REVIEW OF BLEACHING IN PULP WASHING

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Washing in bleach plant is applied between bleaching stages. This process' primary goal is to eliminate inorganic (metals, salts, etc.) and soluble organic materials (lignin fragments, hemicelluloses, etc.). These dissolved elements may cause greater bleaching reagent consumption, decreased pulp brightness, or decreased pulp strength qualities, all of which could be detrimental to the subsequent bleaching stages. [1, 14] Furthermore, washing permits pH, temperature, and consistency adjustments for the subsequent bleaching phase [15].

1. Principles of washing

There are two basic principles in pulp washing:

1) Dilution/extraction washing
2) Displacement washing [1].

Figure 1 illustrates the dilution/extraction washing principle. First, wash liquor is added to the pulp suspension, which is then diluted and pressed or filtered to make it thicker. The quality of the wash water, the consistency following dilution and thickening, the degree of dissolved substance adsorption by fibers, and the amount of time required for desorption all influence how effective the washing is [16].

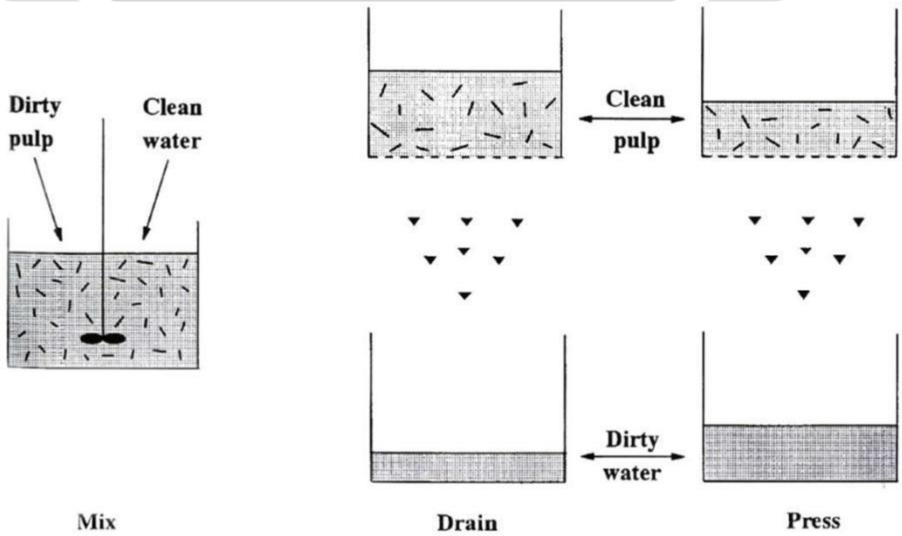

Figure 1. Schematic diagram of dilution/extraction washing [1].

Liquid from the unwashed pulp is substituted with wash liquor "in piston-like manner" (Figure 2) during the displacement washing process. In a perfect world, one volume of the liquor would be displaced in the pulp, eliminating any mixing between the displaced liquid and wash liquor. Because there is some mixing between the wash water and the displaced liquor in practice, as well as because the fibers absorb some dissolved chemicals, a clean displacement washing cannot be accomplished. The variables of temperature, displacing velocity, pulp pad thickness, and consistency all affect how effective displacement washing is. [1]

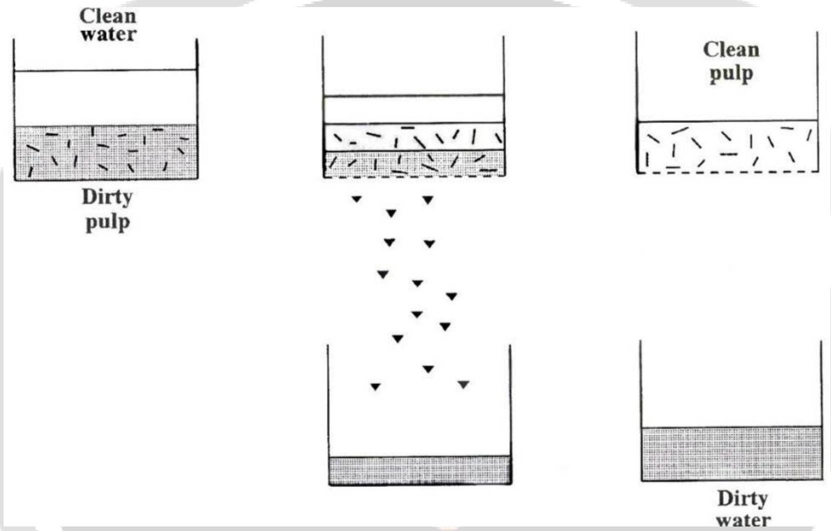

Figure 2. Schematic diagram of displacement washing [1].

High freeness pulps, like chemical pulps, can be cleaned by displacement washing since wash water can readily travel through them. In contrast, extraction/dilution washing is best suited for low freeness pulps (mechanical pulps and recycled fibers) because they form thick mats. [14]

Any pulp cleaning apparatus uses one or both of these procedures. Presses for chemical pulp washing, screw presses, and twin-wire presses for (chemi)-mechanical pulp washing are examples of industrial washers that exclusively use dilution/extraction. Pressure and atmospheric diffusion washers, vacuum drum filters, wash presses, and pressure washers like the Compaction Baffle filter (CBF) and Drum Displacement (DD) washer are examples of washers that combine the dilution/extraction and displacement washing processes. [1]

2. Washing parameters

There are several variables affecting washing: dilution factor, inlet and outlet consistency, pH, temperature, entrained air. All these parameters relate to process conditions. Parameters such as mechanical pressure, fluid pressure (or vacuum) and particular travelling speed are considered as equipment specific parameters. Sheet formation, wash liquor distribution and its quality also have effect on the washing process. In addition to all above mentioned factors, pulp characteristics also have to be considered, especially drainage and sorption behaviour. Not all of these variables can be adjusted, since some of them are peculiar to special process step or piece of equipment. Most of these parameters interact with each other and an improvement of one can differently affects other. [17, 18]

The following terms are used to describe a washing performance: dilution factor, wash and weight liquor ratios, wash yield, displacement ratio, modified (or standardized) Norden efficiency factor and equivalent displacement ratio. [1, 17]

The sketch of washer so-called "black box" is represented in Figure 3, it will be used to describe washing performance.

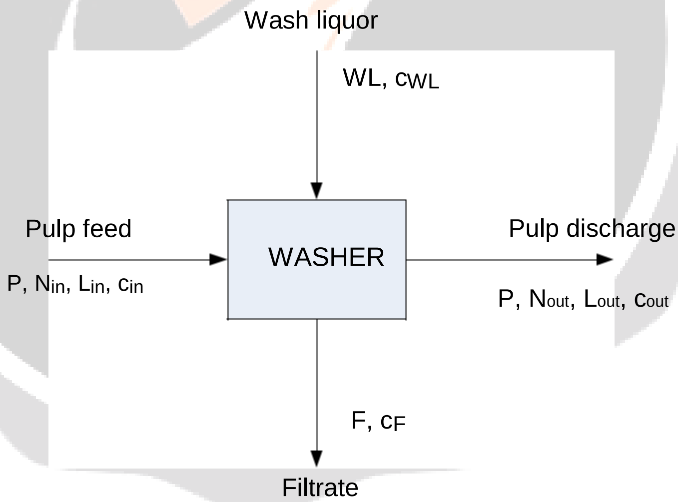

Figure 3. Schematic representation of washer [17].

The inlet and outlet pulp streams are described with such parameters as the amount of oven-dry pulp (P), consistency (N_{in} and N_{out}), corresponding amount of liquid accompanying the pulp (L_{in} and L_{out}) and concentration of solutes (c_{in} and c_{out}). The wash liquor and filtrate streams are characterized with the volumes (WL and F, respectively) and concentration of dissolved materials (c_{WL} and c_F).

Dilution factor can be written in the following form:

$$DF = \frac{WL - L_{out}}{P} \tag{1}$$

This term shows how much liquid is added to the pulp slurry above existing amount. Basically, the higher the dilution factor the better washing. On the other hand, the high value of dilution factor causes higher evaporation load in the case of brownstock washing and effluent volumes concerning the washing in bleaching. [17] Dilution factor can be negative if amount of applied wash water is less than that of liquid leaving washer with the pulp. DF equal to 0 tells that liquid in the pulp is substituted with the same amount of wash liquor. [16]

Wash liquor (R) and **weight liquor** (W) ratios:

$$R = WL/L_{out} \tag{2}$$

$$W = F/L_{in} \tag{3}$$

If the R value equals to 1 for the displacement washing the liquor in pulp is substituted with an equal volume of wash water. R and W are approximately the same if consistency stays unchanged through the washer. [16]

The **wash yield** (Y) is a ratio between the amount of solutes leaving a washer with filtrate (or removed from pulp) and amount of solutes coming to the washer with pulp slurry. This parameter presumes absence of substances in wash liquor.

$$Y = 1 - \frac{L_{out}c_{out}}{L_{in}c_{in}} = \frac{Fc_F}{L_{in}c_{in}} \tag{4}$$

It could be used as a way to evaluate washing efficiency, but due to the assumption it is inapplicable for most of mill’s cases. [17]

Displacement ratio (DR) shows the ratio between actual and maximum possible removal of the solutes assuming that pulp after washing can't be "cleaner" than wash liquor.

$$DR = \frac{c_{in} - c_{out}}{c_{in} - c_{wl}} \tag{5}$$

To compare different wash facilities with the term of displacement ratio dilution factor must be taken into account. [17]

The **Norden efficiency factor** (E) shows the number of ideal counter current mixing stages equivalent to a washer or washing system [1]. It can be calculated as follows:

$$E = \frac{\log\left(\frac{L_{in}}{L_{out}} \times \frac{c_{in} - c_F}{c_{out} - c_{wl}}\right)}{\log \frac{WL}{L_{out}}} \tag{6}$$

Standardized value considers the standard outlet consistency N_{std} and corresponding amount of liquid (L_{st}) accompanying discharged pulp; thus this parameter is independent of discharge consistency. The most frequently used standardized outlet consistency is 10% and after modification the equation will have the following form [17]:

$$E = \frac{\log\left(\frac{L_{in}}{L_{out}} \times \frac{c_{in} - c_F}{c_{out} - c_{wl}}\right)}{\log\left(1 + \frac{DF}{9}\right)} \tag{7}$$

The total efficiency of washing system can be calculated by summing the E_{std} of each stage [1].

Equivalent displacement ratio (EDR) enables to calculate washing efficiency for the hypothetical washer which has the same loss as an actual washer and operates at the same dilution factor. The loss is considered as a difference between the amount of solutes leaving washer with pulp and amount of solutes entering with wash liquor.

$$(1 - EDR) = (1 - DR)(DCF)(ICF) \tag{8}$$

Where DCF is discharge correction factor

$$DCF = \frac{B_{out}}{7.33} \tag{9}$$

And ICF-inlet correction factor

$$ICF = \frac{99(B_{in} + DF)}{B_{in}(99 + DF) - B_{out}(99 - B_{in})(1 - DR)} \quad (10)$$

B_{out} and B_{in} – discharge and inlet ratios of liquor to pulp, kg of liquor/kg of pulp:

$$B_{out} = \frac{100 - N_{out}}{N_{out}} \quad (11)$$

$$B_{in} = \frac{100 - N_{in}}{N_{in}} \quad (12)$$

The equivalent displacement ratio doesn’t depend on inlet and outlet consistencies. It shows a displacement ratio for the standard inlet consistency of 1 % and outlet consistency of 12 %. [19]

3. CONCLUSIONS

The conclusion of the bleaching process in the pulp and paper industry typically results in the transformation of raw pulp into a more refined, brighter, and higher-quality material suitable for producing a wide range of paper products. This process involves the removal of lignin and other impurities from the pulp, resulting in improved brightness, strength, and purity. Moreover, advancements in bleaching technologies have led to the adoption of more environmentally friendly methods, reducing the industry's environmental footprint. Overall, the conclusion of the bleaching process signifies the preparation of pulp for various papermaking applications, meeting quality standards and environmental regulations.

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