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Parameter Optimization for the Treatment of Paper Packaging Industrial Waste in Case of Unlimited Packaging

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Abstract Paper Packaging Industries are manufacturing corrugated boxes or packets from test liner, Kraft liner and fluting medium using different printing inks. In current study unlimited paper packaging incorporates sort of high technology process and hence generating solid as well as liquid wastes. Subsequently further analysis and treatment was expected to be carried out. A Physico chemical characteristic of each waste was analyzed with relevant analytical tools such as AAS, pH, conductometre and titration methods. From the result metal ions such as and Hg were detected to be less than 10^{-4}µg/l both in solid and liquid wastes. BOD and COD were determined both in liquid raw material and liquid wastes and the result showed that BOD; 163.95, 136.5, 1050, 719.22 and 647.15mg/L in glue, starch, ink, effluent before treatment and effluent after treatment respectively. COD was determined to be 33,300, 40,200, 13,200, 1,780 and 3500mg/L in glue, starch, ink, effluent before treatment and effluent after treatment respectively. pH is 4.74 in solid and 4.3 in liquid wastes, phosphorous 2.098 and potassium 2.698 mg/kg in solid wastes. The level of TDS and TSS in effluent before treatment is 3510 and 422 mg/L respectively and 9425 and 588 mg/L in effluent after treatment; electrical conductivity is also detected to be 137.1µg/L. in solid wastes. The method of treatment was optimized to reduce elevated amount of BOD and COD. After optimization the level of contaminants COD reduced by 48.28% and BOD by 82.05%.

Keywords BOD COD, Effluent, Flocculent, Sludge

1. Introduction

1.1. Background

Paper packaging is the method how corrugated and paper boards manufactured from different paper grades. These paper categories are Kraft liner, test liner and fluting medium. Further these products can be manufactured from bagasse, straw and wastes of different agricultural by- products. The main styles of paperboard cases are slotted-type boxes that are made of one blank with a stitched, taped or glued manufacturer's joint and top and bottom flaps. The most frequently used corrugated board package is the regular slotted container (RSC), with features that provide the most economical use of material. The box has flaps with dimensions that are equal in depth to that of the box and the width of the outer flaps equals one-half that of the box, so they meet at the center line of the package when folded. The boxes are shipped flat and ready to use and are used as secondary packaging. The bottom of the box is hinged to form two or all side walls and the cover. Locking tabs, handles, display panels, etc. can be incorporated in the design. The machineries required for the production are corrugator, printer, mixer and cutter. The energy required for bandage of outer and medium surface obtained from steam generated by boiler using filtrated and screened natural water for hardness and related cases [1]

Unlimited packaging is located at east of Addis Ababa at distance of nearly 50 km. The factory is established before seven years on the land area of 30,000 m^2 to manufacture 40-50,000 tons of corrugated boxes per year. Its investment capital was 300,000,000 birr and hence incorporates high technology process of manufacturing corrugated paper box. Its technology is in Europe standard and therefore capable of manufacture high quantity of product per annum of corrugated paper with in one machine part. The raw materials required for the products are categorized to be major and minor. The categories of major raw materials are Kraft liner, test liner, starch and fluting medium. Minor raw materials are additives, aluminum sulfate, glue, and ink.[1]

The paper packaging industry release wastes generating from different stages of the process. From unlimited paper packaging perspective there are solid waste and liquid waste generating. The wastes are directing to treatment before discharging using treatment plants. The factory processes are

operated under high technology systems and hence generating different chemical products in the wastes and the treatment level of the factory involves complex physical technique which is press filtration, coagulation. Therefore the treatment is requiring different parameters correction to handle high load of physicochemical characteristics in the effluent and sludge.

1.2. Statement of the Problem

Paper packaging industry involves the production of new materials or papers from starting materials after several production processes. The mode of production requires both physical and chemical processes. There are by products like effluents and sludge releasing from industrial events. These products most of the time obtained after several chemical and physical treatments are carried out. Physical processes include precipitation, filtration and coagulation used to facilitate treatment processes. Inadequate treatment system and inappropriate set up and proportion of parameters let a lot of contaminants release to the environment such as BOD, COD and TSS. When the levels of such components is beyond the permissive level; environmental disorder at all, deficiency of oxygen and decrease in light can be caused in aquatic environment and natural balance of the ecosystem can also be influenced. According to preliminary exploration carried out on wastes generating from unlimited paper packaging; the levels of BOD and COD was beyond expected. Hence the study is devised to search for the method of reduction of the level of these contaminants from releasing wastes.

1.3. Objectives of the Work

1.3.1. General objective

- To reduce the level of BOD and COD in effluent waste from unlimited paper packaging

1.3.2. Specific objective

- To determine physico chemical characteristics of flocculent, glue, ink, liquid and solid wastes.
- To predict the source of contaminants.
- To optimize method of treatment.

1.4. Significance of the Study

The work introduced scientific approach to handle the problem facing the factory. Hence parameter optimization has got special concern to control industrial wastes than treating with aid of biological and chemical processes. From the study therefore method of managing wastes before discharging is investigated with no further treatment which is better coincide with the fact that prevention is better than treatment.

2. Materials and Methods

2.1. Materials

The apparatus and equipment used during the experiment was plastic bottle, ice bag, atomic absorption spectrophotometer, conduct meter, pH meter, volumetric flask, beakers, and biological oxygen demand incubating apparatus.

Chemicals and reagents - potassium dichromate ($K_2Cr_2O_7$), H_2SO_4, NH_4SO_4, distilled water [2].

2.2. Solid Sample Collection

The main category of wastes in the factory was solid and liquid effluents. The solid waste is generating from precipitation stage during treatment. It was colorful and less heavy solid material. For determination of different waste quality parameters solid waste sample was collected from three positions of layer; which mean middle, top and bottom using plastic bag in ice box then after mixed together to obtain 1kg of representative sample. The representative sample was taken to the laboratory for investigation with respect to pH, magnesium ion, mercury ion, arsenic ion, phosphorus content, potassium content [3].

2.3. Liquid Sample Collection

The liquid samples collected include effluent before treatment, after treatment and raw materials. The raw materials are flocculent, glue and ink or dyes. One liter of each liquid sample was taken separately using plastic bottles and rinsed with hydrochloric acid. The collected sample was taken to the laboratory for the determination of physicochemical characteristics such as BOD and COD. The analysis was conducted at Addis Ababa University environmental and chemistry laboratory. .

2.4. Sample Analysis

Biological oxygen demand (BOD_5) was detected from the difference between first day and after 5 days of incubation. Total dissolved solid (TDS), total suspended solid (TSS), electrical conductivity (EC) and pH were determined on the same day of collection. Chemical oxygen demand (COD), metal ions and phosphorus content were completed on the second day and third day after collection.

2.5. Method Optimization

This method is devised differently from usual factory treatment method. It involves optimization of the parameters such as concentration of flocculent, treatment time, temperature and pH.

3. Results and Discussion

3.1. Raw Materials

Table 1. BOD and COD of raw material (additive) replicate of three measurements (p=0.05)

Samples of Raw materials	BOD(biological oxygen demand), mg/l	COD(chemical oxygen demand) mg/L
Glue	163.95	33,300
Starch	136.5	40,200
Ink	1,050	13,200
Previous work in ink, USA	30,000	40,000

The study on raw material is included to find out the source of unexpected level of the contaminants. Hence the analysis result of raw material revealed that there was high amount of COD and BOD. Accordingly, BOD is 163.95, 136.5 and 1,050 ppm in glue, starch and ink respectively; whereas COD, 33,300, 40,200 and 13,200ppm in glue, starch and ink respectively. The values indicated that the investigated raw materials found to be high in BOD and COD. Chemical oxygen demand is higher than BOD. From the study therefore adhesive, flocculent and ink composed of polymers with high BOD and COD. This are resulted from inorganic and organic components such as MgO, ZnO mercarpet, resins [4].

3.2. Solid Waste

Table 2. Solid waste analysis replicate of three measurements (p=0.05)

Parameters analyzed	Sample
pH	4.74
Available phosphorous mg/kg	2.098
Available potassium	2.698
Electrical conductivity µS	137.1
Mercury	≤0.0001
Arsenic	≤0.0001

According to table 2 the solid waste exhibited pH value 4.74 which indicated that the sample is acidic and further it requires more treatment to neutralize before leaving the process. The other parameters such as phosphorus, potassium, conductivity, mercury and arsenic are analyzed to be 2.098 mg/l, 2.698mg/l, 137.1 µS ≤0.0001mg/l, and ≤0.0001mg/l respectively. The need for analysis of such toxic metal is that to check the attachment of mercury to the waste. When the level of COD exceeds twice of BOD; the concentration of mercury increase and indicated the waste is non-biodegradable. Further the environmental influence of such result is not devastating so safe [5].

3.3. Effluents

The liquid waste of the factory was investigated for the detection of COD and BOD. According to the result the values are somehow higher than expectation. Normally packaging industry is not expected to incorporating high chemical usage like pulp industry during manufacturing process that is why expectation is lower than detected value. The results of the study indicated that after treatment results are better than in before. It is logical that treatment should contribute to the reduction of the level of pollutants in a given discharge. pH, TDS, TSS, Hg, As, COD and BOD was determined to be 4.3, 3510mg/l, 422mg/l, ≤0.0001, ≤0.0001, 1,780mg/l and 719.22mg/l before treatment respectively. After treatment the results indicated that most of the analyzed parameters reduced in amount except COD and TSS. In case of chemical oxygen demand and total suspended solid the values unexpectedly become higher than before. Therefore to solve the problem the method of treatment was extended beyond the installed treatment plant optimizing the procedure. The following method optimization was carried out in order to minimize unexpected values of COD & BOD [6].

Table 3. Liquid effluent analysis replicate of three measurements (p=0.05)

Parameters analyzed	Effluent Before treatment	Effluent after treatment
pH	4.3	4.3
TDS(total dissolved solid), mg/l	3510	588
TSS(total suspended solid) mg/g	422	9425
Mercury, µg/l	≤0.0001	≤0.0001
Arsenic µg/l	≤0.0001	≤0.0001
Chemical oxygen demand, mg/l	1,780	3,500
Biological oxygen demand, mg/l	719.22	647.15

3.4. Optimization

Table 4. Results obtained from optimization replicate of three measurements (p=0.05)

Flocculent (%)	Tem.(^{0}C)	pH	COD(mg/L)	BOD(mg/L)
80	50	6.5	16,951	1051
60	50	5.0	10,051	881
40	50	4.5	8,531	800
20	50	4.0	7,641	785
80	45	7.0	3500	719.2
60	40	7.0	3500	647.12
40	35	7.0	2814	284
20	25	7.0	1,810	115

From table 4 the first phase of experiment was carried out by varying concentration of flocculent from (80-20) % and pH from 6.5 – 4.0 but keeping temperature constant. From this method COD decrease uniformly from 16,951- 7,641 mg/L and BOD from 1051-910 mg/L. It is because at the very beginning the consumption of raw material such as flocculent is high and consequently the amount of different

oxygen demanding organic and inorganic pollutants become high and decrease with time; further when acidity of the system increases more metal ions dissolve and react [7].

The second case is varying concentration and temperature but keeping pH constant. The result of this stage indicated that the level of COD & BOD decreased when temperature and concentration of flocculent decreased. It is explained in two different perspectives which mean from kinetic theory of reaction when concentration of raw material increase rate of consumption increase to some extent and decrease. Similarly when temperature increase the rate of reaction increased indicated more products expected and then decreased gradually in the absence of introduction of new raw material. Hence as no new raw material is not introducing there is decrease in level of product to be discharged as it is indicated in table 1. Therefore high results are caused at the beginning from the contribution of raw materials [8].

4. Conclusions

One of the industrial waste management techniques is biological, chemical or physical. But the method can be effective or not to accomplish treatment process. In unlimited paper packaging almost filtration, coagulation and precipitation methods are in operation. The operational method was not effective to control high level of COD and BOD. Therefore from the current study the treatment method was optimized by varying different parameters such as temperature, pH and flocculent concentration to reduce BOD and COD. From optimization result COD was decreased by 48.28% and BOD by 82.05%.

5. Recommendation

The factory waste management system is operating under the conditions already set up and continuous follow up will be required for efficiency and effectiveness of the method.

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