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Research Article

Experimental Studies on Xylanase Bleaching of Kraft Pulp

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ABSTRACT

Paper pulp bleaching plants using elemental chlorine produced large quantities of dioxins. Dioxins are the organic pollutants that are mostly toxic human-released pollutants in the atmosphere. Dioxins are highly toxic pollutants, which cause a lot of health effects on human's reproductive, developmental, immune and hormonal problems. Dioxins easily reach the human beings through food, as dioxins accumulate in the food chain in the fatty tissue of animals. Elemental chlorine bleaching has been largely replaced by chlorine dioxide and the formation of dioxin is reduced. ECF (Elemental Chlorine Free) bleaching reduces the amount of chlorinated compounds but not fully eliminating from the effluent. The cost of replacement of new technology for the pollution control in pulp and paper industry is generally high. For this reason the pulp and paper industries follow the old bleaching techniques which cause a lot of environmental problems. To overcome this problem in a cost-effective way it is necessary to identify the nature of the problem and compounds that cause human health and environmental problems. At present bio-bleaching of kraft pulp gives better result than ECF bleaching. In the present study three different bleaching sequences are studied $ODoPD_1$, P_1P_2H, and XP_1P_2D and the results are compared, based on physical and chemical properties. In ECF bleaching sequence $ODoPD_1$, the amount of residual chlorine present in waste water is 110ppm which contains significant amount of dioxins. To reduce this amount, replace chlorine dioxide stage (Do) with enzymatic bleaching (X). In this sequence XP_1P_2D, the addition chlorine dioxide is reduced to 1.2% and the amount of residual chlorine is 10ppm.

Keywords: ECF bleaching; Kappa number; Brightness; Enzyme bleaching; Xylanase; Kraft pulp.

1. INTRODUCTION:

In the present study also a solution for the causes of paper industry effluents. This is an opportunity to replace the biological methods in the paper industry instead of chlorine chemicals. Other benefit includes the reduction of energy consumption, reduction of bleaching costs and preservation of the environment.

The major components of wood are cellulose, hemicellulose and lignin. The concentrations of these three components are approximately 50% cellulose, 25% hemicellulose and 25% lignin. Cellulose is a very long linear molecule containing repeating glucose units. Hydrogen bonding takes place between linear molecules to form a strong microcrystalline structure to cellulose. Cellulose is not easily affected by bacteria and moulds, because of the protective layers of hemicelluloses and lignin. Hemicellulose consists of a random arrangement of five-carbon sugars. Hemicellulose forms chemical bond with the next layer, lignin, and it acts as a chemical bonding agent between cellulose and lignin molecules.

Lignin consists of three phenol-based building blocks that polymerize completely in a random manner. This random structure is very difficult to degrade during pulping and bleaching. The aromatic content of lignin, i.e., monomeric phenol, is approximately 51%. It is the phenolic compounds are released from lignin during the chlorine bleaching of kraft pulps

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that are responsible for a large amount of the toxic compounds released in pulp mill effluents.

In kraft pulp bleaching, approximately 1 kg of extractives, 19 kg of polysaccharides, and 50 kg of lignin are dissolved from 1tonne of pulp. Chlorine can react with these organic wastes to produce organochlorine compounds, the reactions take place with lignin is simple but most toxic monoaromatic compounds are formed.TCF (Totally Chlorine Free) bleaching in pulp and paper mill reduces the chlorinated organic compounds in the effluent.

Table 1.1: Commonly applied chemical treatments in bleaching

Treatment	Abbreviation	Description
Chlorination	C	Reaction with elemental chlorine in acidic medium
Hypochlorite	H	Reaction with Hypochlorite in alkaline medium
Chlorine dioxide	D	Reaction with Chlorine dioxide
Enzyme	X	Reaction with enzyme
Oxygen	O	Reaction with molecular oxygen at high pressure in alkaline medium
Extraction with oxygen	EO	Alkaline Extraction with oxygen
Hydrogen Peroxide	P	Reaction with Hydrogen peroxide in alkaline medium
Chelating Agents	Q	Reaction with chelating agent EDTA in acidic medium for removal of metals
Ozone	Z	Ozone using gaseous ozone

2. MATERIALS AND METHODS

2.1 Pulp preparation:

The objective of Kraft pulping is to chemically separate the fibers in wood and dissolve most of the lignin contained in the fiber wall. In Kraft pulping process, a mixture of sodium sulfide (Na_2S) and sodium hydroxide (NaOH) is used to cooking the wood.

2.2 Pulp bleaching procedure:

Bleaching is a chemical process to increase the brightness of the pulp and to make it suitable for the manufacture of printing and tissue grade papers by removal or modification of some of the constituents of the unbleached pulp, including the lignin and its degradation products. The bleaching reactions that occur are highly complex due to the complexity of lignin and the wide variety of reactive bleaching species present in the wood. The progress of bleaching reactions is monitored by measuring Kappa number, pulp brightness and residual chemical present in the pulp. Bleaching chemicals are applied sequentially with intermediate washing between stages, because it is not possible to achieve sufficient removal or decolorization of lignin.

The pulp, as received, has a kappa number of 21.8, brightness 29.5% and 31% consistency are submitted to three different types of bleaching sequences. ECF bleaching- $ODoPD_1$, Hypochlorite bleaching P_1P_2H, and Enzyme bleaching XP_1P_2D. The experimental conditions are fixed according to literature data and the lab experiments conducted in SPB Ltd.

The bleaching experiments are carried out on small batches equivalent to 100 gm Oven dry pulp and bleaching chemicals in water tight polythene bags and the reaction time is 60min. These bleaching sequences are done in stages, using chlorine dioxide (D), hydrogen peroxide (P), extraction with oxygen and peroxide (Eop), hypochlorite (H), oxygen (O) and enzyme(X).The reaction temperature is maintained by immersing the polythene bags containing pulp and added bleaching chemicals in water bath.

Oxygen delignification of Kraft pulp is carried out in laboratory digester under the following conditions: pulp sample 100gm, caustic addition 10 %, oxygen addition 10 kg/cm^2, kappa number 21.8, brightness 29.5.

The enzymatic treatment of the kraft pulp is made with the commercial xylanase: Novozyme. After completion of each bleaching stages, the pulp and black liquor will be separated by manual squeezing method. The pulp is thoroughly washed with fresh water and it is called bleached pulp. The bleached pulp obtained is evaluated for the following properties Consistency, Kappa number, Brightness and Strength properties.

Table 2.1: Bleaching condition of Kraft pulp

Parameter	Unit	$ODoPD_1$				P_1P_2H			XP_1P_2D			
		O	Do	P	D_1	P_1	P_2	H	X	P_1	P_2	D
Oxygen(O) addition	kg/cm^2	10										
ClO_2	%		1.2		0.8						0.8	
Hydrogen peroxide	%			1.2		1	0.8		1	0.8		
Hypo addition	%							1.2				
Enzyme	%								0.03			

3. RESULT AND DISCUSSION:

The use of xylanase enzyme in paper pulp bleaching reduces the consumption of bleaching chemicals, especially ClO_2, saved a large amount of electricity, which in turn reduced the contribution to global warming and other energy-related impacts.

Lignin removal is a time and energy consuming process. Novozyme process is known as bleach boosting offers an effective bleaching alternative. Novozyme is a xylanase enzyme. The characteristics of the pulp bleached accordingly to the different bleaching sequences will now be discussed, highlighting the influence and advantages of the bleaching process.

After completion of each bleaching stages the bleached pulp suspension was filtered through a buchner vacuum funnel for the preparation of hand sheet and air dried for 24 h . The hand sheets are used to measure the brightness, kappa number and strength properties of pulp using TAPPI standard test methods. The filtrate analysis of pulp i.e., residual alkali, residual chlorine and residual peroxide are measured from the general titration methods.

The quality of paper is mainly focused on the strength properties of paper. In the above bleaching sequences, elemental chlorine free bleaching sequence $ODoEopD_1$ having good strength properties but the consumption of chlorine dioxide is high.

In the enzyme bleaching sequence (XP_1P_2D), the final chlorine dioxide stage was introduced to increase the brightness of pulp. This concept is observed from the work performed by Graca et al, (2008). This work has thoroughly analyzed the D_1 and the final P stage ($DoEopD_1$) in terms of the effect of chromophore content on final peroxide bleaching performance compared with chlorine dioxide bleaching. The best choice for completing that particular ECF sequence is to push chlorine dioxide bleaching action in D_1 until at least 87% ISO brightness is reached.

Pratima Bajpai et al, (2006) investigated that, Enzymes improve ECF bleaching of eucalyptus Kraft pulp. ECF bleaching of laccase and xylanase-laccase treated pulps was conducted by using a DEpD sequence. In this work xylanase- laccase enzymes are used only in the pre-bleaching stages after that ECF sequence continued. In comparison with our work novozyme is used directly in the bleaching sequence and reduces the chlorinedioxide consumption in the early stage of bleaching, it reduces cost of chlorine dioxide and AOX content in the effluent at the same time the final brightness 82.3% is achieved.

Ashit et al (2000) also studied that, Use of an extremely high specific activity xylanase in ECF and TCF pulp bleaching. He could be achieved higher brightness 90% from the pulp treated with the xylanase ECF bleaching (OXDP) and TCF bleaching sequence (OXZP).To achieve 90% brightness with TCF sequence and avoid the formation of AOX in the present study to replace the final chlorine dioxide stage by enzymes and chelating agent.

Table 3.1: Comparison of sequences based on the brightness and kappa number of bleached pulp

Bleaching sequence	$ODoPD_1$	P_1P_2H	XP_1P_2D
Brightness (%)	83.9	79.7	82.3
Kappa number	2.5	3	2.3
Residual Chlorine	80	35	-

Table 3.2: Physical strength properties of bleached pulp under $ODoPD_{1,}$ P_1P_2H, XP_1P_2D sequences

Bleaching sequence	Bulk (cc/g)	Burst Factor	Tear Factor	Breaking length (m)
$ODoEopD_1$	1.65	43	83	6300
P_1P_2H	1.52	34	56	5200
XP_1P_2D	1.56	37	68	6100

From these experimental results ECF sequence $ODoPD_1$ produces significant results. These increase brightness and reduce kappa number but this sequence employs two chemicals (i.e ClO_2 and H_2O_2) of relatively high cost, also the formation of residual chlorine is 80ppm. It is also observed that enzyme treatment (XP_1P_2D) prior to chemical bleaching of kraft pulps allow a significant decrease in the consumption of chlorine dioxide and allow higher brightness (82.3%) to be reached.

4. CONCLUSION:

This study summarizes enzymatic bleaching of ECF sequence which gives better results than TCF sequence. This is newly developed ECF sequence and it is easily an adaptable sequence to paper industries. In industrial scale MC pump is required to pump enzyme to the reactor, this is the only cost factor. Implementing this enzymatic bleaching in place of conventional ECF bleaching reduces the formation AOX and consumption of chlorine dioxide. In future work to replace the final chlorine dioxide stage D by enzymatic bleaching X_1 and Hydrogen peroxide P_1 by oxygen O ($OXPX_1$), in this combination totally eliminate chlorine dioxide stage in enzyme bleaching.

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