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Preliminary techno-economic assessment of recovering water and caustic soda from alkaline bleach plant effluent

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ABSTRACT

Increasingly stringent environmental regulations and increasing input costs negatively affects the sustainability and competitiveness of the pulp and paper industry. As a result, it has become necessary that broader strategies aimed at helping the industry to improve the environment performance whilst also reducing the operation costs are initiated. Recovering water and chemical from the bleach plant effluent streams could be one of such initiatives. In this paper, a preliminary techno-economic assessment of recovering water and caustic soda from alkaline bleach plant effluent using ultrafiltration and reverse osmosis membrane systems is presented. The scope of this work included; assessing the practicality and the economic performance of this membrane process. In terms of the practicality, the data acquired revealed that the proposed concept can only be applied to the alkaline effluents from the alkaline extraction stage, where caustic soda, oxygen, and peroxide are used as the pulp bleaching chemicals. Economic performance of this membrane system, however, is dependent on the effluent flow rates and the amount of water recovered. To be economically viable, the flow rates must higher than 480 m^3/day and water recovery rate need to be higher than 70%. At this optimum effluent flow and water recovery rates, the process cost is approximately R 19/m^3. Depending on the flow rates, the investment cost is in the range of R 5–25 million and the payback time is between 3 and 4 years. However, motivations of caustic recovery should be based on environmental rather than economic benefits. Mills can use the detailed information/data acquired in this study to determine whether it would be beneficial for them to implement this type of integrated waste management strategy in their processes.

1. Introduction

Increasingly stringent environmental regulations and increasing chemical costs used in the bleach plant are creating a need for novel technologies for recovering water and chemicals from the bleach plant effluent streams (Johnson et al., 2014; Nordin and Jonson, 2006). This presents an opportunity for pulp mills to lower their operating costs whilst also reducing the environmental impacts. Pulp mills producing bleached pulps consume relatively large amounts of water and chemicals, and discharge effluents loaded with toxic substances than pulp mills producing unbleached pulps. Therefore, it is reasonable that any efforts of water and waste water management in this industry should be focused on bleached pulp mills.

Impacts of the bleaching process on water usage and the environment depend largely on pulping and washing processes used (Johnson et al., 2014). The pulping process is employed to reduce the amount of lignin present in the wood materials, whereas pulp washing is used to wash and displace the spent cooking liquor from the pulp suspension prior and after pulp bleaching (Christensen, 1998). During pulp production, the higher the lignin contents that remain in pulps, the higher the amount of the bleaching chemicals used in the subsequent pulp bleaching process. Subsequently, to displace the spent liquor from bleached pulp suspension, large volumes of water are necessary that also lead to a large volume of effluent loaded with toxic substances being discharged (Christensen, 1998). Similarly, poor pulp washing can lead to more carryover of the dissolved organics to the bleach plant. As a result, more bleaching chemicals can be required to bleach the pulp to the desired pulp quality. This also increases the demand for water and leads to discharge of large volumes of the bleach plant effluent.

In efforts to minimise water usage and/or mitigate

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environmental impacts in these pulp mills, various strategies for modifying the chemical pulping, pulp washing and bleaching processes have been proposed. For example, chemical pulping followed by oxygen delignification stage (extended delignification) has been employed as a means of producing pulp with lower lignin content (Christensen, 1998). In this practice, the amount of lignin remaining in pulp after digesting the wood is significantly reduced. This implies that the amount of bleaching chemicals used in the subsequent process have to be reduced. Consequently, the volume of the bleach effluent and its toxicity is reduced. Furthermore, conventional bleaching with elemental chlorine has been replaced either with elemental chlorine free (ECF) or with totally chlorine free bleaching (TCF).

Despite all these efforts, water system closure in these pulp mills has not been fully realised. For example, although most of the South African mills have adopted the afore-mentioned technologies, still the effluents from their bleach plants are not reused, and instead, are discharged into the environment. New environmental legislation prohibiting this practice not only in South Africa but even also in another part of the world will in future be implemented.

In efforts to maximisize the water system closure in the bleaching plant effluent systems, previous studies have explored the possibility of treating the alkaline bleach plant effluents. For example, Quezada et al. (2014) tested the effectiveness of the tubular membrane on treating alkaline bleach pant effluent. They successfully demonstrated that when the alkaline effluents are pre-treated using ultrafiltration membrane, a significant reduction in colour, BOD as well as COD can be achieved. This also resulted in improvement of the traditional waste water treatment process efficiency. Similar findings have also been reported by Falth (2000) and Meuller et al. (2003). Besides membrane filtration method, adsorption technology is also considered as a promising alternative because of its ability in removing micro pollutants (Gupta et al., 2013). In particular, when there is a need for recovering valuable chemicals, polymeric adsorbents can be applied (Zang and Chung, 2001). A combination of membrane filtration and adsorption could also be an interesting alternative (Jain et al., 2009). For example, the application of the adsorption process steps prior membrane can help to reduce pollutant load and subsequently in the next process step the membrane fouling problems can be minimised or avoided. However, in these studies water and caustic soda recovery were not attempted. Furthermore, it appears that these studies they were more interested in using the membrane filtration method either as a pre-treatment process step or as water polishing process step so as to enhance the performance of the traditional waste water treatment processes (Bodalo-Santoyo at el., 2003; Quezada et al., 2014). Nevertheless, there are limited data that could be used for justification of the economic performance of these membrane systems. It was, therefore thought that it would be very interesting to perform a preliminary techno-economic assessment of recovering both water and caustic soda from that alkaline effluents from the alkaline extraction stage, where caustic soda, oxygen, and peroxide (EOP) are applied as pulp bleaching chemicals. Furthermore, water resource is increasingly becoming scarce in South Africa, therefore the rationale for treating and recycling the EOP effluent is based on the need for maximising water system closure in the South African pulp mills. When the chemicals are recovered and reused the amount of the chemicals purchased or processed at the mills will consequently be reduced, leading to savings in chemical costs. Likewise, in the bleach plant, the total volume of waste water discharged to the environment will be reduced. The mills could use such information/data to determine whether it would be beneficial to implement such an integrated waste management strategy in their mills. A membrane filtration method was preferred over adsorption method not necessarily that adsorption methods are inferior but rather than the fact that the South African pulp mills have a specific interest in the method. This is based on industrial experience at their pulp and mills in which they are using the membrane method, but for different waste water treatment strategies.

2. Material and methods

2.1. An insight of the bleach effluent systems in the South African pulp mills

Current practice at the reference mills is that the alkaline effluent streams are mixed with acidic effluent streams and thereafter the resulting effluent is either discharged into the sea or is used for land irrigation (Fig. 1). In particular, the problem with land irrigation practice is that the mixed effluent stream becomes highly loaded with sodium salts (Subramanian et al., 2013). Subsequently, the soil quality has been adversely affected. In the proposed concept (Fig. 2), the UF-OR membrane systems are applied to recover the concentrate that is rich in caustic soda and at the same time the water also recovered from the EOP effluents. This could lead to better management of the water resource through maximising water system closure in the bleach plant effluent systems, for example in the South African pulp mills. However, in most mills, adoption of this strategy will require modification of existing effluent handling systems to allow segregation of bleach plant effluent streams. This is because when the various effluent streams are mixed, the resulting effluent may have a chemical composition that can interfere with the quality of sodium salts and/or may complicate its recovery. Furthermore, chemical species formed after mixing these effluents are not known and may have a negative effect on the membrane filtration. As you will see later, caustic soda recovered (concentrate) is proposed to be used in the chemical recovery loop, as a make-up of the weak white liquor traditionally used in the production of green liquor (dissolving the smelt recovered from the recovery boiler). Due to the high quality of the water recovered, this water may be used as boiler feed water.

Upon completion of the initial evaluation of the practicality and the potential economic performance, a suitable configuration of the membrane filtration process was recommended for the experimental work. This work is currently in progress and the result will be published elsewhere.

2.2. EOP effluent samples

The EOP effluent samples were acquired from one of the local pulp mills. The EOP effluent at this mill is pre-treated through neutralisation using acidic effluent streams and thereafter the resulting effluent is discharged into the environment.

2.3. Characterisation of the EOP effluent

The total dissolved solids were determined gravimetrically according to standard method APHA 2540. The total suspended solids were determined gravimetrically as described in the standard method APHA 2540 D. The total solids were determined gravimetrically according to the standard method APHA 2540 B. The content of dissolved and colloidal substances were measured using the method adapted from Jidong et al. (2011). The COD was measured using the ASTM D 1252-00 standard method. The turbidity was measured using a HACH 2100P turbidity meter according to the standard method APHA 2130. Chlorides in the samples were determined using the ASTM D 512-89 standard method. The concentration of aluminum (Al), magnesium (Mg), and iron (Fe) were determined by inductively-coupled plasma