



Physicochemical Parameters and Purification of Pulp Effluent (Black Liquor)

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Abstract

Pulp and paper Industry poses a great significant problem in Environmental pollution and they consume high energy, water and resources. The present study was undertaken to purify pulp effluent (black liquor) using sand bed filters and adsorption method (Activated Carbon). The physicochemical parameters carried out were pH, colour, temperature, turbidity, total alkalinity (TA), total hardness (TH), chemical oxygen demand (COD), total suspended solids (TSS), total solids (TS) and total dissolved solids (TDS) using standard methods by American Public Health Association (APHA). The results obtained for black liquor and treated effluent were; colour (dark brown), pH (11.59 & 9.14), temperature (31°C & 30 °C), turbidity (1.78 & 0.77 NTU), TA (10,000mg/L & 300mg/L), TH (325 mg/L & 220 mg/L), COD (2663 mg/L & 174.85 mg/L), TSS (0.09 mg/L & 0.00 mg/L), TS (0.9 mg/L & 0.17 mg/L), TDS (1354 mg/L) respectively. Highly significant differences were found between the effluent and treated water. The results indicated that pulp and paper Industrial effluents are highly polluted and can be toxic or harmful to human beings when released into water bodies without being treated.

Keywords: Pulp effluent (black liquor), Sand bed filters, Activated Carbon, Physicochemical parameters, APHA

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1 Introduction

The use of wood to make paper is a known process and Nigeria is the only country in West Africa known for the production of pulp and paper, yielding only 6% of the sub region's total paper products consumption [1]. Apparently, all the other countries in the sub-region depend on

imports to meet their domestic needs on printing and writing paper products, newsprint and other paperboard products [2]. The dominance by small to medium enterprises (SMEs), most of which operate in the informal sector, coupled with the use of obsolete equipment and low recovery rate remain the

problem in the wood-processing sector in the sub-region [3]. It was declared by Food and Agricultural Organization [4], that Nigeria has about 1000 wood-processing units (sawmills and units producing panels and matches, and three paper factories. Low value addition of these plants resources has remained a major feature of African's wood production as majority of the wood produced in Africa is used as fuel [4]. In 2000, Africa's share of global wood fuel was 30%. On the other hand, the global contribution of the value added biomass like wood-based panels, sawn wood, fiber boards and paper and paperboard products was only 1.1, 1.8, 0.7 and 0.9% respectively [4].

The Pulp and Paper Industry has been noted to be energy, water, resources intensive and the sixth largest industry causing pollution to the environment and water bodies. It generates as low as 1.5m³ of effluent/tonne of paper [5]. This effluent (black liquor) contains high concentration of lignin giving its brown coloration, high COD, TDS, suspended solids, turbidity etc. The brown color is due to the complex organic compounds like tannins, cellulose, phenolic compounds and inorganic compounds like sodium, & sulphur compounds [5]. There are two components of wood: Cellulose and Lignin. Cellulose is the fibrous component of wood, been used to make Pulp and Paper. Lignin is the glue that joins wood fibers together [6].

Pulping is the process of reducing wood to a fibrous material by separating the cellulose from the lignin [6]. The effluent or waste water generated is called black liquor. Pulping process usually can be categorized into chemical, mechanical, or semi-chemical. These three chemical pulping methods are known as Kraft, sulphite and soda. The kraft and sulphite process are the most commonly used method [6]. The waste water generated is almost equal to the same quantity of water consumed. The high increased in the volume of effluent and the economic constraints make paper industries to restrict themselves to treat the waste water, where the quality of effluent comes within the norms of pollution control boards and other authorities [7]. The release of this effluent to water bodies is toxic to aquatic animals [8], and this necessitates the need to develop a waste water purification technology which is economical and efficient. There are various

physical, chemical and biological methods been used to purify paper and pulp effluents such as Sedimentation, Chemical precipitation, Chemical flocculation process [9], membrane filtration, floatation, adsorption, aerobic and anaerobic treatment [10].

All of these treatment processes are quite expensive to build, maintain, operate and require skilled [11]. However, an alternative method is being used; adsorption method using adsorbent materials like carbonaceous waste material which can be converted into activated carbon [12].

Activated carbon is an important chemical adsorbent. It is used in various industrial applications due to its large surface area together with surface chemical structure. One of its commonly used importance is in the removal of toxic pollutants like phenols and phenol derivatives [13], which has been carried out by various researchers using this method [14], [15].

This study was aimed at purifying an effluent from pulp also known as black liquor and determining the physicochemical parameters of the untreated and treated effluent and these properties include total dissolved solids, total hardness, total alkalinity, pH, turbidity, total suspended solids etc.

2 Materials and Methods

2.1 Wood sample, waste water collection and Analysis

The wood sample (palm kernel frond) was collected from Babcock University, Horticultural garden. This wood sample was dried and later subjected to Kraft pulping process. Thereafter, the effluent was collected in a cleaned 25 Liter keg and was taken to the laboratory for analysis. pH, temperature, color, total solids (TS), total dissolved solids (TDS), total suspended solids (TSS) etc. were determined by standard methods [16]. The pH and temperature were determined using a well calibrated pH meter and thermometer, respectively. The total hardness and chemical oxygen demand (COD) were determined using titrimetric methods while TDS and TSS were determined using gravimetric methods

2.2 Sand bed filtration

The sharp sand and gravel of different grades used for the purification process were collected from Babcock University, construction sites. The sharp sands and gravel were sorted to remove dirt and was washed thoroughly with distilled water till clear water appeared.

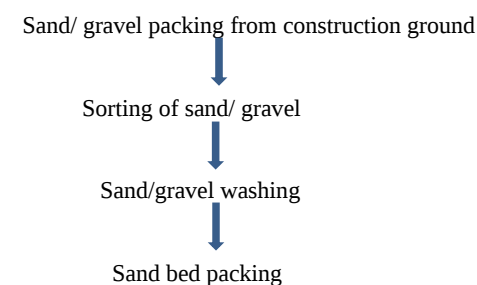


Figure 1: Flow chart of sand bed packing

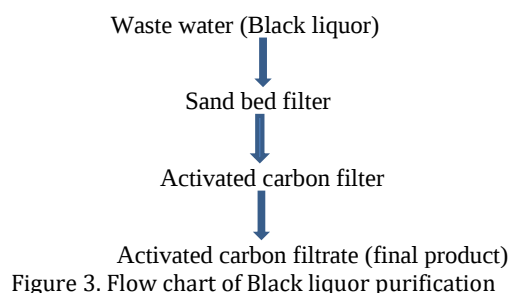


Figure 3. Flow chart of Black liquor purification



Plate 1. Treated Activated Carbon Charcoal

2.3 Preparation of Activated Carbon

The activated carbon was prepared from wood charcoal using the following processes.

1. **Miller:** The samples were cut into small pieces using mortar and pestle and were sieved through a sieve with pore size of 0.25mm.
2. **Treatment:** The sieved samples were treated by boiling with 0.1M NaOH
3. **Washing and drying:** The samples were washed with 2% HCl (v/v) and then with distilled water to remove any activating agent. It was then dried at 110°C. The dried samples were transferred into a container for purification process.

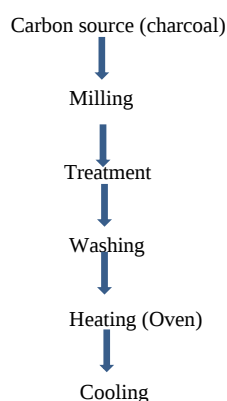


Figure 2. Flow chart of charcoal treatment

3 Results and Discussion

3.1 Colour

Color is usually the first and obvious contaminant to be seen in waste water and this affects water transparency and the gas solubility of water bodies [7]. The colour of the effluent mainly arises owing to the presence of low and high molecular weight chlorinated organic compound generated from the lignin degradation product which are produced during different stages like pulping, bleaching and alkali extraction [17]. The color of the effluent was dark brown and after treatment, it reduced to a clearer liquid. Similarly, most workers have reported the colour of the discharged effluent has dark brown to light color [18], [19].

3.2 pH

pH is an important parameter in water body, it measures the acidity or alkalinity of water and is one of the stable measurements. It measures the hydrogen ion concentration of the waste water. The pH of the effluent and treated sample was found to be 11.59 and 9.0 respectively. The untreated effluent pH was far higher than WHO recommended value. However, the purified effluent has a pH value of

9.0 (alkaline) which is still within the pH tolerance limit of 6-9 recommended by WHO [20] and ISI standard [21]. The alkalinity of the

effluent was because of chemicals used during the pulping process and these chemicals hydrogen peroxide, caustic soda [17].

Table 1. Physicochemical parameters of effluents, treated water and control

Parameters	Sample A	Sample B	Control	WHO (HDL)	WHO (MPL)	ISI (PL)	ISI (EL)
Colour	Dark Brown	Light brown	Colourless	...	....	.....	....
Odour	Unpleasant	odourless	Odourless	.....	....	.....	....
pH	11.59	9.0	5.82	6.5-8.5	No relaxation	6.5-8.5	6.5-9.2
Temperature (°C)	31	30	29	.....	.....	.....	.....
Turbidity(NTU)	1.78	0.77	0.00	5	.....	10	.....
TH (ppm as CaCO ₃)	325	220	76	300	600	300	600
TA (mg/L)	10000	300	110	200	600	.....	.....
TSS (mg/L)	0.09	0.00	0.00	.....	.....	100	----
TS (mg/L)	0.90	0.17	0.00	.....	.....	.....	----
TDS (mg/L)	1354	1343	0.00	2000	----	2100	----
COD (mg/L)	2663	175	100	1000	----	.....	----

SAMPLE A- untreated (Black liquor); SAMPLE B- treated water; SAMPLE C- Table water (control); TH-Total Hardness; TS- Total Solids; TSS- Total Suspended Solids; TDS- Total Dissolved Solids; COD- Chemical Oxygen Demand; TA- Total Alkalinity; WHO- World Health Organization, ISI- Indian Standard for water; HDL: Highest Desirable Limit, MPL: Maximum Permissible, PL: Permissible Limit, EL: Excessive Limit.

3.3 Temperature

Temperature is basically an important factor for its effect on other properties of waste water. The temperature of the black liquor and purified sample was 31 and 30 respectively. These values are within WHO recommended value.

3.4 Turbidity

Turbidity reflects water transparency and it is an important parameter for accessing the quality of water. The turbidity values for the effluent and its treated form were 1.78 and 0.77 NTU respectively which were within WHO standard of 5 NTU and ISI standard of 10 NTU

3.5 Total Hardness

The hardness of water is caused by the presence of calcium and magnesium. The total hardness obtained for the untreated and treated effluents were 325 ppm and 220 ppm as CaCO₃ respectively. These values were lower than those obtained by Saravana *et al.* (2014) [22]. However, they were within the permissible limits of WHO and ISI

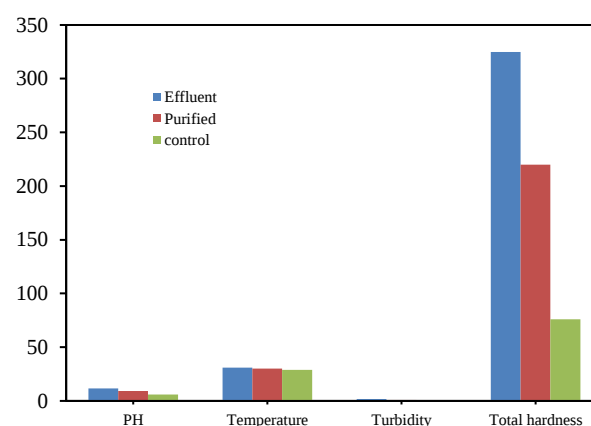


Figure 4. Graph of pH, temperature, turbidity, and total hardness

3.6 Total Solids

This parameter affects the clarity of water. The higher the solids, the lower the light that will pass through the water and this slows down photosynthetic process. The total solids in this study were greatly low, far lower than those reported by Saravana *et al.* (2014) [22]

3.7 Total Suspended Solids

These are portion of waste water that contains un-dissolved suspended materials. These solids can reduce photosynthetic work. There was no suspended solid observed in the effluent.

3.8 Total Dissolved Solids

The measurement of organic matter, inorganic salts and other materials dissolved in water is referred to as total dissolved solids. It can also be defined as the overall composition of cations and anions in water [23]. The values obtained were within the WHO standard of 2000 mg/L and Indian standard of 2100 mg/L for the release of waste water into surface water, however it was higher than the threshold values of 1000mg/L set for irrigation purposes according to CPCB [24]. It means the effluent can't be used for irrigation purposes.

3.9 Total Alkalinity

The total alkalinity obtained was within the WHO standard of HDL & MPL of 200-600 ppm. The alkalinity was higher than the total hardness which indicates basic salts like sodium and potassium is present in addition to calcium and magnesium.

3.10 Chemical Oxygen Demand (COD)

COD is the measure of the amount of oxygen required to break down organic and inorganic matter [22]. The COD obtained in this study was 175 mg/L which was lower than those obtained by Saravana *et al.* (2014) [22] and lower than WHO guidelines of 1000mg/L.

The higher the COD the more toxic the waste water is, in addition to their presence of resistant organic compounds which are biological [25].

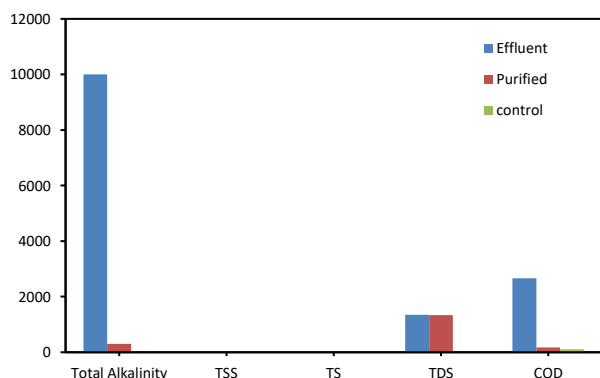


Figure 5. Total alkalinity (TA), total suspended solids (TSS), total dissolved solids (TDS), total solids (TS) and chemical oxygen demand (COD)

4 Conclusions

The pulp and paper industry is one of the fastest growing industries and one of the major causes of water pollutants. The physico-chemical characteristics of effluent from this black liquor revealed that the effluent is dark brown and this is due to dissolved lignin, and its pH is alkaline in nature. The TA, SS, TSS, TDS, COD, from the treated effluent are within the standards of WHO and ISI. On this note, it can be concluded that the final treated effluent discharged from pulp and paper industry is not much contaminated. It can also be concluded that the waste water samples cannot be used for irrigation purposes and other activities associated with the ecosystem because they were below the CPCB standard for irrigation. The waste water should therefore be treated before they are discharged into the environment.

5 Authors Contributions

Shokunbi Oluwatosin carried out the experiment, drafted and revised the manuscript. Omenka conceived the project, designed and supervised the project. He also edited the manuscript.

6 Conflicts of Interest

The authors declare that there is no conflict of interest.

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