SHOULD WE BE REFINING FIRST, THEN DISCARDING FINES, THEN BLEACHING?

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Pulp fibers' bleaching technology has been developing mainly by applying increasingly intensive delignification in the cooking department and implementation of elemental-chlorine-free chemicals in the bleaching department. The resulting effluents load is still considerable, and the environmental consequences largely depend on the effectiveness of wastewater treatment. Now it is well established that pulp fibers' surface layers contain comparatively higher amounts of residual lignin, heteroaromatic compounds, and other lignin-like substances. Based on this knowledge an approach is proposed for consideration. As the pulp fibers' refining process also includes the peeling of fiber wall surface layers, it could be useful to perform such refining first, followed by appropriate screening techniques before the pulp bleaching. The main objection to this approach is related to efficient utilization of the fines, i.e., fractions of the surface layers.

Keywords: Pulp bleaching; Fiber surface layers; Lignin; Heteroaromatic compounds; Refining; Environmental impact

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Stark Challenges Face Bleaching Technology

Due to environmental and financial considerations the bleaching technology related to pulp fibers has been developing notably during recent decades. The implementation of oxygen delignification and extended cooking in the pulping department, introduction of new chemicals such as chlorine dioxide, ozone, and peracetic acid in the bleaching department, thickening of the fibers' suspensions to medium and high concentration in towers and connecting pumps, combined with efficient washing have improved the process considerably. It should be noted that modification of delignification is continuing by optimizing the cooking and oxygen delignification to a low lignin content in consideration of the environment, the pulp quality, and economics of the operation.

Despite this, pulp bleaching technology itself is not environmentally benign, and the effluent load still depends on the efficiency of wastewater treatment. It is supposed that further reduction of emissions will be very complex and will require costly measures. Finally, bleach plant liquid circulation closure is expensive and technically complicated. These considerations prompt the following question: Could we propose a distinct approach to deal more directly with this pulp and paper industry problem?

Evidence from Recent Research

Let us now turn to the data on pulp fiber submicroscopic structure and the composition of fiber wall layers, especially that of the surface material. Abundant results have been collected by hydromechanical, chemical, and enzymatic peeling methods, which provide the possibility to isolate and to analyze the residues of primary wall P and outer layer S_1 of the secondary wall. Novel instrumental methods such as X-ray Photoelectron Spectroscopy (XPS, ESCA), Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS), and Scanning Electron and Atomic Force Microscopy (SEM, AFM) confirm the assertion that unbleached pulp fibers' surface composition is considerably different from that of fiber wall main part.

Now it is well documented that surface layers of kraft pulp fibers contain comparatively higher amounts of residual lignin, hemicelluloses, and their products of conversion, including heteroaromatic compounds (olygofuranoids and oxypolysaccharides). Cellulose content has been shown to be lower in the surface layers, where it also has a lower degree of polymerization. Moreover, the concentration of metals and metal ions, requiring incorporation of a chelation stage, is found to be higher on the pulp fibers' surface. *In short, all evil is concentrated in one place …*

Taking into the account these realities, we have to conclude that the material of pulp fibers' surface requires higher specific consumption of bleaching chemicals. And it is not unlikely that certain delignification reactions in the surface layers and in the main part of fiber wall differ. Thus, possibly also the contribution of these reactions' products to effluent pollution is out of proportion. Is it feasible to release the fibers from the *malicious* surface layers before bleaching? The answer is positive: it can be done by controlled refining of fibers, as an element of this process is the peeling of the surface material. Then, after the discarding of the fines by appropriate existing screening techniques, the bleaching of the *open* main part of fibers follows.

A Historical Note

It is surprising to recall that in the *old times*, meaning the 18th and 19th centuries, after the invention of "Hollander" type equipment for milling of fibers from rags and wood, the machine was used also for bleaching of fibers with chlorine-containing chemicals. In addition, old Hollander beaters often were equipped with dewatering devices, which would be expected to remove some fines, along with the filtrate. In this way the manufacturers, probably without intending to do so, partly got rid of the fibers' surface material and opened the main part of the fiber wall for a more efficient bleaching process. It should be noted here that sometimes the new is a well-forgotten old idea.

To Answer the Title Question

In light of these reflections, the answer to the title question (Should we be refining first, then discarding the fines, then bleaching?) could be "yes"… and also "no". The main objection to such a procedure is related to the considerable loss of fibers' material, maybe up to 5-8%. Can we find an alternative way to use the discarded material from the fiber wall surfaces? I suppose this is not an easy task. The problem may be solved if instead of just a pulp mill we operate a biorefinery, generating a variety of products of carbohydrate or aromatic nature.