuser was studied. The effect of the downward velocity of the screen on the pressure diffuser's washing efficiency was also studied. In test week I, the effect of feed consistency (7.6, 8.0 and 8.4) and different discharge consistencies (7.7, 7.9 and 8.1) on the pressure diffuser performance was studied. In test week II, the effect of the screen velocity and the effect of the discharge consistency using constant feed consistency (8.25) on the pressure diffusers washing efficiency was studied. The measurement of total dissolved solids (TDS) by a process refractometer was used as a wash loss measurement unit and the refractometer's results were used in the E_{10} and Y_{10}-value calculations. The E_{10} and Y_{10}-value calculations were performed using on-line data and Tervola's 2018 formulae (Tervola 2018). TDS measurement by process refractometer has been introduced in our previous papers (Kopra et al. 2008, Kopra et al. 2011, Kopra 2015). The COD and conductivity were also measured and their results compared to the TDS results. In addition, the performance of a portable refractometer was studied in the laboratory. This section presents the test arrangements, stepwise trials and analytical methods.

Installation of the Refractometers

The installation sites of the refractometers and sample points on the pulp mill's brown stock washing line are shown in Figure 2. The beginning of the SW pulp brown stock washing line consists of high-heat washing, a pressure diffuser and an atmospheric diffuser. Measurement arrangements have been made such that the performance of the diffusers' washing can be monitored and the pressure diffusers' E_{10}- and Y_{10}-values can be calculated in real time.

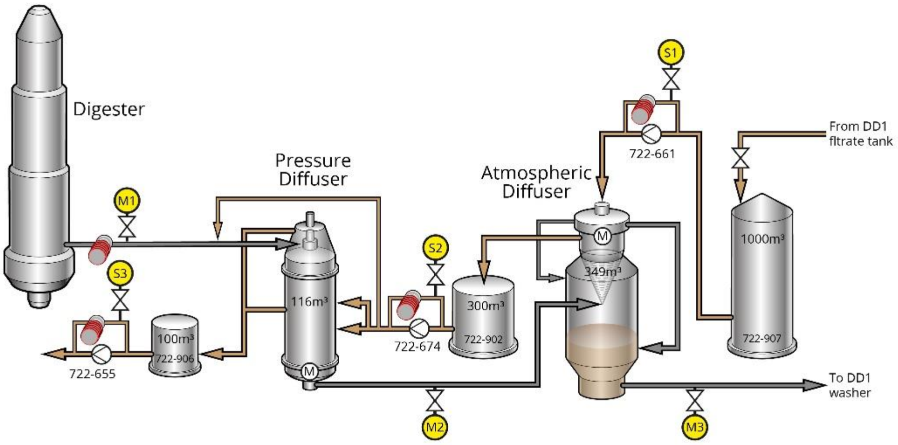

Figure 2. Installation sites of the refractometers on the pulp mill's brown stock washing line

Pulp and filtrate samples were taken from the washer's inlet and outlet pulp and from the filtrates. Three sample laps were taken from the all ten test points, see Tables I and II. From the pulp line, the filtrate sample was extruded from the pulp through wire gauze around 30 min after sampling. The conductivity of all samples was determined on the spot. The TDS by laboratory standard, TDS by portable refractometer and COD of all samples were determined afterwards in the laboratory. In the portable refractometer analysis, the temperature of the samples was controlled to 40°C using a thermostat.

Stepwise Trials

In test week I, the effect of the feed and discharge consistencies on the pressure diffusers' (PD) washing efficiency were studied by changing the set point of the feed and discharge consistency. The downward velocity of the screen was 1.2 m/s. Production was quite stable, at about 725 Adt/d. The experiments for test week I are shown in Table I.

Table I. Experiments for test week I.

Feed consistency, PD	Discharge consistency, PD
7.6	7.7
8.0	7.7
8.0	7.9
8.0	8.1
8.4	7.7

In test week II, the effect of the feed and discharge consistencies on the pressure diffusers' washing efficiency were studied by changing the set point of the discharge consistency. The downward velocity points 1.1 and 1.2 of the screen were also studied. The experiments for test week II are shown in Table II.

Table II. Experiments for test week II.

Feed consistency, PD	Discharge consistency, PD	Downward velocity of the screen
8.25	7.7 (production 650 Adt/d)	1.2
8.25	7.7 (production 700 Adt/d)	1.1
8.25	7.5 (production 725 Adt/d)	1.2
8.25	7.5 (production 725 Adt/d)	1.1
8.25	7.7 (production 725 Adt/d)	1.2

Analytical Determinations

The samples were analyzed using the following methods:

- Determination of dry matter content (analytical) (ISO 638 "Paper, board and pulps—determination of dry matter content—oven-drying method")
- Determination of dry matter content (on-site), process refractometer or (in laboratory) portable refractometer
- Conductivity (on-site), conductometer (Mettler Toledo; Columbus, OH, USA)
- COD liquor, COD liquor samples were filtrated using 1000 µm paper and then analyzed in a COD analyzer (ISO 15705 "Water quality determination of the chemical oxygen demand index [ST-COD] small-scale sealed tube method")

RESULTS AND DISCUSSION

As can be observed from Figures 3 and 4 (test week I), with a higher feed and discharge consistency, the washing efficiency of the pressure diffusers increases. Figure 3 shows that increasing the feed consistency from a value of 7.6 to 8.4 increases the E_{10}-value by about 1.5. The level of the E_{10}-values based on the laboratory analyses were approximately 1 unit lower than the on-line E_{10} values. The reason for the differences in the results from different methods could not be fully explained. It is likely that the on-line blowpulp measurement level was a couple of tenths wrong and this caused higher values for the on-line E_{10} calculations. Feed consistencies over 8.4 were not tested, because with higher feed consistencies, and especially discharge consistencies, the load on the bottom groove increases, causing operational problems. Based on these results, for the second test week, the pressure diffuser was selected as the monitored washer. The maximum feed consistency which can be run for a long time at the mill was tested.

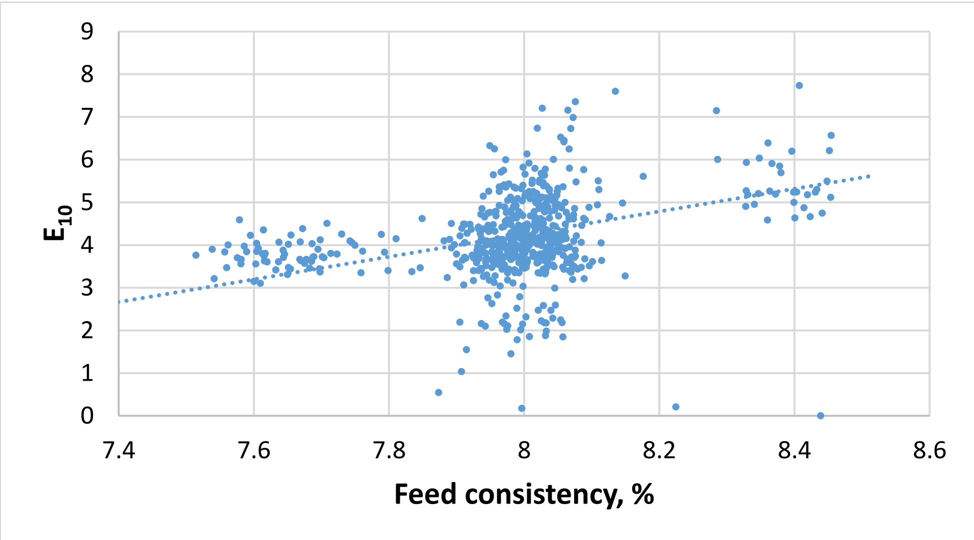

Figure 3. Effect of the pressure diffusers' feed consistency on the washing efficiency.

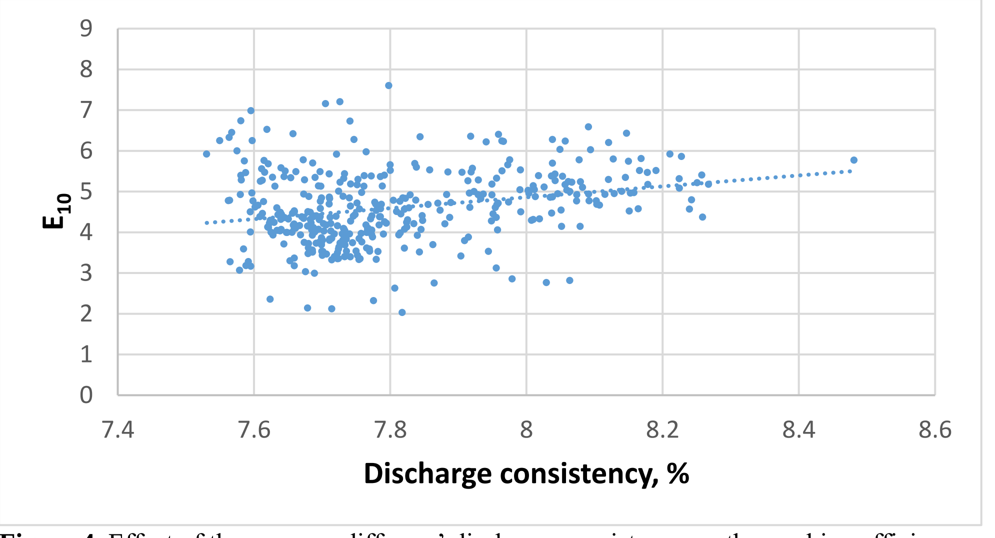

Figure 4. Effect of the pressure diffusers' discharge consistency on the washing efficiency.

The experimental results for the effect on E_{10} of the discharge consistency in two different downward velocities of the screen are shown in Figure 5 and the effect on Y_{10} is shown in Figure 6 (test week II). It can be seen that the E_{10} values are lower than in test week I. At this time, the on-line E_{10} values were at the same level as the values calculated from the laboratory analysis results. However, it can be seen again that the higher the feed consistency, the more effective the washing is. The E_{10} values are relatively low compared to the values presented by the manufacturer. Conventionally, the feed consistency of the pressure diffuser should be at a level 10%. In addition to low feed consistency, other reasons for low E_{10} values may be the condition / purity of the screen, hydraulic problems or other issues arising from the setting of the device. This pressure diffuser's maximum capacity is about 1600 Adt/d. Because of the low production rate of 725Adt/d, the diffuser is not in the optimum operating range. In such a situation, the pulpcake may precipitate too much.

In this case, a downward velocity of the pressure diffuser's screen of 1.2 gives 1 unit higher E_{10}-values than a velocity of 1.1. In our previous study (Kopra et al 2012) we obtained similar results. It was found that when the velocity ratio between the pulp and the screen unit is in the optimum range, the pressure diffuser works well but at higher values the efficiency deteriorates rapidly. Lysen (1987) has stated that the increase in the washing efficiency is due to the fact that breakage of the pulp web is avoided when the downward velocity of the screen is adjusted correctly. If the velocity of the screen units is too fast, the pulp cake will be whipped, which disturbs the displacement operation. Thus there is too little time for stable displacement. (Kopra 2015)

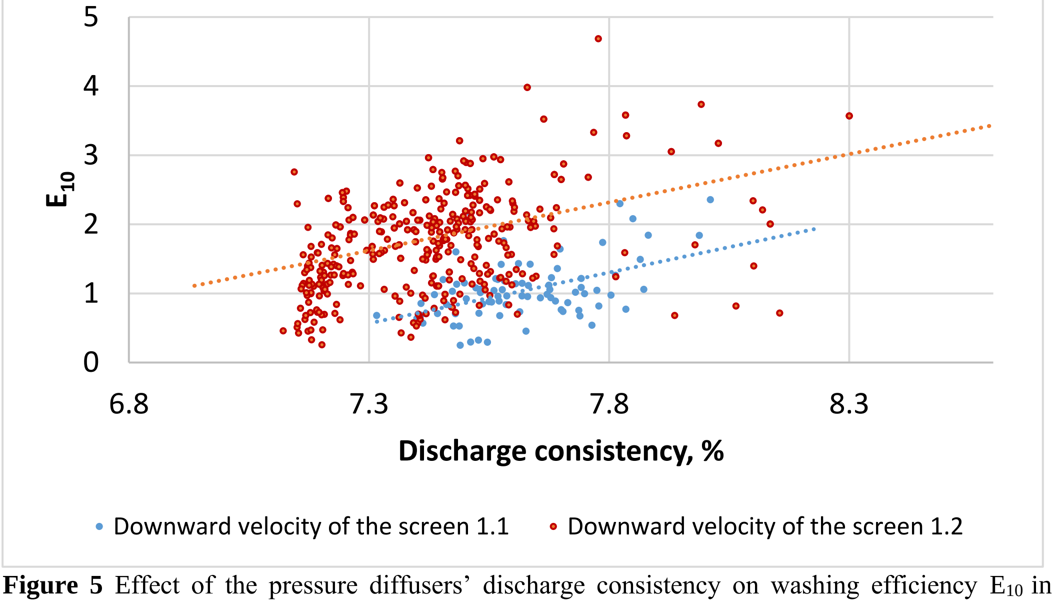

Figure 5 Effect of the pressure diffusers' discharge consistency on washing efficiency E_{10} in two different downward velocities of the screen.

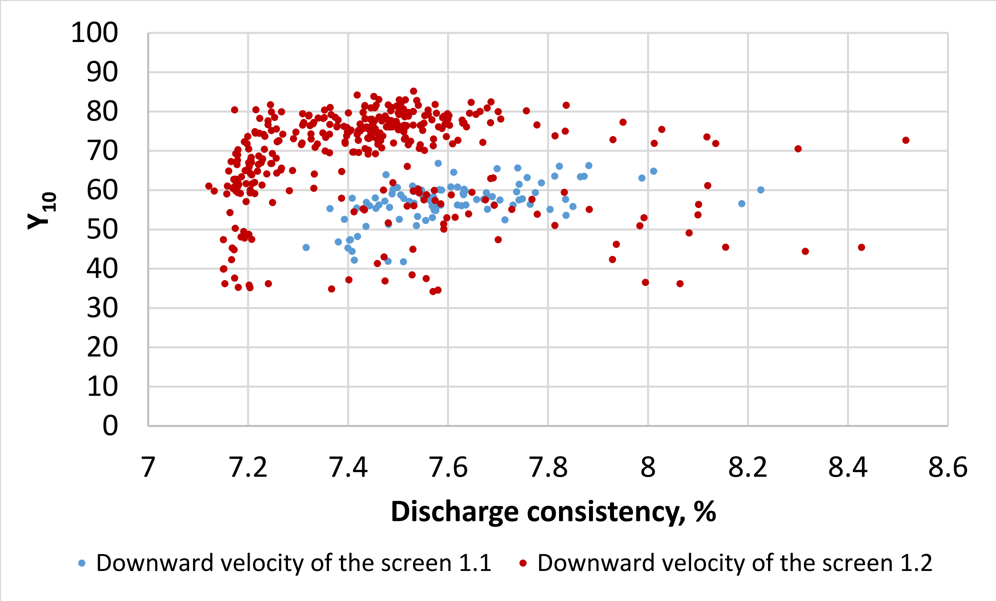

Figure 6 Effect of the pressure diffusers' discharge consistency on Y_{10} values in two different downward velocities of the screen.

Figure 7a shows the on-line E_{10} values calculated using Tervola's method for the test week II. It can be seen that the efficiency of the pressure diffuser varies considerably. By measuring the washing efficiency in real time using TDS measurements and by adjusting the process parameter in the appropriate direction, the inefficient operation of the washers can be reduced. Figure 7b shows the results published in Tervola (2018) based on continuous TDS measurements with a pressure diffuser at a different experiment mill. The variation is very similar in both cases.

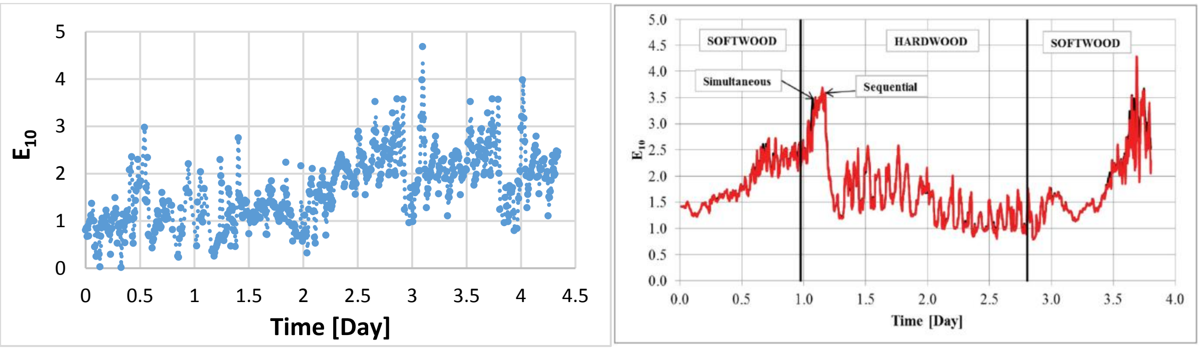

Figure 7a. On-line E_{10} values from test week II calculated by Tervola's method and 7b. Tervola's (2018) estimated value during his test runs using the sequential and simultaneous methods.

Pressure Diffuser Filtrate Measurements, Mill Test

Figure 8a shows the COD content of the SW pulp filtrate fraction (S3) compared with the TDS measured with a portable refractometer and 8b the conductivity content compared with the TDS in the five-day period. It can be seen from the figures that both the COD and conductivity behave in a similar way to the TDS. However, when comparing the COD and conductivity results over diffuser washers, it can be seen that organic material (COD) washes away relatively faster than inorganic material (conductivity): in that case, see Figure 9. It was not possible to completely understand a clear reason for the better washability of the organic matter, but it must be taken into account that relative efficiency can also be a function of process variables, e.g. pH, and washer type. However, the organics were in a soluble form and in a higher proportion relative to the inorganics, whereas Na-based matter could be adsorbed in the surface of the fibers because of the charges. This being so, the conductivity would not give representative wash result information and the COD would also give good wash results and be influenced by the non-washable components. Measurement using a refractometer shows the TDS content of washable compounds in the filtrate, which describes the washing success relatively well.

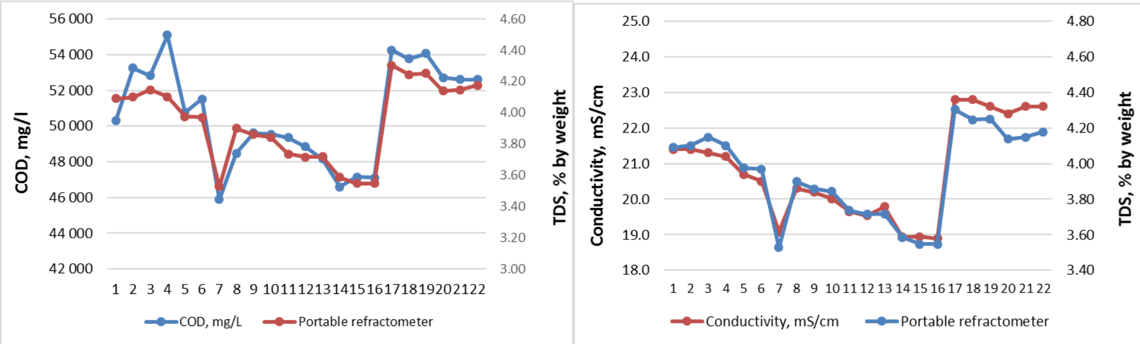

Figure 8a. COD content of SW pulp filtrate fraction compared with TDS measured with a portable refractometer and **8b** conductivity content compared with TDS at the S3 filtrate (test week I)

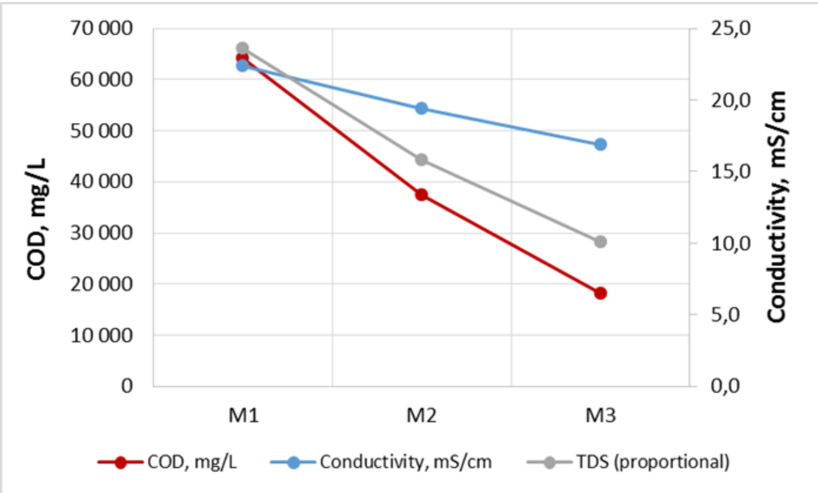

Figure 9. SW pulp filtrate fractions COD compared with at the beginning of the line (test week I)

Figure 10 presents the relation between the COD content and TDS content measured using a portable refractometer for SW line diffusers' filtrates. The results show that the COD and refractometer have an excellent site-specific correlation (R^2 0.988). By setting the slope to the refractometer calibration, the refractometer can also be used for COD measurement at the mill. However, it is a good idea to check the calibration regularly, a few times a year.

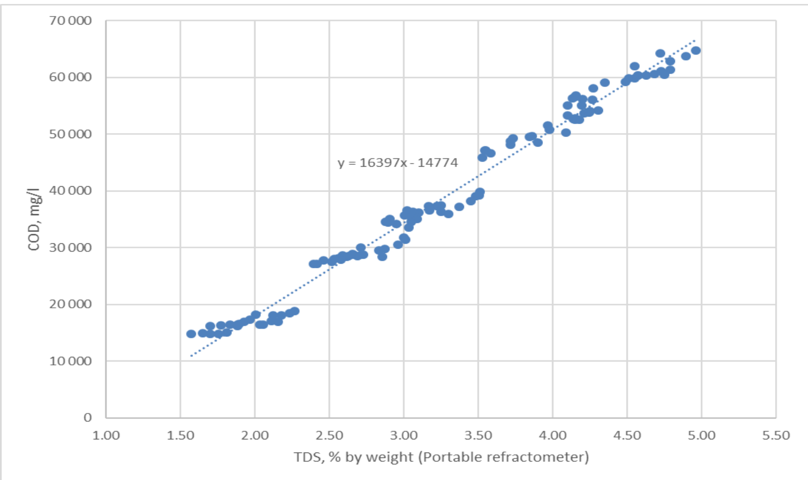

Figure 10. COD content of diffusers' filtrate fractions analyzed in the laboratory versus TDS measured by a portable refractometer (test week I)

CONCLUSIONS

By utilizing refractometers and data-analyzing tools, it is possible to discover the black spots in the washing line and evaluate a washing result continuously. In this experiment, by finding optimal process values for the pressure diffuser and using on-line measurements for monitoring effectiveness, the effectiveness of the pressure diffusers could be increased at least by a 1.0 E_{10} value. The controlled parameters of the feed and discharge consistencies and the downward velocity of the screen had a clear impact on the operation of the pressure diffuser. In other words, it enables the improvement of the washer's efficiency and reduces the level of wash loss to oxygen delignification and bleaching.

The results indicated that when using different measurement methods, the level differences remain quite constant. The results also showed clear differences between, for example, how organic and inorganic materials are washed away. Consequently, monitoring the performance of the washing using only one method that emphasizes either organic or inorganic material can obtain misleading washing results. Measurement using a refractometer shows the TDS content of washable compounds in the filtrate, which describes washing success relatively well.

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