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The link to this publication is https://ajoeer.org.ng/otn/ajoeer/2024/qtr-1/04.pdf

Evaluation of the Treatment Potentials of Bamboo Based Activated Carbon for Paint Wastewater Management

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Abstract

This article focused on the application of activated carbon produced from dry bamboo for the removal of pollutants from paint based waste water. Wastewater samples were collected from paint making industry in Awka, Anambra State and subjected to treatment using activated carbon produced from waste dry bamboo by adsorption and filtration method. The raw wastewater and the treated water were tested for physicochemical parameters using the ASTM testing methods. The results showed evidence of the presence of heavy metals (lead, mercury, chromium, copper, etc), oil and grease as well as dissolved oxygen and biochemical oxygen demand. The concentration of pollutants in the raw and treated waste water were pH: 7.13 and 7.92, turbidity: 790 and 6.30, colour: 22 and 5.2TCU, sulphate: 1025mg/l and 163mg/l, COD: 5211mg/l, and 70.27mg/l, BOD: 3125mg/l and 48.93mg/l, TSS: 1010mg/l and 23.19mg/l, TDS: 2100mg/l and 439mg/l, Calcium: 401.45ppm and 8.9ppm. Hardness: 550mg/l and 139.83mg/l, Lead: 13.8mg/l and 0.33mg/l, Cadmium: 41.1mg/l and 0.89mg/l and Total Coliform: 1220 cfu and 433 cfu. Heavy metals, total dissolved solid, total suspended solid, chemical oxygen demand, biochemical oxygen demand, etc. were present in high concentration in the paint's based waste water but the treatment reduced these pollutants significantly.

Keywords: Bamboo, Activated Carbon. Paint, waste water, Treatment, Adsorption

Introduction

Application of activated carbon is a classical procedure for removing impurities from wastewater or gas mixtures. It serves as a filtering medium acceptable in several applications including water purification and gas filtration. This is due to its potency to remove contaminants (Ahmed, 2016. Md et al., 2020), Activated carbon is characterized with super physicochemical characteristics including large surface area, pore volume, chemical structure and surface morphology. It is also described as a group of carbonaceous adsorbents (Abbas and Ahmed, 2016).

In the production of activated carbon, carbonaceous raw materials that are usually considered as waste are selected and used examples are bamboo waste from building site, palm kernel shell and other agricultural wastes. The process of production are firstly carbonized in the absence of air and activated either physically or chemically for improved properties, efficiency and effectiveness (Sujiono et al, 2022).

Liquid Effluent from paint making industry are major source of pollution to the environment. Paint making industries generate wastewater with high chemical oxygen demand (COD) and turbidity, Biochemical Oxygen Demand (BOD), highly alkaline, along with organic matter, Total suspended solids, heavy metals such as lead, mercury, chromium, etc. (Nair et al., 2021)) that cause environmental damages. These pollutants generation in the industry comes from the use of various raw materials which contains solvents and toxic metals. Waste water from paint making industry are also generated from equipment cleaning which is regarded as the main stream of wastewater from paint making industry. About 80% of effluents come from equipment cleaning. (Ghaly et al., 2011)

Residual toxic metals such as mercury, lead, chromium, etc. and solvents are found in a paint sludge (Aniyikaiye et al, 2019). Adsorption method which is categorized under physicochemical treatment method is very efficient in removing of heavy metals. It is also often employed in treating liquid effluents from paint industry. This is made possible by using adsorbents possess the capacity to bind and eliminate heavy metals from liquid effluents. These adsorbent could be chemical or natural (Maduabuchi, 2018). Examples of natural adsorbents include coconut shell, dry bamboo waste, rice husk, palm kernel shell, etc, that are regarded as carbonaceous and materials of low economic demand (Achadu and Akpan, 2022). Therefore treatment of this liquid effluent before discharge to the environment are highly essential to avoid degradation and depletion to recipient soil and water bodies and treating with activated carbon locally produced from bamboo could be effective and productive in purifying this effluent especially at low cost (Akpan et al., 2022).

Environmental degradation is rampant in recent times because of the increase in manufacturing of goods and services. This production processes generates a lot of wastes especially liquid waste that often discharged into empty lands or surface water bodies (Uyigue and Achadu, 2020). These effluents are either not treated or inadequately treated and hence fails to meet the regulatory requirements. This failure to sufficiently treat this waste water leads to contamination of the recipient soils and water bodies thereby resulting in poor productivity of crops planted on the polluted lands, heavy metal accumulation in the fishes with negative effect on the food chain. (Ugwu and Achadu, 2021) Generally the waste water from the paint industry, usually small scale with small amount of waste water have really not been looked into by regulatory bodies, may be because of the sizes of the industry notwithstanding they produced a lot of wastewater. This study therefore seeks to access the pollution loads of the waste water treat using local waste material and re-access to determine the extent of the treatment (Maduabuchi, 2018).

Many industrial activities and processes released hazardous substances into the environment in large quantities that pose risk to human health, and because most of these substances, example heavy metals are dangerous to human and animal (toxic, mutagenic and carcinogenic), therefore, their elimination from industrial effluents before disposal into the environment is very necessary (Güven et al., 2017).

Liquid effluent from paint making industry is classified as a major source of environmental pollution and poses a whole lot of hazard and danger to human lives and ecosystem at large while most paint industries with treatment plant facilities do not treat the wastewater to the acceptable limit (Vishali et al., 2018). This could be linked to high economic demand (Güven et al., 2017). This therefore gave rise to evaluation of pollution load from paint making industry to determine and analyze the most efficient, effective and sustainable method of treating wastewater from paint industry.

2.0 Materials and Methods

This chapter covers the various materials and methods employed in the study to achieve the objectives of the study. The methodology of this research carried under the following sub-headings:

2.1 Materials /Apparatus /Equipment

2.1.1 Materials
The materials used for this study include coconut shell and dry bamboo waste.

2.1.2 Apparatus
The apparatus used for the investigation include the following: Beaker conical flask, burette, retort stand, volumetric flask, cylindrical furnace, oven, horizontal alumina tube, desiccator, pipette, Atomic Adsorption Spectrophotometer (AAS).

2.1.3 Reagents
The following reagents KOH, HCl and distil water.

2.2 Production of Activated Carbon from dry Bamboo Waste

2.2.1 Sample Collection
Bamboo wastes were collected from a construction site where a building was being erected.

2.2.2 Carbonization of Bamboo Samples
The 1000 grams of the bamboo samples were measured and positioned on a horizontal alumina tube and heated to 800 °C in a furnace to carbonize for three (3) hours and then placed in a desiccator to avoid contact with oxygen.

2.2.3 Activation of Carbonized Samples
50 grams of the carbonized samples were mixed with 150gram of KOH pellets. The mixture was poured into a foil and then subjected to activation heat (800 °C) treatment under N_2 flow for one hour in a cylindrical furnace. The mixtures were cooled, then crushed and washed with 1.0M solution of HCL to get rid of the activating agent residues and other inorganic species that were created during the procedure. Hot distilled water were used until a pH of 6.88 was attained. The activated carbon was sieved to obtain particles a size in the range of 0.5 mm to 1.0 mm, oven-dried at 120°C for 24 hours, and then kept in a desiccator.

2.3 Paint wastewater collection
Wastewater from a paint manufacturing company in Awka, Anambra State was collected in 2 litre glass bottles and stored in Ice Park prior to laboratory analysis.

2.4 Treatment of Raw Wastewater with dry Bamboo based Activated Carbon
An open ended cylinder with sieve at one end was used for the adsorption/filtration treatment process for raw wastewater using the produced bamboo activated carbon. The column was packed with the produced activated carbon while the other end of the columns were covered with a sieve of 150mm size. The wastewater was poured into the column from the top, passing

through the packed activated carbon and exiting as droplets into the recipient vessel with a filter paper. Figure 1 is the schematic representation of the adsorption / filtration treatment of the process.

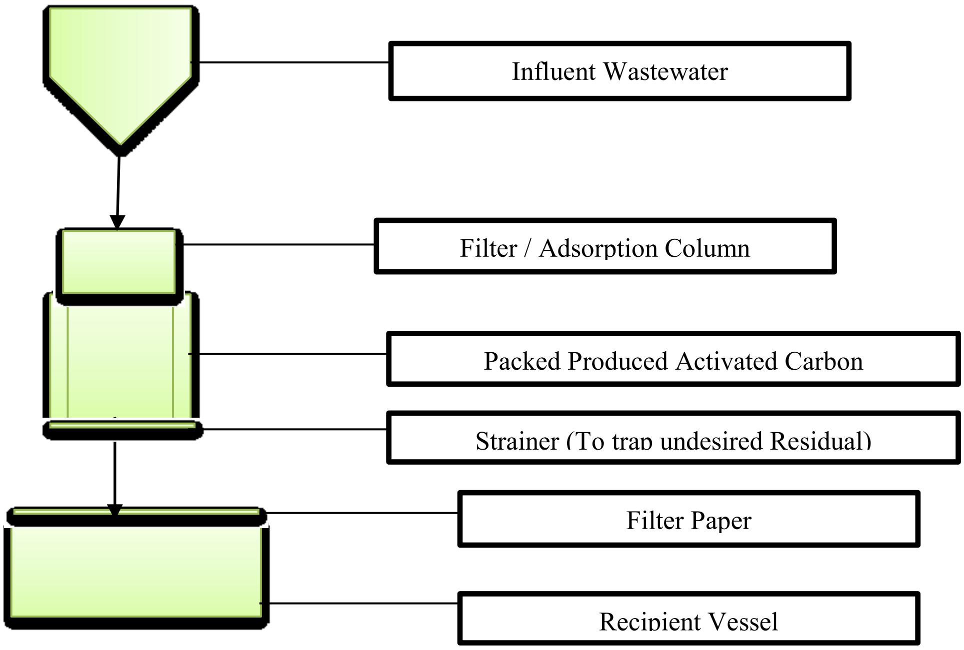

Figure 1: Paint wastewater Treatment Scheme

2.5 Evaluation of Raw and Treated wastewater Pollution Loads Concentration

The pollution loads for the two water samples (raw and treated) were carried out using the American Public Health Association (APHA) standard methods for physical analysis of water samples while the atomic adsorption spectrophotometry equipment was employed for determining the level of heavy metal contamination in the samples.

2.5.1 Determination of pH

Physical parameters of the water samples (pH, electrical conductivity, temperature, and TDS) from paint making industry were determined by using methods stipulated by Achadu et al (2022).

2.5.2 Determination of Turbidity

The cloudiness of both raw and treated water samples were measured using 2100Q HACH Turbid-meter in harmony with APHA 2130B method. The equipment was first calibrated with formazin standard solution of 20, 100 and 800 prior to use. For measurement, the water sample was then transferred into the cuvette, then placed in the sample holder. The dial knob was turned to display the reading in NTU which yielded the turbidity value.

2.5.3 Determination of water hardness

50.0 cm^3 of the raw waste water sample was poured into a beaker, then 1.0 cm^3 NH_3 buffer solution of was added to it. The solution was adequately swirled after three drops of solocrome Black T indicator were added and allowed until the mixture's color changes from wine red to pure blue with no bluish tinge present was attained. It was then titrated with 0.01 EDTA solution. The process was repeated for the treated water. The water samples' overall hardness were estimated using Equation 3

$$T_H = \frac{V_T}{V_S} X \frac{1000}{1} \quad 3$$

Where
T_H = Total hardness (mg/CaC0$_3$), V_T = Titrate Volume and V_S = Sample volume

2.5.4 Sulphate. Total hardness, BOD COD and DO

The parameters above were tested according to the various method specified by APHA standard method and adopted by Achadu et al (2023).

2.5.5 Methods for the Elemental Metal Analysis

Using a Varian AA240 Atomic Absorption Spectrophometer and the American Public Health Association's 1995 methodology, Elemental analysis was carried out.

Atomic absorption spectrometer's working principle depend on the atomization of the samples when light beam from atomic adsorption spectrometer is directed through the flame, into the monochromator and onto the detector, which measures the amount of light adsorbed by the atomized element in the flame. The method is comparatively free from spectral or radiational interference because metal source lamp use their own unique characteristic absorption wavelengths as specied in the study conducted by Achadu et al, 2022.

2.5.10 Determination of and Fungi counts in Water

The Total Bacterial Count was done by carrying out ten-fold serial dilution of the water and soil samples and plating out appropriate dilution on Nutrient agar. Thereafter, the Total bacterial count determined and the developing colonies characterized and identified. Whereas, the coliform count for soil was done on EMB

The calculations were thus:

Faecal and Total Coliform: No. of colonies per 100ml = $\frac{\text{No. of colonies counted on plate}}{\text{Volume filtered}} \times 100$

3.0 Results and Discussion

This section detailed the result and discussion from the study effect of treatment of waste water from paint making industry using locally prepared activated carbons from waste bamboo. The adsorption of pollutants from the sampled waste water using prepared activated carbons were carried out in batch process at an ambient temperature using the optimum conditions. This experiment in turn gave rise to results in Table 2.

Table 2: Raw and Treated Paint Waste Water Characteristics

	Concentration of Water Sample			
Parameters	Raw	Treated	Percentage Change	NESREA
Temperature ^{0}C	45	27	40	40
pH	7.13	7.92	10	6.5 – 8.5
Turbidity NTU	790	6.3	99.2	5
Colour	22	5.2	76.36	7

Phosphorous mg/l	29.5	5.89	80.03	2
Sulphate mg/l	1025	163	84.1	250
COD mg/l	5211	70.27	98.65	90
BOD mg/l	3125	48.93	98.43	50
TSS mg/l	1010	23.19	97.7	25
TDS mg/l	2100	439	97.09	500
Calcium ppm	401.45	8.9	97.78	10
Hardness mg/l	550	139.83	74.58	100
Lead mg/l	13.8	0.33	97.61	0.05
Cadmium mg/l	41.1	0.89	97.83	1
Chromium mg/l	3.75	0.8	78.67	0.05
Zinc mg/l	16.75	1.93	88.48	1
Chromium VI mg/l	0.2	0.03	85	0.05
Manganese ppm	25.1	0.167	99.33	0.1
Aluminum ppm	1.34	0	100	0.02
Total coliform (cfu)	1220	433	64.51	400

3.1 Discussion of Results

Temperature

The degree or intensity of heat present in the sampled raw wastewater is referred to as temperature. Water temperature is a physical parameter that generally express the hotness or coldness of water samples. Water temperature is an important parameter in water quality assessment because of its impact on other parameters that affects other physical and chemical properties of the water. In using the produced activated carbon from waste bamboo to treat the wastewater from paint making industry, a temperature of 45^{o}C and 27^{0}C were recorded raw and treated water respectively. There were reduction in the temperature of the raw waste water. These results showed reduction in temperature after treatment with produced activated carbons because the cleaner the water, the lower its temperature gets. When water gets polluted, there reaction between the pollutants, cause rise in temperature. The values after treatment was below NESREA tolerance value of 40 ^{o}C.

pH

This is a measurement of hydrogen concentration in aqueous solution. pH value less than 7 is acidic, greater than 7 is alkaline while pH of 7 denotes neutral. The pH of the raw paint wastewater was 7.13 while that for waste water treated with waste bamboo based activated carbon was 7.92. This pH value of the treated waste water tilted towards basicity due to the reduction in the chemical substances content in the raw wastewater, therefore is regarded safer for the environment and are within NESREA tolerance range of 6.5 - 8.5 for discharge into inland water ways.

Turbidity

Turbidity is an optical determination of water clarity. The parameter shows the level of cloudiness or haziness of water. It is also a key test for water quality. The turbidity of the raw and treated wastewater were 790 and 6.30 respectively. These turbidity values were all higher than the recommended value (5.0) by NESREA. This implied that reduction of the dissolved solid and suspended solids in the untreated after the treatment. The value of turbidity recorded for the treated wastewater was still higher than the tolerable value, thus there is need to probably increase the activated carbon dosage and contact time during treatment of wastewater to achieve lower value. This will also increase the adsorption of dissolved oxygen by aquatic species when discharged in a water body.

Colour

Colour is a parameter that is used for evaluating the transparency of wastewater and is often linked to the presence of dissolved and suspended solids. Clean water is colourless, therefore any kind of colour noticed in water reveals contamination. Test for colour in wastewater samples is very important because colouration in water indicate the presence of pollutants. Colour of wastewater are classified as apparent or true colour. Apparent colour of wastewater samples collected is due to presence of both dissolved and suspended solid in the water while true colour of waste water is as a result of presence of only dissolved material. The colour of the raw waste water was 22 TCU while 5.2 TCU was recorded for bamboo treated wastewater. These colour values for treated wastewater is in line with NESREA tolerance value of 7.0 TCU. These showed that the treatment was effective in reducing the level of dissolved and suspended solid and other pollutants in the raw sampled wastewater.

Sulphate

Sulphate (SO_4^{2-}) is a chemical compound composed of sulphur and oxygen atoms and is widely used in industries. For instance, barium sulphate is a metallic sulphate and a type of synthetic pigment used in paint making industry to give the paint the right colour. Hence, sulphate in wastewater sampled from a paint making industry may be due to the use of barium sulphate. Sulphate changes the taste of water to bitter and causes corrosion in plumbing especially when copper piping is used. The sulphate concentration recorded for raw wastewater and wastewater treated with bamboo based activated carbon were 1025mg/l and 163mg/l respectively. The sulphate concentration for treated wastewater was within NESREA tolerance value of 250mg/l.

Chemical Oxygen Demand

Chemical Oxygen Demand is the mass of dissolved oxygen that will be consumed during oxidation of chemical organic pollutants in water which is also refer to an indicator of the amount of chemical organic pollutant in a wastewater sample. The values of COD for raw waste water was 5211mg/l, while that for the treated wastewater using the locally produced activated carbon from bamboo was 70.27mg/l. This value for treated waste water was less than the NESREA tolerance value of 90mg/l. COD value is an excellent way of monitoring the efficiency of wastewater treatment. Reduction in COD concentration of the wastewater after treatment was observed. This shows that adsorption process using activated carbon in treating wastewater with high Chemical Oxygen Demand concentration is very effective.

Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) is an estimation or measure of dissolved oxygen consumed (or required) by aerobic microorganisms while decomposing organic matter under aerobic conditions. It is generally used as an indicator of the amount of organic pollutants in a given wastewater sample. The higher the BOD level in a wastewater sample, the more polluted the wastewater and the lower the Dissolved Oxygen. The concentration of BOD in the raw wastewater was 3125mg/l while that of the treated water with bamboo based activated carbon was 48.93mg/l. The final value complied NESREA tolerance limit (50mg/l).

The high value of BOD implied presence of large quantities of aerobic microorganisms that utilizes the dissolved oxygen in the untreated wastewater sample while the reduction in the BOD values after treatment indicate the decrease in the quantity of the microorganism less dissolved oxygen are consumed. The wastewater treated with bamboo based activated carbon have concentration less than the tolerance value of 50mg/l, making bamboo based activated carbon more effective in reduction of BOD in wastewater from paint making industry.

Total Suspended Solid

Total Suspended Solids (TSS) are fine particulate matter that remains suspended in water and are categorized as particles that are larger than 2 microns found in water column. These particles in water can be trapped in a filter and provides an actual particulate matter for a given volume of water sample. TSS is the most visible indicator of water quality as the more solids present in water, the less clear the water. TSS in the wastewater sample contains particle of raw materials for making of paints and also impacts negatively on color or overall turbidity of water. The total suspended solid values were 1010mg/l and 23.19mg/l for raw and treated wastewater samples respectively. The reduction in TSS value of shows that the particles of pollutants present in the wastewater decreased and now safe for discharge because the TSS value is now below the tolerance value.

Total Dissolved Solid

Total Dissolved Solid (TDS) is the concentration of dissolved substances in water and particles that are less than 2 microns in water columns. TDS are made up of inorganic salts and other small amount of organic matter. TDS is also regarded as dissolved ions, including salts, minerals and metals found in waste water. The TDS levels recorded for the raw and treated waste were 2100mg/l and 439mg/l respectively. The result of the analysis shows that values obtained after treatment complied with the regulatory tolerance value was a significant decrease in TDS value of raw wastewater.

Calcium

Calcium exist naturally in water owing to its natural occurrence in the earth's crust. Calcium is a chemical element categorized as an alkaline earth metal, calcium is a reactive metal that forms a dark oxide-nitride layer when exposed to air whose physical and chemical properties are most similar to its heavier homologues. High concentration of soluble calcium in industrial wastewater is problematic due to calcification during downstream processing and largely responsible for water hardness and may negatively influence toxicity of other compounds. The calcium concentration in the raw wastewater was 401.45ppm while that of treated wastewater sample was 8.9ppm. Significant reduction in calcium concentration was recorded with treatment, hence, activated carbon from bamboo are effective material in wastewater treatment.

Hardness

Water hardness are usually attributed to high mineral content and are classified into permanent and temporary hardness. Generally, the presence of metallic cations makes water hard; permanent hardness are linked to the amount and concentrations of cations with charges greater than or equal to 2+ while temporary hardness are due to the presence of dissolved bicarbonate minerals (calcium bicarbonate and magnesium bicarbonate). Permanent hardness is linked to the presence of sulfate and chloride compounds. The hardness level in the raw and treated wastewater samples were 550mg/l and 139.83mg/l respectively. The final value for the parameter was greater than the tolerance value of 100mg/l.

Lead (Pb)

Lead pigment is one of the primary materials used for paint making, hence its presence in paint based waste water. Exposure to Pb is dangerous because of its poisonous nature, thus there is a strong need for its elimination from paint making wastewater before discharge to the environment.

Lead is one of the components of paint that helps to hasten drying, improve durability as well as keep fresh appearance and fend against corrosion – causing moisture. It is therefore corrosion resistant, hence its application in paint manufacturing. There are three common forms of lead pigment use in paint making industry and these includes lead (II) chromate (PbCrO4) refers to as yellow lead, lead (II, IV) Oxide (Pb_3O_4) refers to as red lead and lead (II) carbonate ($PbCO_3$) also known as white lead. The lead concentration in the raw wastewater was 13.8mg/l while the level after treatment with bamboo based produced activated carbon was 0.33mg/l. The value obtained after treatment was still higher than the NESREA tolerance value (0.05mg/l) thus there is need to employ other treatment method.

Cadmium

Cadmium pigment is a type of pigment containing cadmium and serves as the main source of cadmium in paint making wastewater. The Cd concentration in the raw wastewater was 41.1mg/l while the level after treatment with bamboo based produced activated carbon was 0.89mg/l. The value obtained after treatment was within the NESREA value (1.0mg/l) thus the treated waste water can be discharged into the environment.

Total Coliform

Total Coliform are bacteria that are usually found in paint and they shortens the life span of paints. These class of microorganism are the most prevalent spoiling organisms hence the addition of biocide during paint manufacturing. The biocide renders the bacteria that made up the total coliform immobile and therefore elongates the life span of such paints. The total coliform counts recorded in the raw waste water was 1220 cfu while 433 cfu was recorded for the treated waste water using dry bamboo based activated carbon. The value obtained was still slightly higher than the NESREA tolerance value (400 cfu).

4.0 Conclusion

The following were observed and deduced from the study that employed dry bamboo based activated carbon for paint wastewater treatment:

- ✓ Heavy metals, total dissolved solid, total suspended solid, chemical oxygen demand, biochemical oxygen demand, etc. were present in high concentration in the raw paint’s based waste water.
- ✓ The produced activated carbon from agricultural waste when used for treatment of waste water demonstrated high efficiency and effectiveness in treating wastewater from paint industry as a result, making the waste water acceptable for discharge in the environment.
- ✓ There were reduction in concentration of pollutants in raw wastewater after treatment. Lead was reduced by 97.61%, cadmium 97.83%, total dissolved solid 79.10% and hardness 74.58% respectively.
- ✓ The activated carbon produced was effective and efficient when employed for treatment of waste water from paint making industry.

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