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Remediation of Textile Wastewater Using Activated Rice Husk

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Abstract: Textile production plays a major role in the social-economic development and industrialization system of a nation, but the wastewater generated by the industry is one of the most polluting amidst all industrial sectors because the number of contaminants in the wastewater are often very high compared to municipal or domestic wastewater.Characterization and remediation of textile wastewater are essential to achieving a clean and sustainable environment. In this study, discharged wastewater which had been pre-treated with bentonite and alum was collected from a textile industry in Ikeja Industrial Estate, Lagos State, Nigeria. Collected textile wastewater was treated by varying the dose of Activated Rice Husk (ARH), at a constant shaking speed of 150rpm, centrifuging speed of 400rpm at room temperature. The comparison was made between the collected and treated wastewater to determine variation in concentration of selected parameters. Maximum removal efficiency were recorded for total alkalinity, turbidity, Cd and Pb with values between 95 - 97%, 80% - 92%, 99.3% - 99.8% and 80 - 98% respectively. Percentage reduction in concentration recorded for TDS, COD, BOD, DO, Mg, Zn and Cr were 22-46%, 23 – 51%, 44 – 50%, 6 -13%, 28- 41%, 23 – 54%, 30- 52% respectively while negative increment was observed in the concentration of copper. ARH proved to be an effective adsorbent for remediating textile wastewater. Remediated wastewater can be reused by the textile industry for various production and housekeeping operations.

Keywords: Textile Wastewater, Sustainable Environment, Activated Rice Husk, Remediation, Wastewater Treatment

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I. INTRODUCTION

In most developing countries, wastewater from textile industries(cotton, woollen, synthetic) is often time not fully treated before discharge into the water system[1,2]. Discharge of uncontrolled textile wastewater is harmful not only to water bodies but also to the aquatic system, animals, plants and the environment. Although, textile production plays a major role in the social-economic development and industrialization system of a nation, the wastewater generated by the industry is one of the most polluting amidst all industrial sectors because the number of contaminants in the wastewater are often very high compared to other municipal wastewater from domestic or residential sources, commercial or institutional source wastewater[3]. It is often richer in colour, higher COD and BOD concentration, high chromium, left over reactive dyes, oil, grease, suspended solids, inorganic substances and other contributing substances[4].

All over the world, indiscriminate discharge of wastewater constitute an environmental and health concern. In China, about 70 billion tonnes of wastewater from textile and dyeing industry are produced annually which requires proper treatment before discharge (State Environmental Protection Administration, 1994). In Nigeria, Uwidia and Ejeomo[5] revealed an average annual textile wastewater discharge of 130 – 160 thousand metric tonnes each from two textile industries in Lagos with an average daily discharge of 4.2×10^6litres. Ogunlaja and Aemera[6] also affirms a daily discharge of 1577m^3 from another textile industry in Oshodi, Lagos State, Nigeria. Therefore, an efficient and appropriate technique is required to reduce the potentially damaging substances from the wastewater generated during textile production processes.

Some of the general techniques to reduce or remove pollutants from textile wastewater are coagulation, aerobic and anaerobic microbial degradation, ozonation, membrane processes, precipitation, filtration, adsorption process[7]. Among these, moringaoleifera seed powder as a natural coagulant had received much attention in the treatment of water and wastewater[8,9,10,11]. The dried seed powder had been used to remove reactive dyes from textile wastewater, reduce turbidity, alkalinity, hardness and TDS [12,13,14]. Recent studies revealed an alarming result for the emissions from the conventional wastewater treatment plants around the globe as the leading cause of greenhouse gases (methane, ammonia, carbon dioxide, nitric oxide) with high global warming potential. However, today, the adsorption method had proven to be very efficient and in-expensive compared to other methods. Several agricultural waste products had been tested for their adsorbent properties and found to be effective and useful resources and not waste product. A large volume of these agricultural waste product like sawdust, tea waste, coffee waste, millet husk, rice husk and others which are often disposed indiscriminately are now useful for wastewater treatment[15].

The use of activated adsorbent like rice husk is one of the most acceptable methods for the treatment of wastewater because of its availability, low cost and removal efficiency. Rice husk generated from rice production is cheap and in abundant in most part of the world. Nigeria was rated the highest rice producer in West Africa and the third largest in Africa, after Egypt and Madagascar [16]. Rice husk accumulation over time has become an environmental concern [17]. In 2010, FAO reported that about 748,000 – 990,000 tonnes of rice husk were generated from 3.4 – 4.5 million tonnes of rice [18]. In Malaysia and India, 408,000 tonnes and 19.5 million tonnes of rice husk are produced annually respectively [19]. These waste can be turned to useful resource by direct and indirect utilization to treat wastewater, because the cellulose material in them has the potential of attracting pollutants to its surface.

The use of rice husk as adsorbent had concentrated and limited to treatment of prepared aqueous solution of synthetic dye (by dissolving dye powder in distilled water) or artificial textile wastewater, discolouration[20, 21, 22] or heavy metal removal [23, 24]. More often activated rice husk carbon had been used to remove one form of colour or the other. It had been used to reduce reactive blue 2, reactive orange 16 and reactive yellow dye from textile wastewater [25]. Rice husk had also been used to treat dairy wastewater [26]. In this study, discharged wastewater which had been pre-treated with bentonite and alum was collected from a textile industry and remediated by varying the dose of Activated Rice Husk (ARH) to determine the adsorbent effect on the concentration of the wastewater.

II. MATERIAL AND METHODS

The materials needed include; Filter Papers, weighing meter, shaker, angle centrifuge machine, stop watch, conical flasks, pH meter, oven, hand gloves, nose pad, test tubes, tube rack, funnel, Hanna Multiparameter instrument HI 9812-5 instrument, DO/COD/BOD Hanna instrument H1 9141-04 instrument, 210VGP Atomic Absorption Spectrophotometer (AAS).

2.1 Wastewater Collection and Storage

Effluent samples were collected from Wollen and Synthetic textile manufacturing industry, Oba Akran Avenue, Ikeja Industrial Estate, Lagos State, Nigeria. The collected wastewater had been pretreated in the effluent treatment plant (Plate 1) with bentonite and alum to reduce the pollution level before discharge. Wastewater sample was collected in a clean plastic container and stored appropriately for analysis.

2.2 Preparation of Activated Rice Husk

The rice husk needed for this work was collected from Institute of Agricultural and Research Training, Ibadan/Abeokuta Road, Ibadan, Oyo state, Nigeria (Plate 2a). It was made free of dust and other particles attached to it surface by washing with clean water and sun dried. 300g of the dried rice husk was activated by soaking it in 350mL of nitric acid (HNO_3) with 2mol/L concentration for a contact time of 60 minutes to make the surface porous.The gas from this reaction was thick and choking (Plate 2b). The soaked rice husk was rinsed with distilled water and left to dry in an oven for 2 hours at a temperature of 110°C (Plate 3). The oven dried sample was grounded into smaller sizes and sieved through BSS - mesh 30(Plate 4). The dry sieved ARH was kept for dosing. Similar procedure was used by Bhowmick[27]and Gidde[19]when preparing ARH.

Plate1: Effluent Treatment Plant (ETP)

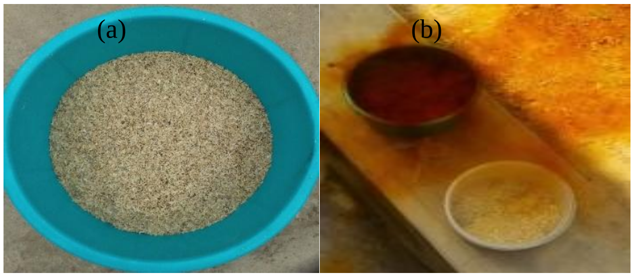


Plate 2: (a) Raw rice husk (b) Reaction between rice husk and HNO_3


Plate 3: Oven drying of ARH


Plate 4: ARH after grinding and sieving

2.3 Remediation Procedure

A litre of textile wastewater was collected in five different bottles, and prepared adsorbent (ARH) was varied in each of the samples. Sample A was left untreated. Sample B was treated with 4g of ARH, sample C was treated with 8g of ARH, sample D was treated with 12g of ARH, sample E was treated with 16g of ARH and sample F with 20g of ARH (Appendix). Samples B - F were thoroughly mixed with a shaker at a constant contact time of 60 minutes at 150rpm to ensure equilibrium in concentration for adsorption to take place. Similar procedure was carried out by Gidde[19]. 25ml of samples B – F were measured in triplicates, kept in an angle centrifuge machine at a constant revolution of 400rpm for 40 minutes at room temperature for the residue to settle to the bottom of the test tube. The samples were then filtered through Whiteman filter paper. The liquid filtrate from each sample was collected in a 10ml test tube and taken to the laboratory for physico-chemical characterization. The following parameters were analyzed: pH, Colour, Total Alkalinity, Turbidity, Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Heavy Metals; Copper (Cu), Lead (Pb), Cadmium (Cd), Zinc (Zn), Chromium (Cr). Concentration before treatment (sample A) and after dosing with ARH (samples B - F) was compared with the World Health Organization (WHO), the National Agency for Food and Drugs Administration Council (NAFDAC) and the Lagos state Environmental Protection Agency (LASEPA) effluent discharge limits.

Pollutant removal efficiency in percentage (% R) was computed using the equation;

$$\% \text{ R} = \frac{Cc - Cf}{Cc} x100$$

Where C_c = concentration of collected wastewater

C_f = concentration of wastewater filtrate

2.4 Characterization of wastewater

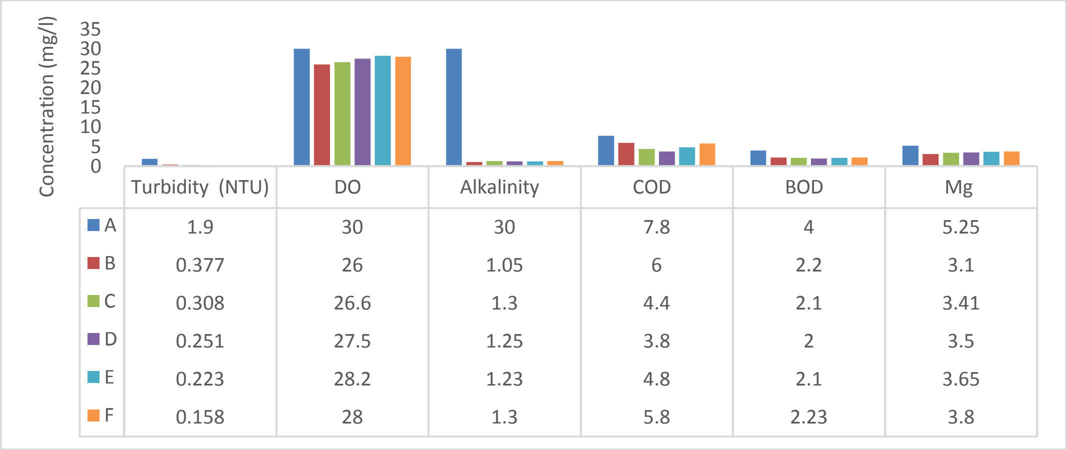
The sample was analyzed as described in the Standard Methods for the Examination of Water andWastewater (APHA, 2005). Scientific 210VGP Atomic Absorption Spectrophotometer was employed for the determination of heavy metal concentration. The TDS and pH values were analyzed using Hanna Multiparameter instrument - HI 9812-5. The instrument was first calibrated before the reading were taking and the probe was rinsed twice before subsequent sample reading. Alkalinity was determined using the potentiometric method of titration. Magnesium was analyzed using titration method. The titration was repeated and the average value was recorded.For the determination of DO/COD/BOD Hanna H1 9141-04 instrument was used. The electrometric (DO Meter) was used to measure the DO after calibration of the instrument.

III. RESULT AND DISCUSSION

3.1 Characterization of collected and treated effluent

The collected wastewater presented a dark grey colour. The mean pH of the effluent samples discharged from the ETP into the surface water body was 6.8, this indicates that the pretreated wastewater is slightly acidic. As the dose of the ARH increases, the pH values also increases with value between 8.2-8.5. This implied that ARH increases the pH value of the wastewater, thereby making it alkaline. The resulting values fell within the pH of 6.5–9 and 6.5-8.5 recommended by WHO and NAFDAC. Data obtained from the characterization of effluent samples before and after the application of ARH is shown in Figure 1 and Figure 2. The initial mean concentration of TDS was 690 mg/l, and it reduces to 370 – 680 mg/l with doses of ARH. Turbidity, alkalinity and magnesium content of the collected wastewater were within the permissible limits of 5, 200 and 50 mg/l respectively. COD and BOD contents of the collected wastewater were within the required threshold. The permissible limit of textile wastewater discharge for COD and BOD are80mg/l or 100mg/l and 20mg/l or 25 mg/l respectively, depending on local conditions and environmental protection requirements put in place.

Results show that the remediation process with ARH dosage influences the concentration of the physico-chemical parameters tested, as it further reduces their concentration. Turbidity was reduce to as low as 0.158 NTU, DO reduce to 26 mg/l, alkalinity to 1.05 mg/l, COD and BOD to a minimum concentration of 3.8 mg/l and 2.0 mg/l respectively, while the concentration of magnesium was reduce to 3.1 mg/l.



	Turbidity (NTU)	DO	Alkalinity	COD	BOD	Mg
🟦 A	1.9	30	30	7.8	4	5.25
🟥 B	0.377	26	1.05	6	2.2	3.1
🟩 C	0.308	26.6	1.3	4.4	2.1	3.41
🟪 D	0.251	27.5	1.25	3.8	2	3.5
🟦 E	0.223	28.2	1.23	4.8	2.1	3.65
🟧 F	0.158	28	1.3	5.8	2.23	3.8

Figure 1: Average wastewater concentration before and after remediation

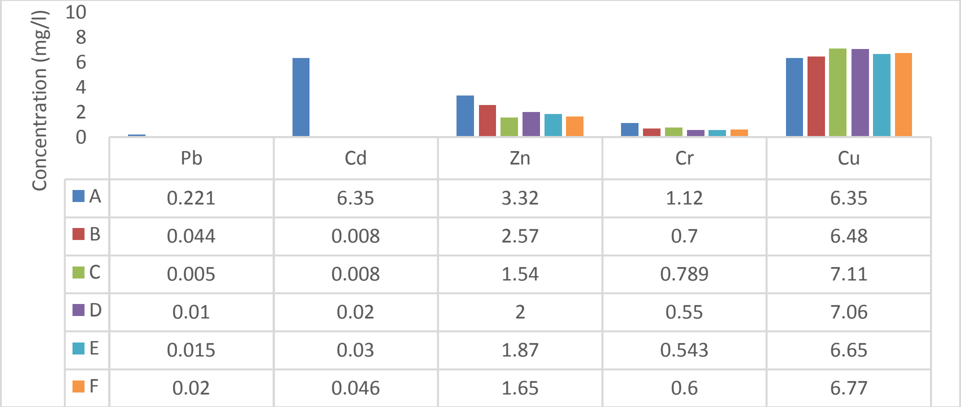
However, heavy metal concentration in the collected textile wastewater was above the permissible limits (Figure 2). Average concentration of copper, lead, cadmium, Zinc and chromium were 6.35, 0.221, 6.35, 3.35, and 1.12 mg/l, against the expected permissible concentration of 0.5, 0.05, 0.002, 1.5 and 0.10 mg/l respectively. Excessive concentration of heavy metals in wastewater is a great concern today because of its toxicity and adverse effect on human health, accumulation in fishes and other aquatic life (able to enter food chain) and the environment. Hence, the enforcement of effluent regulatory before discharge.

With the introduction of ARH at different doses, mean concentration of lead were between 0.005- 0.02 mg/l. The concentration of lead after the remediation process complied with WHO, NAFDAC and LASEPA standard with permissible concentrations of 0.05, 0.01 and 0.10 respectively for discharge. Naiya [28] and Wong[29] also reported a reduction in lead concentration with rice husk carbon treatment.

Cadmium was reduced with the application of ARH, in support of earlier work of Ye [30]. The concentration was reduced to as low as 0.008- 0.046 mg/l from the initial concentration of 6.35 mg/l. The remediation process reduced the concentration of Zinc to 1.54 – 2.57 mg/l. El-Shafey[31], also confirmed the reduction of Zinc with rice husk carbon. The concentration value of chromium in the wastewater became 0.543 – 0.789 mg/l after ARH doses. These final concentrations of chromium reflected a reduction but did not meet the permissible discharge concentration of 0.1, 0.05 and 0.5 mg/l recommended by WHO, NAFDAC and LASEPA standard respectively. Chromium is often found to be high in textile and dyeing plants due to the presence of chromium and reactive dyes in aqueous solution.

The concentration of copper increased with an increasing dose of ARH. The concentration of Copper observed in treated samples were as high as 10.37 – 13.77 mg/l from an initial value of 6.35mg/l. This inferred that ARH increases the concentration of copper. None of the samples tested complied with the discharge threshold value of 0.5, 1.0, and 0.5 mg/l for copper recommended by WHO, NAFDAC and LASEPA respectively. Wong et al., 2003, reported a reduction in the concentration of copper using rice husk modified with tartaric acid at low pH of 3. Hence, the suitability of rice husk activated with nitric acid for the removal of copper in textile wastewater required further investigation.

Excessive intake of copper leads to various health issue in man, toxic to aquatic organisms and plants alike. The recommended permissible potable concentration of copper by WHO is 1.5 -2 mg/l in order to reduce health effects and pollution.



	Pb	Cd	Zn	Cr	Cu
A	0.221	6.35	3.32	1.12	6.35
B	0.044	0.008	2.57	0.7	6.48
C	0.005	0.008	1.54	0.789	7.11
D	0.01	0.02	2	0.55	7.06
E	0.015	0.03	1.87	0.543	6.65
F	0.02	0.046	1.65	0.6	6.77

Figure 2: Average wastewater concentration before and after remediation

3.2 Removal efficiency

The removal efficiency in percentage with varying dose of ARH is presented in Figure 3 and Figure 4. For TDS, the removal efficiency initially increases with an increase in the dose before a decline. The maximum removal efficiency of TDS was 46% at 12g dose of ARH. Turbidity removal increases with dose and the maximum percentage of removal was 92%. As the dose of ARH increases the removal efficiency of DO decreases. Maximum removal was observed at 4g of ARH. Removal efficiency for alkalinity was relatively same with increase in ARH dose. Recommended dose for maximum removal of alkalinity of 96.5% was 4g. The removal efficiency of COD and BOD with varying dose of ARH shows that average dose of 12g for a 51% and 50% removal efficiency respectively was possible. As the dose of ARH was increased, decrease in removal efficiency of magnesium was observed. A maximum dose of 4g of ARH is recommended.

Figure 4 shows that Lead reduction was between 80 – 98%, efficiency of removal reduces with increase in ARH dose. Cadmium exhibit good reduction with ARH at a relatively constant rate.

Zinc removal efficiency varies with ARH dose (22.59 – 53.61 %), maximum removal of 53.61 % was observed at 8g of ARH. Percentage removal of chromium lies between 29.55 – 51.51%, maximum removal was observed at a 12g dose of ARH.

Amidst all the heavy metals tested, copper exhibits a different reaction with increasing dosage of ARH. The percentage removal was negative compared with other heavy metals. As the dose of ARH increases the concentration also increases.

Results revealed that most of the pollutants were reduced at relatively low adsorbent dosage of ARH. At ARH dose of 8g most of the pollutants (physico-chemical and heavy metal concentration) were reduced to an acceptably discharged concentration except copper. The treated wastewater could be reused in specific production processes and for general housekeeping operations.

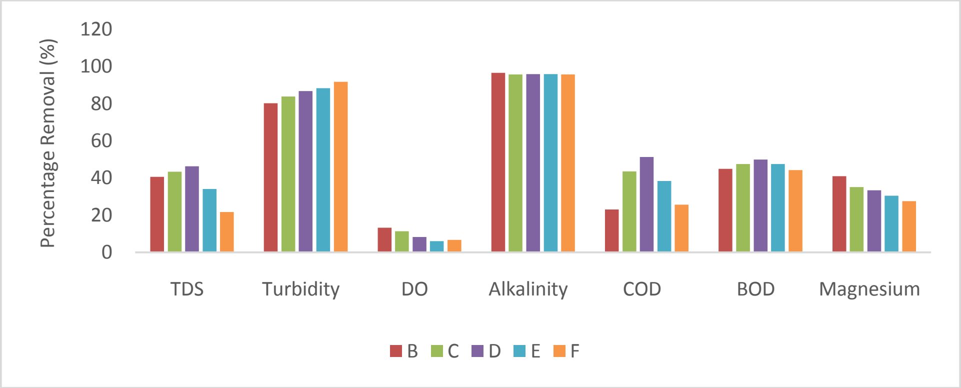


Figure 3: Removal efficiency with ARH

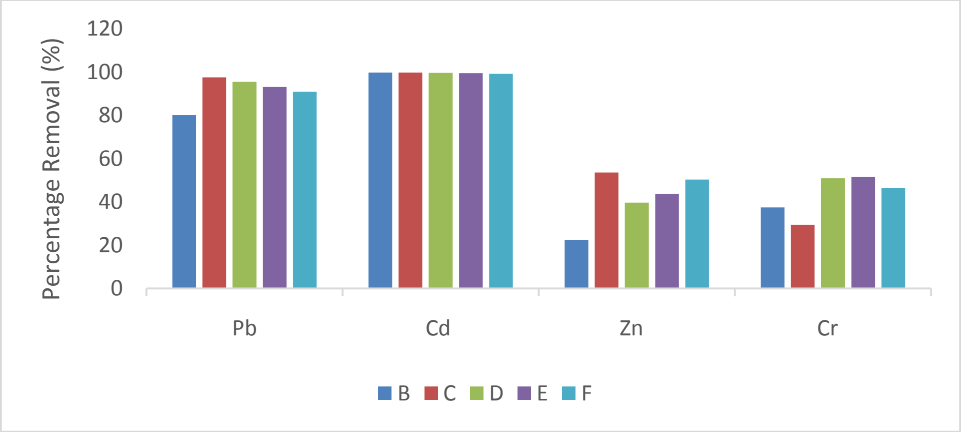


Figure 4: Removal efficiency of heavy metals with ARH

IV. CONCLUSION AND RECOMMENDATION

The discharged wastewater by the textile industry is not free from pollutants. The use of bentonite and alum as pretreatment has not completely reduce the concentration of the heavy metals to acceptable limits.

This study has shown that ARH as an adsorbent will further reduce the concentration of textile wastewater. Parameters such as TDS, Turbidity, DO, Total Alkalinity, COD, BOD, Mg, Zn, Cr, Pb and Cd in the textile effluent were reduced after the remediation process.

Maximum removal efficiency were recorded for total alkalinity, turbidity, cadmium and lead with percentage values between 95 - 97%, 80% - 92%, 99.3% - 99.8% and 80 - 98% respectively. Percentage reduction in concentration recorded for TDS, COD, BOD, DO, Mg, Zn and Cr were 22-46%, 23 – 51%, 44 – 50%, 6 -13%, 28-41%, 23 – 54%, 30- 52% respectively. Adsorption was found to be more effective at lower adsorbent dose because the concentration of most of the parameters tested was reduced at ARH dose of 8g. In this work, rice husk activated with nitric acid prove to be ineffective for the removal of copper. All the parameters tested met the discharge standard except Cr and Cu. Further work is needed to check the effect of varying the pH, contact time and temperature on the removal efficiency of these parameters.

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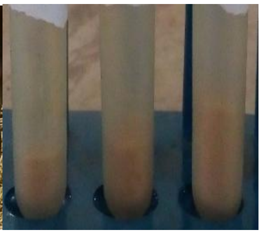
Collected wastewater

Raw rice husk

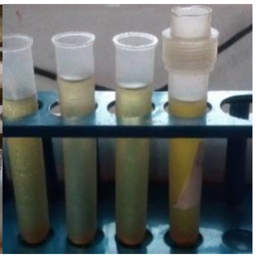
Wet ARH



Oven dry ARH

Wastewater with ARH

Agitated samples



Filtrate samples

Remediated wastewater