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Professional paper

THE INFLUENCE OF PROCESS PARAMETERS ON BROWN STOCK PULP WASHING AT NATRON-HAYAT MAGLAJ

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ABSTRACT

Brown stock washing is one of the major unit operations within the pulp manufacturing business. Poor operating washers have the potential to significantly and negatively affect almost every other area of a pulp and paper mill, including the mill's environmental performance. The objective of the pulp washing is to remove the soluble impurities such as organic solids (lignin), fines, inorganic solids (Na, Mg, Ca, and K ions), and byproducts after each processing step. The present paper attempts to look at various parameters influencing pulp washing at Natron-Hayat Maglaj to ensure a complete understanding of the process. The results showed for this mixture of raw materials (15 % pine and 85 % fir) that the most influential parameters are Kappa number and dilution factor. Working with a high Kappa number above 50 requires additional equipment. Online control of the dilution factor would further improve the quality of the washing process and provide additional saving water and savings at the Evaporation plant. The First step for the future to improve the washing of unbleached kraft pulp is the optimization of the washing process through advanced control.

Keywords: pulp washing; wash loss; dilution factor, ,inlet and outlet consistency, pH, temperature

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1. INTRODUCTION

The objective of brown stock washing is to separate the product (cellulose fibers) from the process chemicals (black liquor), which mainly include alkali, sodium salts, lignin, and other chemically degraded wood components while using a minimal amount of wash water [1]. Reducing wash water results in higher black liquor solids, which in turn reduces steam demand in the evaporation process of the recovery cycle and increases energy recovery in the co-generation plant. In modern Kraft mills, usually, 96%-99% of the inorganic cooking chemicals are recovered back into the system. There are several variables affecting washing: dilution factor, inlet, and outlet consistency, pH, temperature, and entrained air. All these parameters relate to process conditions. Parameters such as mechanical pressure, fluid pressure (or vacuum), and particular traveling speed are considered equipment-specific parameters. Most of these parameters interact with each other and an improvement of one can differently affect the other [2].

The goal of the research is to identify important parameters visible on the Histograms, based on the results of the process management during three months of operation of the brown stock washing whose optimal management led to high-quality results in the washing line at Natron-Hayat.

1.1. Dilution factor

The dilution factors represent the net amount of water that is added to the washing system. The dilution factor is defined by considering the evaporation costs of black liquor, the manufacturing cost of fresh water, savings of condensates, losses of salt cake, losses of organic material, and treatment costs of the effluent treatment. Typically, the DF varies from 2-4.5 $m^3/_{oven\ dry}$ ton in the most relevant studies in this field [3].

1.2. Kappa number

The kappa number describes the amount of lignin remaining in the pulp after cooking – the higher the number, the higher the amount of residual lignin content. It should be noted that there is no general and unambiguous relationship between the Kappa number and the lignin content [4].

1.3. Inlet and outlet consistency of the pulp

Feed consistency plays an important role in the formation of the cake. If the consistency is too low, the pulp cake is too tightly packed, which deteriorates the washing liquid permeability. On the other hand, if the consistency is too high for the washer, the pulp cake might carry air thus declining the performance [5]. The Fiber consistency is found to decrease linearly with the cake thickness [4].

Design parameters for all washing equipment (inlet and outlet consistency) are given in Table 1.

1.4. pH value

In the weakly acidic region, reduced fiber swelling and improved dewatering can have a favorable effect on the washing process. Literature sources agree that maximum swelling of unbleached Kraft pulps is observed near the pH value of 9 [6].

Table 1. Design parameters for washing equipment [6]

Equipment for pulp washing	Inlet consistency (%)	Outlet consistency (%)
Continuous digester	10	10
Modified discontinuous digester	7-10	7-10
Diffuser	10	10
Wash Press	3-9	28-35
Pressure washer	3-4	12-14
Vacuum washer	1-2	12-14
DD washer	4-10	12-14

1.5. Entrained air

Prevention and elimination of entrained air are also important to maximize brown stock washing. Air trapped in the pulp also increases the drum speed by decreasing the stock drain ability and reducing the displacement ratio [7].

1.6. Wash liquor temperature

Liquor temperature plays an important part in influencing the viscosity of the washing liquor. For unbleached kraft pulp suspended in water between 20°C and 90°C, the rate of the leaching of lignin from the fiber wall increased with the temperature. From 20°C to 70°C, the change in the interfiber diffusion coefficient with temperature varied directly as expected for a diffusion process. Above 70°C, there was a much larger dependence of the diffusion coefficient on temperature than was observed at the lower temperature [8].

1.7. Specific parameters

Drum speed is another important variable when one is trying to achieve improved washing efficiency. Drum speed should vary as a function of vat level or sheet formation.

If the mat is too thick, it will carry over more of the dirty liquor because the shower water will not be able to fully displace the dirty liquid retained in the mat when it was formed on the drum. The thin mat will not provide good resistance to air penetration of the sheet into the liquor and the drum will tend to seal over, resulting in no drainage and no liquor displacement. The combination of drum speed and vat consistency should be the best available option when one is looking for a productivity increase [2]. Increased the rpm of the drum from 1 to 4 and found that the capacity of the drum increased by 2.5 times [4].

2. EXPERIMENTAL SECTION

The experimental work aims to monitor the influence of parameters on brown stock washing over a period of three months at Natron-Hayat. The experiments were carried out on a washing pulp line. The washing line consists of two stages of washing: washing pulp on a Rauma Repola drum washer (P = 38 m^2) that works under pressure and washing pulp on two vacuum drum washers (P_1 = 35.3 m^2, P_2 = 35.3 m^2). The experiments were carried out on softwood pulp samples containing 15% pine and 85% fir. The average Kappa number for all samples was 48. The cake was washed with hot water on the last drum washer. Flow, pressure, temperature, and level control are installed on the washing equipment. To obtain a realistic assessment of washing efficiency and alkali loss in the production of unbleached softwood pulp, the following research was conducted: sampling locations on the washing line were selected (at the output of the washers), measurements were made on laboratory devices and instruments in the Natron-Hayat laboratory according to ISO standards (the standard method of determining the Kappa number, consistency and wash alkali loss), research was carried out in industrially stable conditions of the brown stock washing at Natron-Hayat (optimal and stable production). Based on the obtained results it is important to see which parameters have the main effect on the Alkali loss, which is the main indicator of the quality of washing, and, based on that, propose measures to improve the pulp washing line.

3. RESULTS AND DISCUSSION

The effect of kappa number, dilution factor, wash water usage, temperature, number of rotations, outlet consistency, and alkali loss on the performance evaluation parameters is discussed. Histograms are added for better understanding and show, the underlying frequency distribution (shape) of a set of continuous data.

3.1. Kappa number

The Kappa number is one of the most important parameters measured in chemical pulping. The quality of pulp is also related to its Kappa number. The level of sobbed sodium varies with Kappa number and pH. Figure 1 shows the Kappa number from the digester. It indicates the pulp mill works with a higher unbleached Kappa number 47±3.

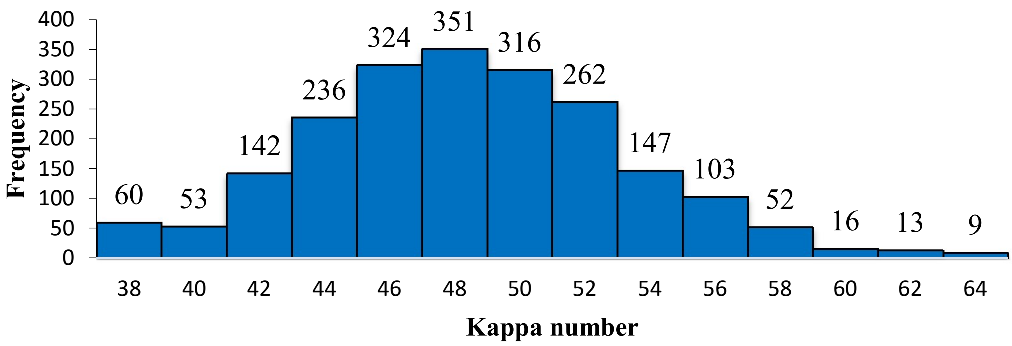

Figure 1. Kappa number of unbleached softwood pulp for the period of three months in 2022

Lower kappa-number pulping has two main limitations. The first is that pulping to lower kappa numbers can potentially damage pulp strength. The second is that, as delignification enters the residual pulping phase, the rate of carbohydrate dissolution becomes faster than the rate of delignification, resulting in a substantial loss in pulp yield. That is the main reason why the mill is working with a higher Kappa number but it also means that the mill needs better management of the washing process because Kappa number is a very significant factor in the washing process.

3.2. Wash water Usage

Figure 2 shows the Wash flow distribution in brown stock washing (m^3/t pulp). Wash water flow per ton of pulp varies over a wide range. Note that the specific wash flow generally drops as the production rate is increased.

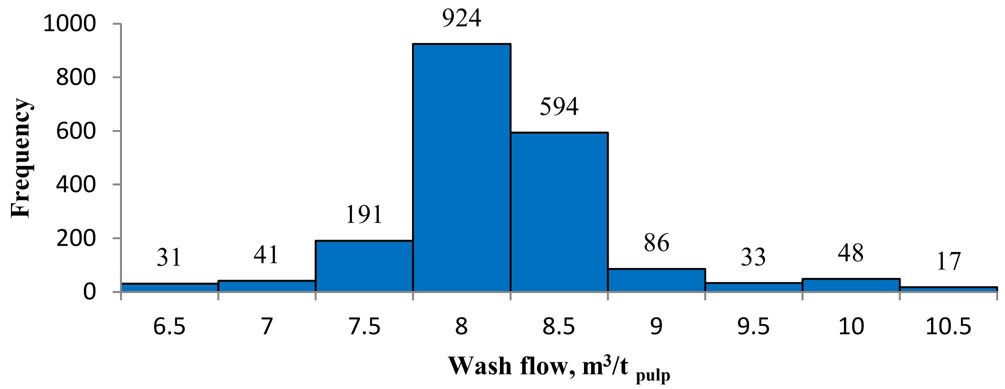

Figure 2. Wash flow distribution in brown stock washing for three months in 2022

3.3. Dilution Factor

Figures 3 and 4 show the dilution factor for the digester and the brown stock washing. Increasing the dilution factor improves washing results. On the other hand, when the dilution factor decreased below unity yielding a low washer performance. The dilution factor should therefore be above unity to guarantee unimpeded washer performance. However, the use of a dilution factor above two is not feasible, because the higher amount of wash water would increase the cost of black liquor evaporation.

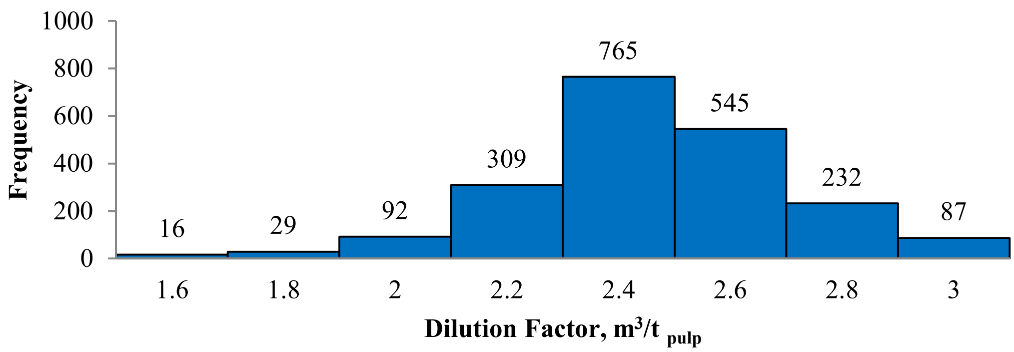

Figure 3. Dilution Factor in Kamyr digester for three months in 2022

Figure 3 shows a result of DF above 2 m^3/t pulp and it means good washing result in a first stage washing (Kamyr digester) and shows that the first step is well managed. Figure 4. Shows that result of DF at the last stage of washing is worse because the highest frequency of result is at 1.4 m^3/t pulp, which can affect the final washing result-the washing loss. Considering that the parameters are interrelated, this result may be the result of poor management of some of the parameters in the washing line (drum speed, level of production, liquid level).

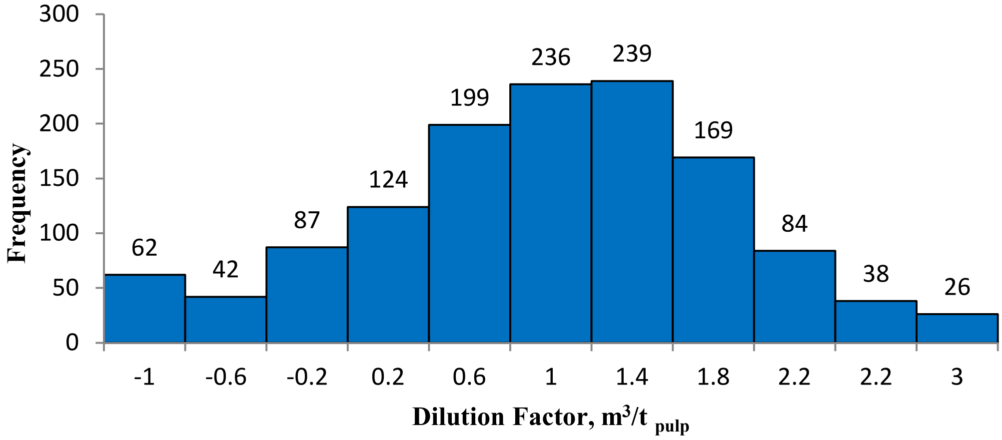

Figure 4. Dilution Factor in brown stock washing for three months in 2022

3.4. Temperature profile on brown stock washing

Figures 5-7 show the temperature profile on the washing line. At higher temperatures, viscosity is lower, less air remains in the pulp, the fiber pad is more porous, and foaming is less likely to occur. The effect of temperature on washing appears to be especially important in the pulping of pine and a little less so in spruce, presumably because of the larger size of the pits and larger relative pit area in pine parenchyma cells, which allow easier a toward diffusion of resin components.

Figure 5 shows the temperature of the filtrate used for washing in a pressure washer. This temperature is lower, which will affect the result of washing pulp from this washer, and if other parameters are not well managed, this impact on the result will be significant.

Figure 6 shows the temperature of filtrate used for washing on vacuum washer No. 2. This temperature must be high, near 70 °C. Because the washing result of this stage directly affects on total result.

Figure 7 shows the temperature of hot water used for washing pulp in the last stage of the washer. It is very important that the temperature of hot water be above 70 °C. On the Histogram, it is visible good distribution for temperatures.

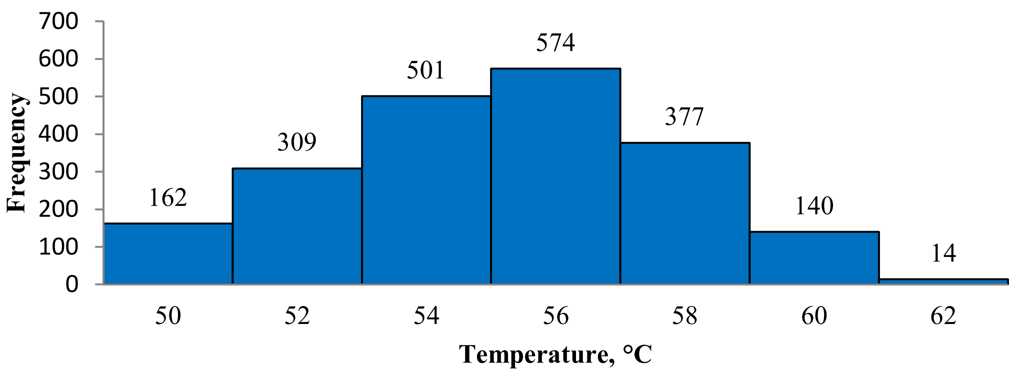

Figure 5. The temperature profile in the pressure washer for three months in 2022

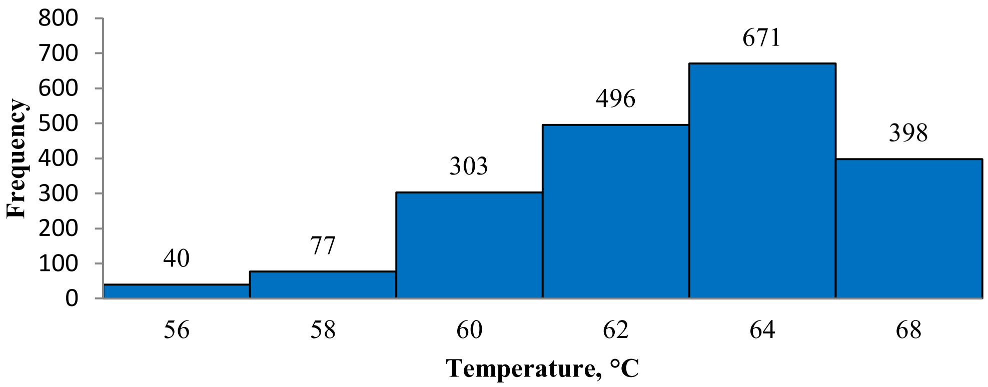

Figure 6. The temperature profile in vacuum washer No. 2 for three months in 2022

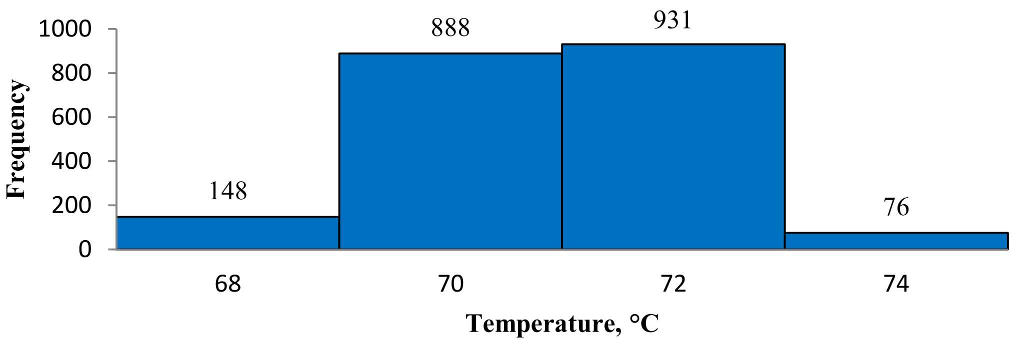

Figure 7. The temperature of water for washing on vacuum washer No. 3 for three months in 2022

3.5. Drum speed

Figures 8-10 show the number of rotation washers (Rauma Repola washer, vacuum washer No. 2, and No. 3). The pressure washer has a slower drum speed and it is normal for this equipment. It is expected that the same two vacuum washers have the same number of rotations but they do not, which will result in a different effect on washing loss. The optimal speed of the washer drum is very important for good washer results

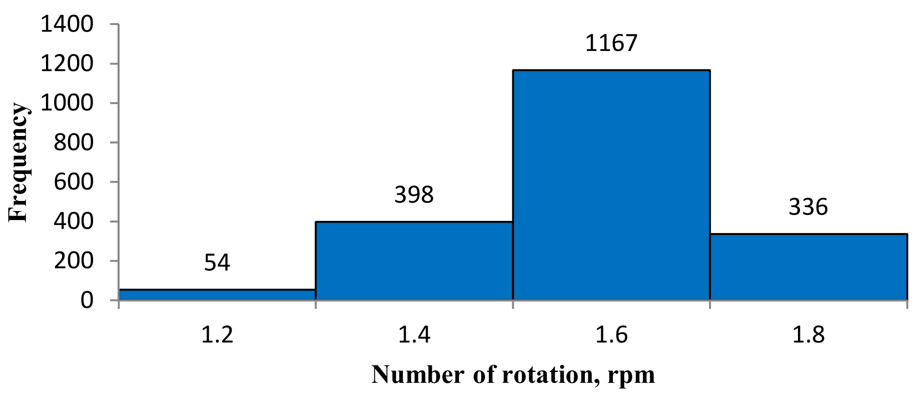

Figure 8. Number of rotation pressure washers for three months in 2022

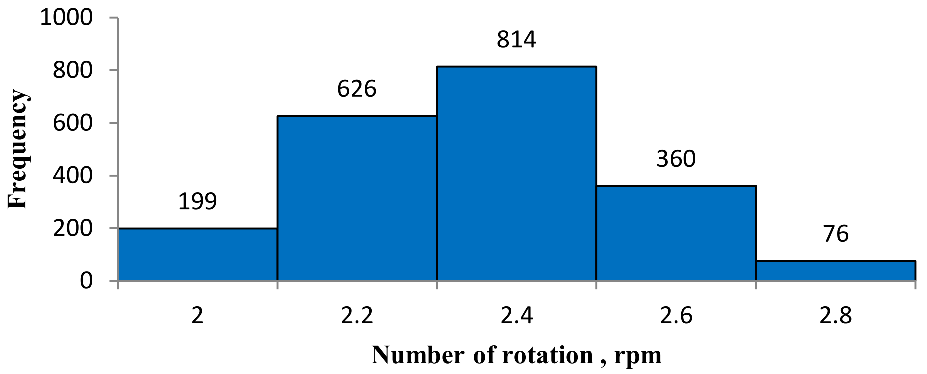

Figure 9. Number of rotation vacuum washers No. 2 for three months in 2022

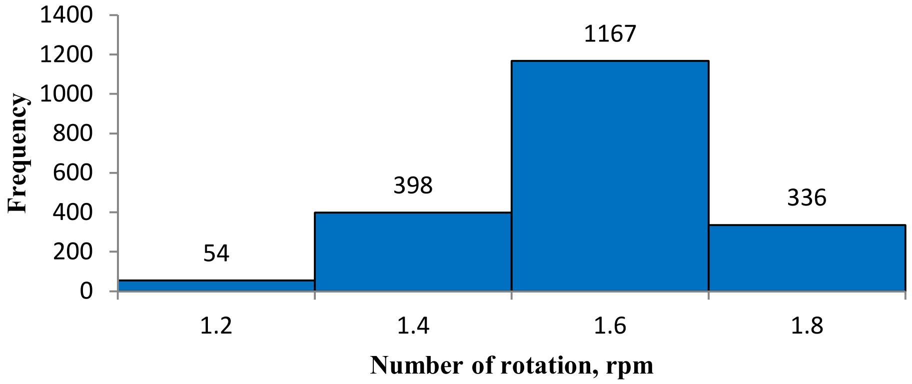

Figure 10. Number of rotation vacuum washers No. 3 for three months in 2022

3.6. Washer Outlet Consistency

Figures 11-13 show outlet consistency (pressure washer, vacuum washer No. 2, and No. 3). Washer performance is strongly dependent on the consistency achieved in the outlet pulp. Higher consistency means better drainage and lowers dissolved solids carryover.

Figure 11 shows the frequency of outlet consistency for the pressure washer and the result > 15% is a very good result for washing pulp on this type of equipment. Outlet consistency has the main effect on washing results and it depends on other parameters (DF, drum speed).

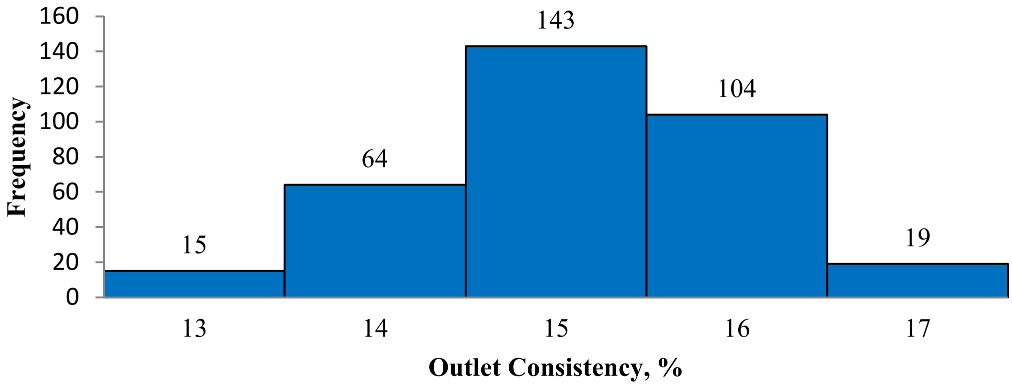

Figure 11. Outlet consistency (pressure washer) for three months in 2022

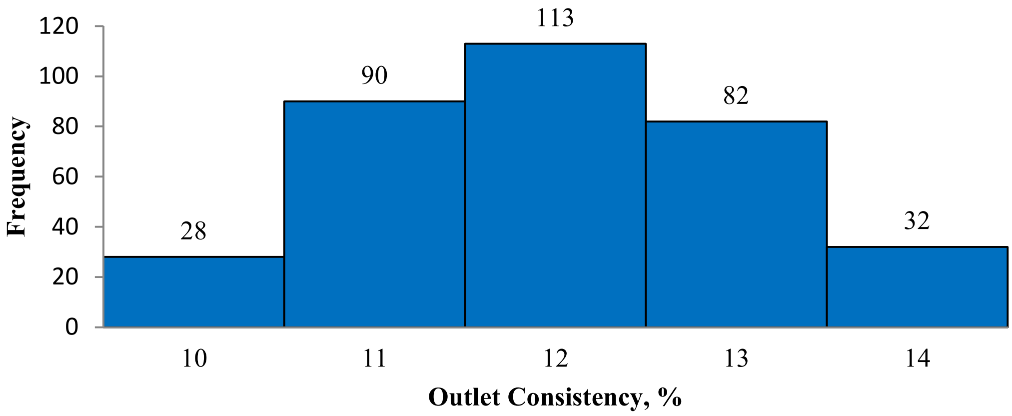

Figure 12. Outlet consistency (vacuum washer No. 2) for three months in 2022

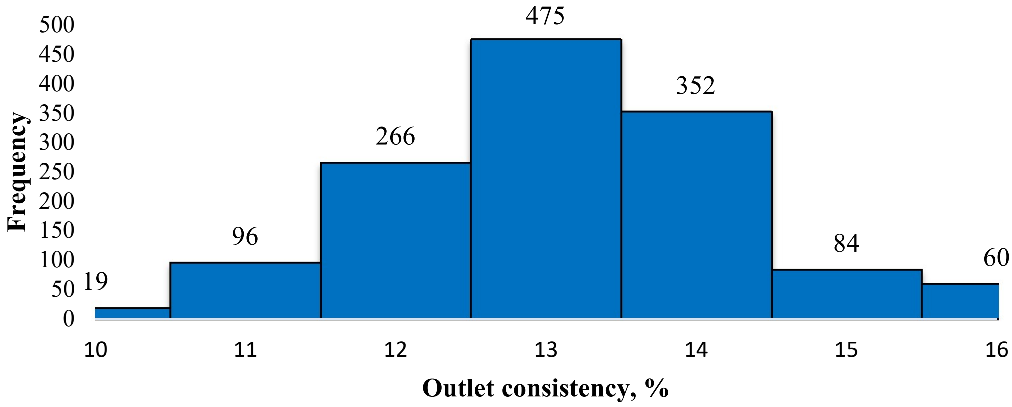

Figure 13. Outlet consistency (vacuum washer No. 3) for three months in 2022

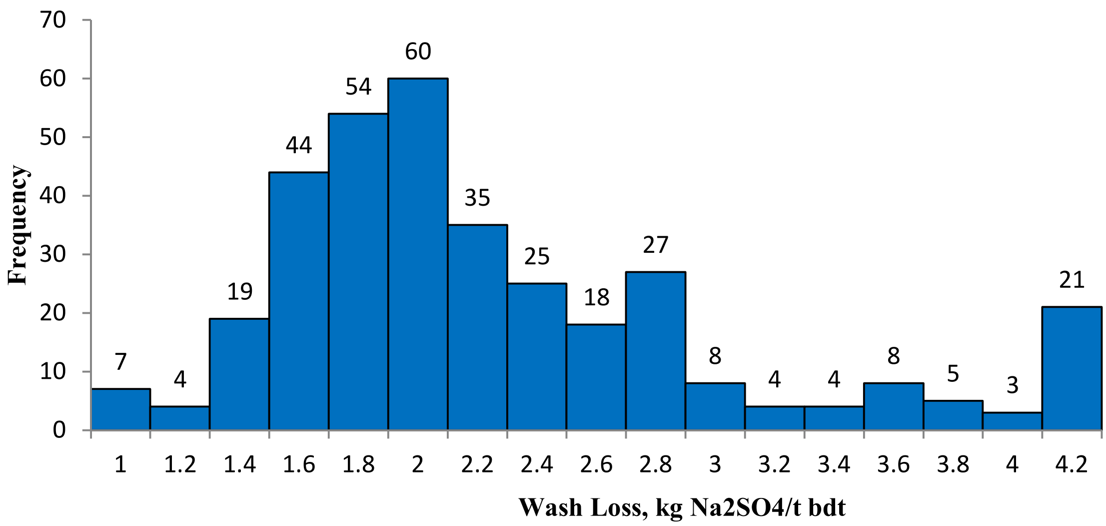

Figure 14. Wash loss (scan 37:98) for three months in 2022

Figure 12 shows the frequency of outlet consistency for vacuum washer No. 2 and consistency < 12% is not so good for this type of equipment. Figure 13 shows the frequency of outlet consistency for vacuum washer No. 3 and a consistency of 13% is a good and expected result for this type of equipment.

3.7. Wash loss

The Wash loss was measured every hour in the laboratory at Natron-Hayat. Wash loss is defined as the number of washable compounds in the pulp suspension which could have been removed in washing.

Figure 14 shows the amount of sodium in the pulp suspension after washing has typically been used as an indicator of wash loss, usually expressed as kg Na_2SO_4/oven-dry ton of washed pulp. From the Histogram, it is visible that 71% of very good pulp washing results but only 6% of results have a very significant negative impact on paper production. These results show good managed process brown stock washing with a high Kappa number.

4. CONCLUSION

The results obtained by experimental work showed that the process parameters did not affect or slightly affected the results of wash loss because they are guided and maintained by the technical standards of designed technological process equipment. It is completely satisfactory at all levels and complies with world standards for the given equipment. Because brown stock washing is one of the key aspects of a well-running integrated mill, reviewing and understanding brown stock washing fundamentals is important for all mill operations personnel. It is possible to affect and improve the carbon footprint of the product, partially the yield, chemical consumption (material efficiency), and water footprint (at least washing stages) by improving the washing efficiency.

Some optimum conditions for a rotary vacuum filter are:

- pH 9.5
- Temperature profile between 55-65 °C
- Rpm between 2.2-2.4
- Outlet consistency 13%
- The dilution factor is around 1.8

This results in low washing alkali loss between 1.8 and 2 kg $Na_2SO_4/t_{bdt.}$ This area is one of the key areas of improvement and investment thus ensuring technical efficiency of the overall pulp production process (washing efficiency, reduction of alkali loss, increase the quality pulp), improving environmental protection, improving the degree of regeneration chemicals, higher heat recovery, and ultimately affects the productivity, cost prices and profitability of the pulp mill. The results showed for this mixture of raw materials that the most influential parameters are Kappa number and dilution factor. Continuous working with a high Kappa number above 50 requires the addition of washing equipment. Online control of the dilution factor would further improve the quality of the washing process and provide additional saving water and savings at the Evaporation plant. The first step for the future to improve the washing of unbleached Kraft pulp is the optimization of the washing process through advanced control.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] R. Santos, and P. Hart, Brown Stock Washing –A Review of Literature, *Tappi Journal,* 13 (2014) 1, p. 9-19

[2] K. Gabov, *The effect of pulp washing on bleaching efficiency*, [Master´s thesis], Lappeenranta University Finland, Faculty of Technology, Lahti, 2009

[3] R. Kopra, E. Kari, M. Harinen, T. Tirri and D. Olli, Optimization of wash water usage in brown stock washing, *Tappi Journal,* (2011), p. 27-33

[4] V. K. Kukreja and J. Kumar, Rotary Brown Stock Pulp Washers through Mathematical Models -A Review, *Mathematical Theory and Modeling,* 2 (2012) 3, p. 43-51

[5] K. Koivula, *Improving the efficiency of brown stock washing line,* [Master´s thesis], Aalto University Finland, School of Chemical Technology, Espoo, 2014

[6] J. Kumar, V. K. Kukreja, Efficiency of Brown Stock Pulp washing in Liquid Properties. *International Journal of Engineering Science and Technology*, 3 (2011) 11, p. 8004 - 8011

[7] A. Mačković, *Uticaj procesnih parametara na gubitak alkalija u proizvodnji nebijeljene četinarske celuloze*, [magistarski rad], Tuzla, Tehnološki fakultet u Tuzli, 2016.

[8] B. D. Favis, J. M. Willis, D. A. I. Goring, High Temperature Leaching of Lignin From Unbleached Kraft Pulp Fibers, *Journal Wood Chemical Technology*, 3 (1983), p. 1–**7**