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Assessment of Rice Husk-Based Activated Carbon as Adsorbent in Domestic Wastewater Treatment

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ABSTRACT

Indiscriminate discharge of wastewater into the environment is of utmost concern, especially in developing countries. This study evaluated the efficiency of rice husk based activated carbon in wastewater samples harvested from a students' hostel and a restaurant within the Federal University of Technology, Akure. The adsorbent used was produced from rice husk using hydrogen tetraoxosulphate (VI) acid (H_2SO_4) as the activating agent. The aim of this study was to assess rice husk-activated carbon for the reduction of physicochemical parameters such as hardness, pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), total dissolved solid (TDS), total suspended solid (TSS), and heavy metals which include chromium (Cr), lead (Pb), manganese (Mn), and iron (Fe). The wastewater samples were treated using activated rice hush ash of particle size (180 µm) at four different doses (30, 35, 40, 45 grams/400 ml). The results showed that the different doses of activated carbon had different removal efficiency. It was observed that the optimum dosage was 40g for DO, COD, BOD, and TDS while 30g was optimum for Hardness. It was also observed that an increase in the concentration of rice husk adsorbent led to an increase in the removal efficiency for the heavy metals (Cr, Mn, Pb, and Fe). The maximum percentage removal of DO, COD, BOD, TDS, and TSS, with rice husk was 21%, 58%, 72%, 21%, and 57% respectively. After the treatment of the domestic wastewater and comparing with the WHO standard, the treated wastewater quality was found to be safe for direct discharge into surface water bodies and irrigation purposes.

Keywords: Rice husk, Adsorption, Activation carbon, Domestic wastewater

INTRODUCTION

Domestic wastewater simply refers to used water that are mostly discharged from residential sources and are produced by activities including food preparation, laundry, cleaning, and personal hygiene (Ojo, 2022). Kitchen wastewater may have minimal pathogenic content and low pollution strength depending on its quality and composition. It may also contain easily biodegradable organic components. As a result, this effluent will be considerably simpler to clean, safer to recycle, and more likely to be reused (Bernard et al., 2003).

Rice husk is an undesirable agricultural mass residue in the Southwest region of Nigeria and is a by-product of the rice milling industry. In quantity, it's one of the world's largest agriculture residues. Based on the weight of the whole rice, it represents about 20% of the total rice produced (Daifullah et al., 2003). Around 100 million tons of rice husk are accessible each year for use in developing nations alone, where there is an estimated yearly production of 500 million tonnes of rice. In earlier times, rice husks were used to make panels and blocks for use in civil building. The rice business also used them as an alternative source of energy for boilers (Abdelwahab et al., 2005).

As stated by Daifullah et al. (2003) rice husk is made of the following substances: 32.24% cellulose, 21.34% hemicellulose, 21.44% lignin, 1.82% extractives, 8.11% water, and 15.05% mineral ash. However, there is significantly more rice husk available than is needed locally, which has made disposal difficult. Research on fully utilizing agricultural waste means avoiding burning the rice husks as wastes are worth like. The industrial utilization of rice husks is currently being used for fertilizer, building materials, and pillows (Shuhadah and Rohasliney, 2011). The utilization of rice husk will benefit environmental management in two different ways. The first was the possibility of partially reducing and producing valuable, value-added adsorbent from the vast volume of rice husk trash. Second, the creation of a cheap adsorbent may allow for the affordable eradication of air and water pollutants (Hameed and Ahmed, 2009). The effectiveness of using agricultural products as adsorbents for water purification has been studied by numerous scientists, engineers, and environmentalists (Adeolu et al., 2016). In addition to being extremely affordable, they are also made in big enough quantities to be widely accessible. The low-cost agricultural waste materials that have been researched include yam peels, banana peels, soy bean hulls, cowpea husks, rice husks, and so on (Singh et al., 2004). Mohan and Singh (2004) defined Activated carbon (AC) as a black, amorphous solid containing a significant portion of fixed carbon content and other materials such as ash, water vapor, and volatile matter in smaller percentages. Activated carbon (AC) is a material with a high degree of absorbency and an extended surface area (Bansal and Goyal., 2005).

The objectives of the study are therefore to carry out water quality tests on the wastewater samples before and after the treatment and compare the results obtained with the World Health Organization (WHO) standard for treated wastewater.

MATERIALS AND METHODS

Activation of Rice Husk

Rice husk was collected and washed in distilled water to remove the dirt and then oven dried at a temperature of 30°C. The oven-dried rice husk was then ground to fine particles and carbonized under a temperature of 700°C for two hours in a closed system (porcelain crucible, which is a local clay pot), and then cooled to room temperature. After that, the rice husk ash produced was then ground and sieved in order to obtain particle size passing through 300 µm and retained on a 180 µm sieve. The rice husk ash was then washed in distilled water and then activated chemically by soaking it in a 10% diluted sulfuric acid for 16 to 18 hours. The rice husk-based activated carbon obtained was rewashed in distilled water to remove the free acid and dried on a hot plate to obtain the final result.

Experiment Procedure

Water samples were collected in already washed sample bottles from a hostel and a restaurant in the Federal University of Technology, Akure, and taken to the laboratory for treatment and analysis using standard laboratory procedures and methods. Different doses (ranging from 30g – 45g) of each activated carbon were added to 400ml of the water sample and then the beakers were placed on the orbital shaker machine. The machine was set at about 150rpm for rapid mixing for 1 hour in order to agitate the samples. The samples were filtered using a filter paper, the filtered sample was kept in 100ml bottles and then the test to measure each water parameter was carried out on each sample.

RESULTS AND DISCUSSION

The effect of the activated adsorbent while changing the dose was studied using a particle size of 180µm at four different concentrations (30, 35, 40, 45grams /400 ml) in order to check the effect of dosage on the reduction of impurities present. Experimental results obtained from rice husk are discussed below. The optimum dosage for the activated carbon is 40g for DO, COD, BOD and TDS while 30g is optimum for Hardness. The removal efficiency of the activated adsorbent increased by increasing the concentration for the heavy metal (Cr, Mn, Pb, and Fe).

Effect of adsorbent dosage on Hardness

Figure 1 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of hardness on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The water sample can be classified as very hard water since its concentration of Calcium Carbonate for the Hostel sample and Restaurant sample is 263mg/L and 394mg/L respectively but the effect of rice husk activated carbon gave a moderately hard water. Also, from Figure 1, it can be concluded that the activated carbon dosage is most effective at 30g having a %removal of 58% and 74% for the Hostel water sample and Restaurant water sample respectively.

Effect of adsorbent dosage on pH

Figure 2 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of pH on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The pH sample of the wastewater sample before treatment for the Hostel and Restaurant was 7.3 and 7.2 respectively. It was observed that the adsorbent did not in actual fact affect the pH value as it is still within the WHO recommended pH value which is 6.5 – 8.5.

Effect of adsorbent dosage on dissolved oxygen (DO)

Figure 3 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of dissolved oxygen (DO) on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The DO value of the water sample for the Hostel and Restaurant before treatment was 7.8mg/L and 8.3mg/L respectively. It can be deduced that the value increased for all doses except for 35g. Also, the value increased for the Restaurant sample for all doses except for 35g which decreased.

The adsorbent can be said to increase the DO value of the sample to moderately above the acceptable limit of WHO which is 5mg/L. The optimal dosage for DO improvement for both samples can be said to be 40g.

Effect of adsorbent dosage on chemical oxygen demand (COD)

Figure 4 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of COD on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The COD value of the wastewater samples for the Hostel and Restaurant before treatment were 1,200 mg/L and 1,100mg/L. From Figure 4, COD values decrease largely to 400mg/L. For the Hostel sample, the least COD value is 500mg/L at 40g and for the restaurant sample, also the least COD value is 400mg/L at 30g. Although the treated value is above WHO standard but also the effect of the adsorbent could be seen.

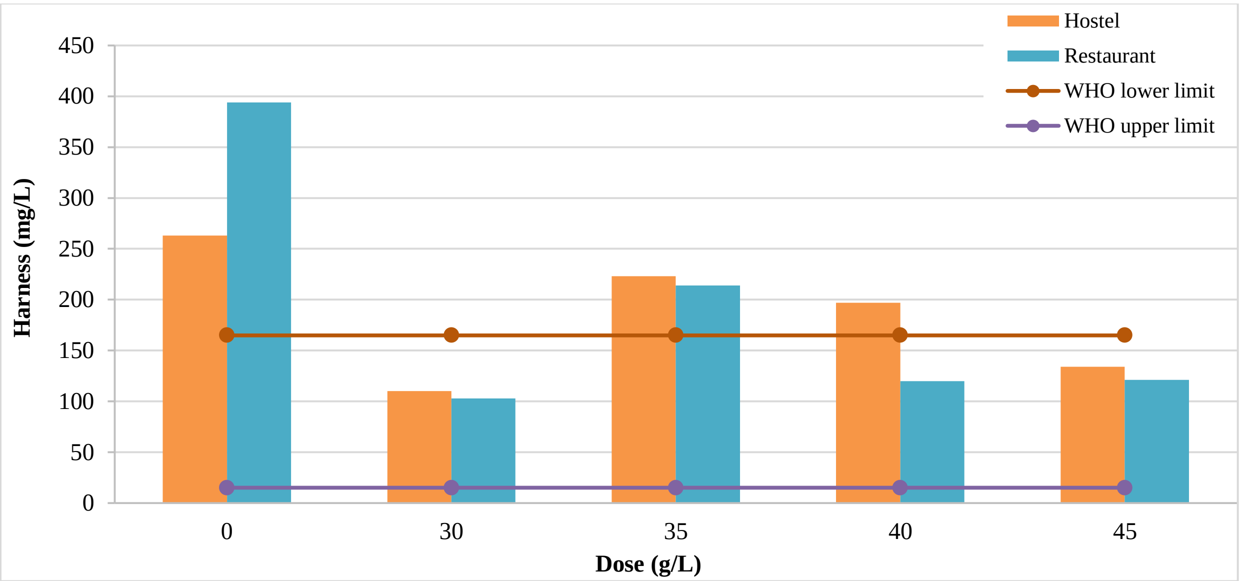

Figure 1. Effect of adsorbent dosage on hardness

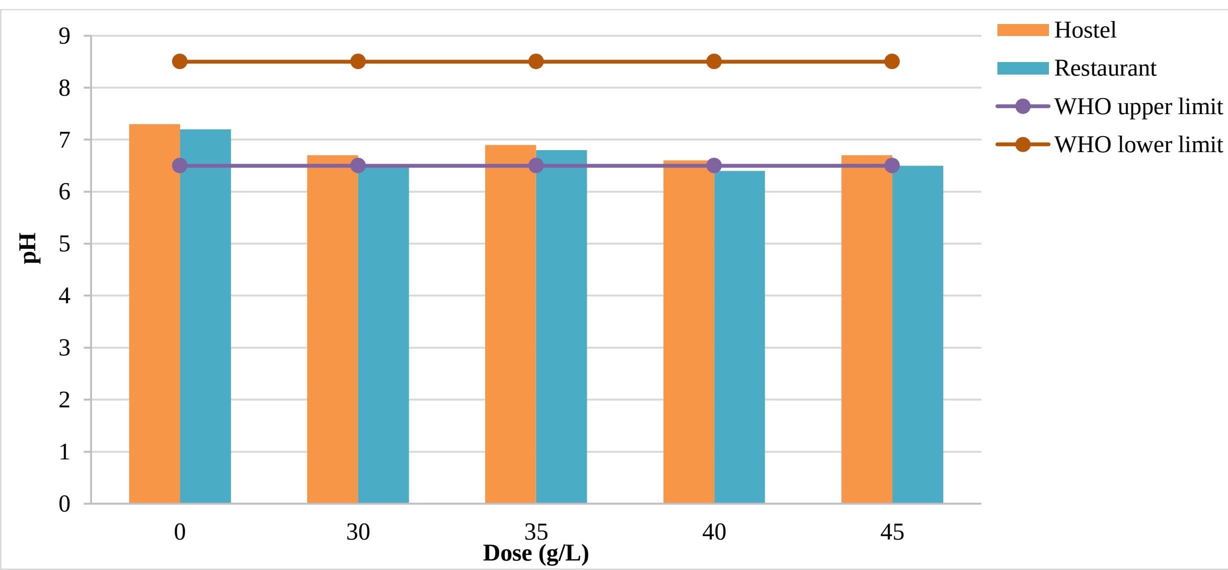

Figure 2. Effect of adsorbent dosage on pH

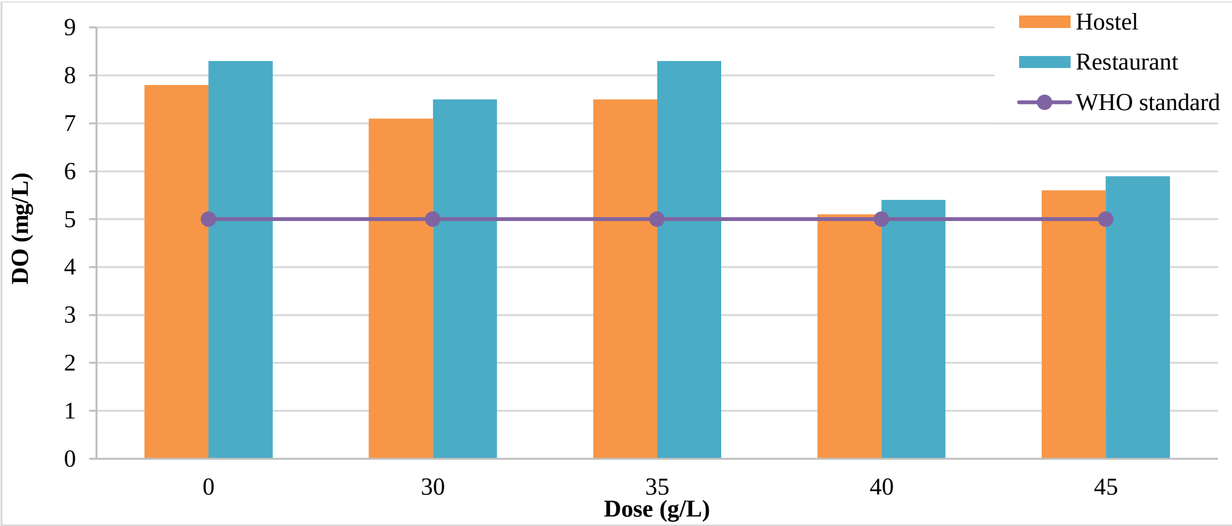

Figure 3. Effect of adsorbent dosage on dissolved oxygen (DO)

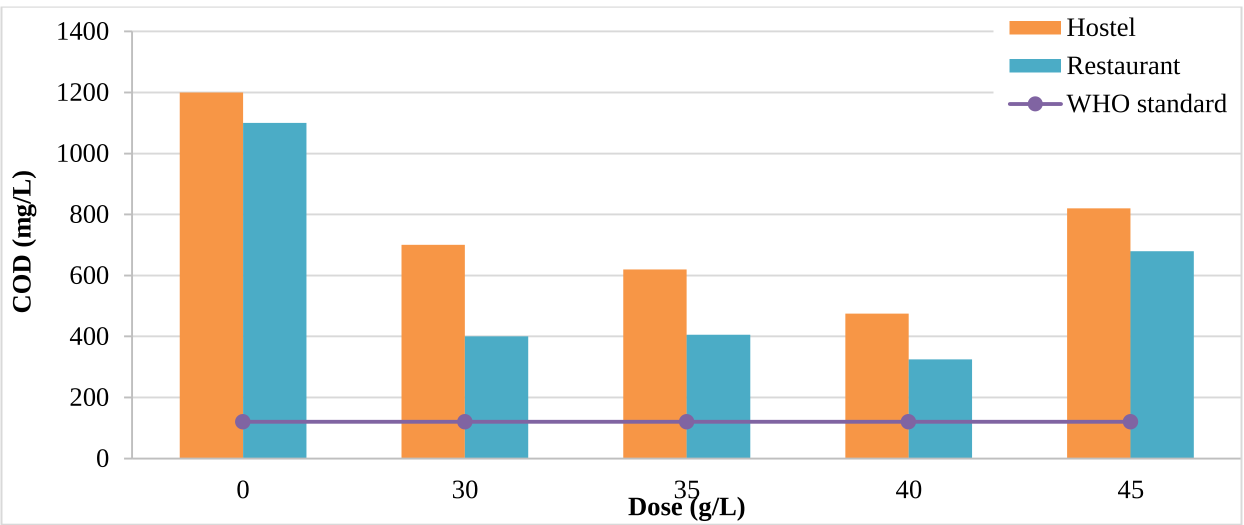

Figure 4. Effect of adsorbent dosage on chemical oxygen demand (COD)

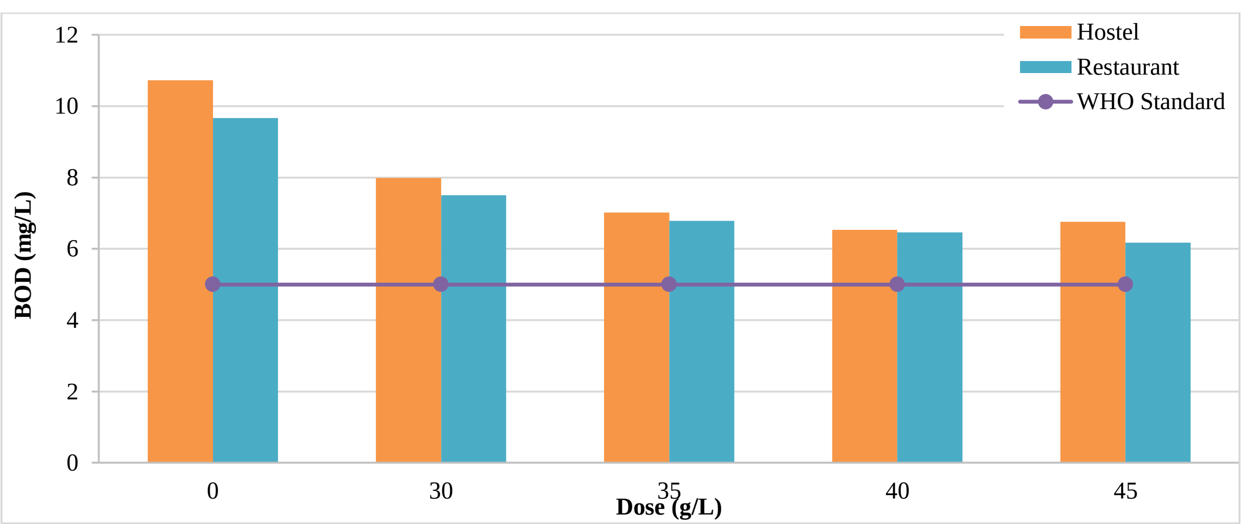

Figure 5. Effect of adsorbent dosage on biochemical oxygen demand (BOD)

Effect of adsorbent dosage on biochemical oxygen demand (BOD)

Figure 5 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of BOD on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The BOD value of the wastewater samples for the Hostel and Restaurant before treatment were 10.73mg/L and 9.67mg/L. From Figure 5, the values for BOD decrease to 6.46mg/L. For the Hostel sample, the least BOD value is 6.53mg/L at 40g and for the restaurant sample, the least BOD value is 6.17mg/L at 45g. Although the treated value is above WHO standard but also the effect of the adsorbent could be seen.

Effect of adsorbent dosage on total dissolved solid (TDS)

Figure 6 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of TDS on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The TDS value of the wastewater samples for the Hostel and Restaurant before treatment were 714.50 mg/L and 651.00mg/L. From Figure 6, TDS values increased due to the effect of the adsorbent used. For the Hostel sample, the highest TDS value is 865mg/L at 40g and for the restaurant sample, the highest TDS value is 816.50mg/L at 40g. Although the treated value is below WHO standard but also the effect of the adsorbent could be seen.

Effect of adsorbent dosage on Chromium (Cr) Content

Figure 8 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of Chromium (Cr) on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The Cr value of the wastewater samples for the Hostel and Restaurant before treatment were 0.089mg/L and 0.113mg/L. The effect of adsorbent dosage on the adsorption of Cr was examined as a function of varying the adsorbent dosage 30g, 35g, 40g, and 45g and keeping all other parameters constant (T_{room} = 23°C, RPM = 100, V=400 ml) with the help of magnetic shaker. It was observed from Figure 8 that, as the adsorbent dosage increases, the Cr removal also increases, which can attribute to the increased adsorbent surface area. It can be concluded that the optimum dosage is 45g.

Effect of adsorbent dosage on total suspended solids (TSS)

Figure 7 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of TSS on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The TSS value of the wastewater samples for the Hostel and Restaurant before treatment were 425.50 mg/L and 572.00mg/L. From Figure 7, the least TSS value for the Hostel sample is 182.00mg/L at 45g, and for the restaurant sample, the least TSS value is 280.00mg/L at 45g, therefore it can be concluded that the effective dosage is at 45g. Although the treated value is above WHO standard but also the effect of the adsorbent could be seen.

Effect of adsorbent dosage on Iron (Fe) content

Figure 9 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of Iron (Fe) on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The Fe value of the wastewater samples for the Hostel and Restaurant before treatment were 0.110mg/L and 0.195mg/L. The effect of adsorbent dosage on the adsorption of Fe was examined as a function of varying the adsorbent dosage 30g, 35g, 40g, and 45g and keeping all other parameters constant (T_{room} = 23°C, RPM = 100, V=400 ml) with the help of magnetic shaker. It was observed from Figure 9 that as the adsorbent dosage increases, the Fe content increases, thereby increasing the Fe present afterward, which can attribute to the increased adsorbent surface area.

Effect of adsorbent dosage on Manganese (Mn) Content

The Figure 10 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of Manganese (Mn) on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The Mn value of the wastewater samples for the Hostel and Restaurant before treatment were 0.069 mg/L and 0.150mg/L. The effect of adsorbent dosage on the adsorption of Fe was examined as a function of varying the adsorbent dosage 30g, 35g, 40g, and 45g and keeping all other parameters constant (T_{room} = 23°C, RPM = 100, V=400 ml) with the help of magnetic shaker. It was observed from Figure 10 that as the adsorbent dosage increases, the Mn removal also decreases, thereby increasing the Mn present afterward, which can attribute to the increased adsorbent surface area.

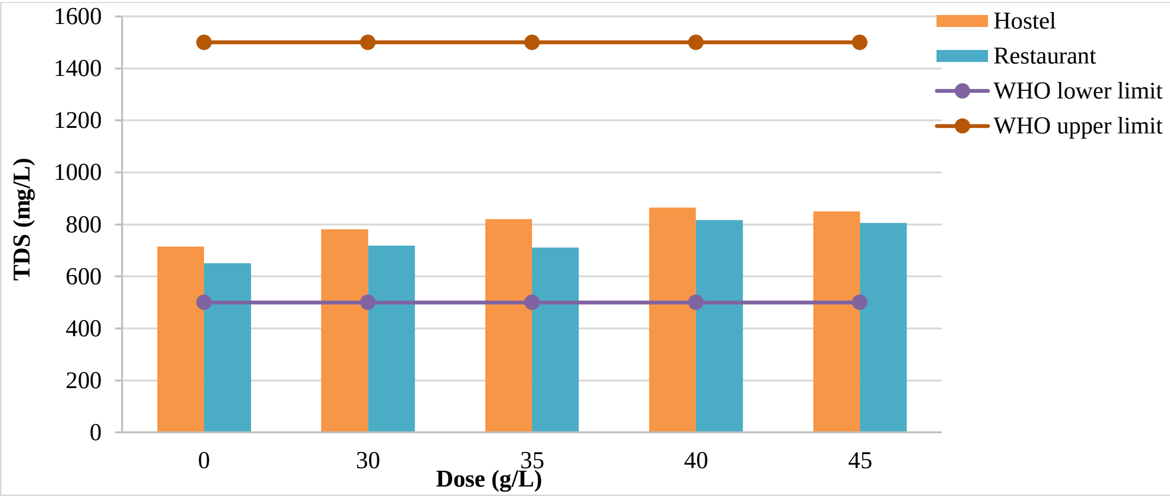

Figure 6. Effect of adsorbent dosage on total dissolved solid (TDS)

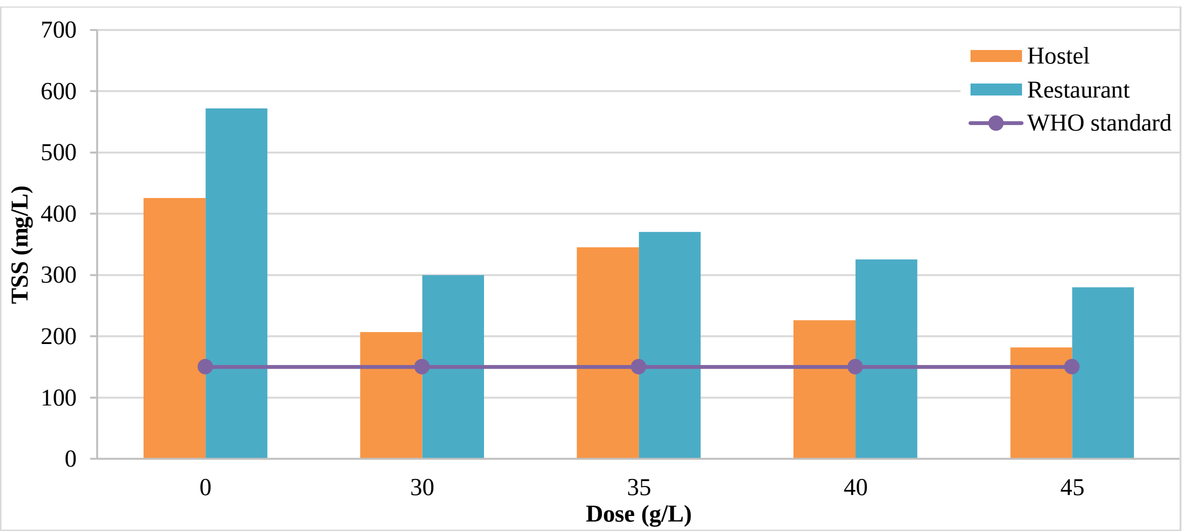

Figure 7. Effect of adsorbent dosage on total suspended solids (TSS)

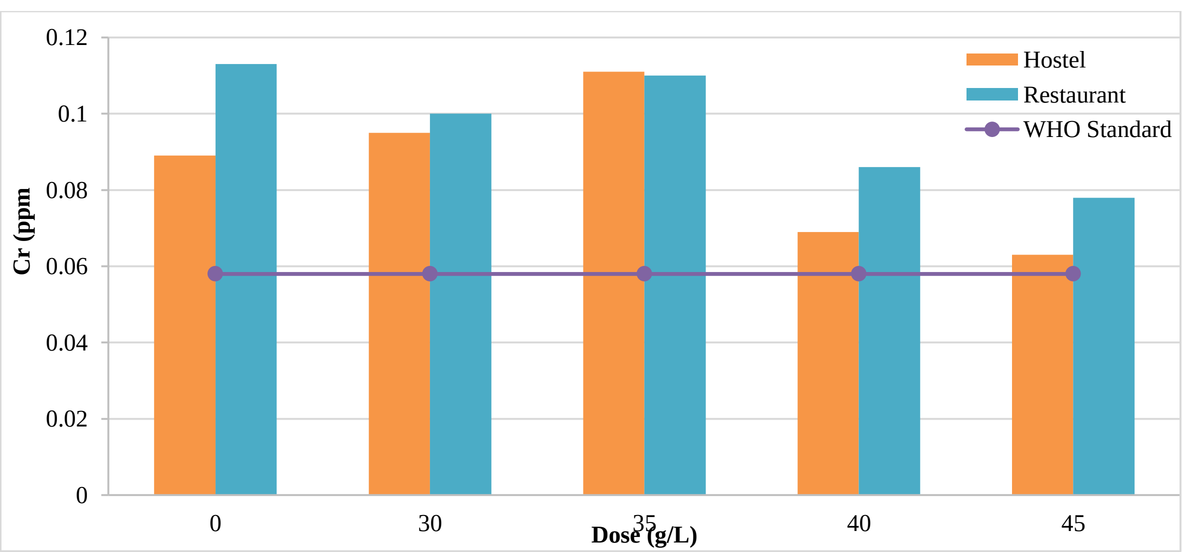

Figure 8. Effect of adsorbent dosage on Chromium (Cr) Content

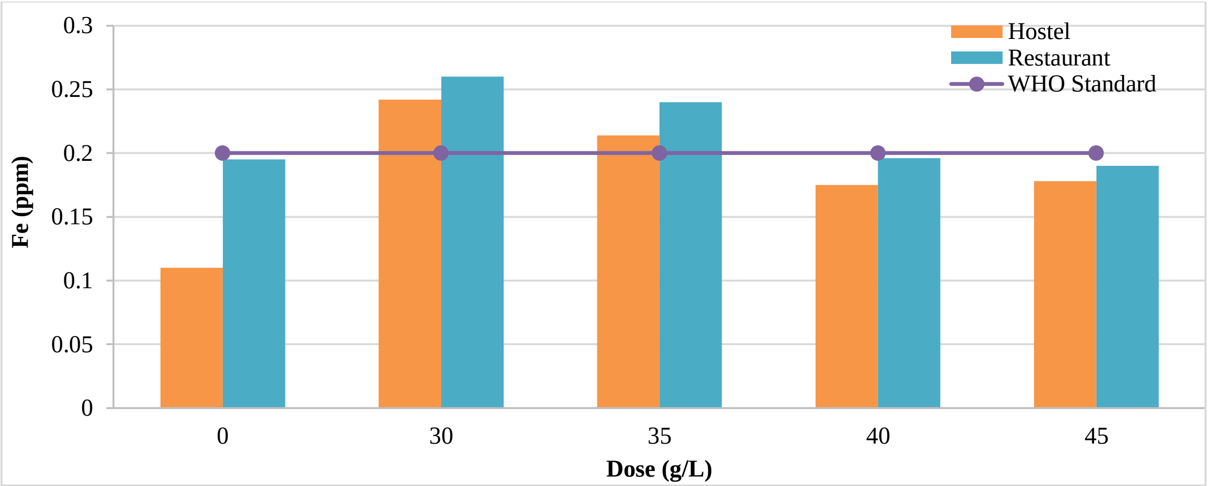

Figure 9. Effect of adsorbent dosage on Iron (Fe) Content

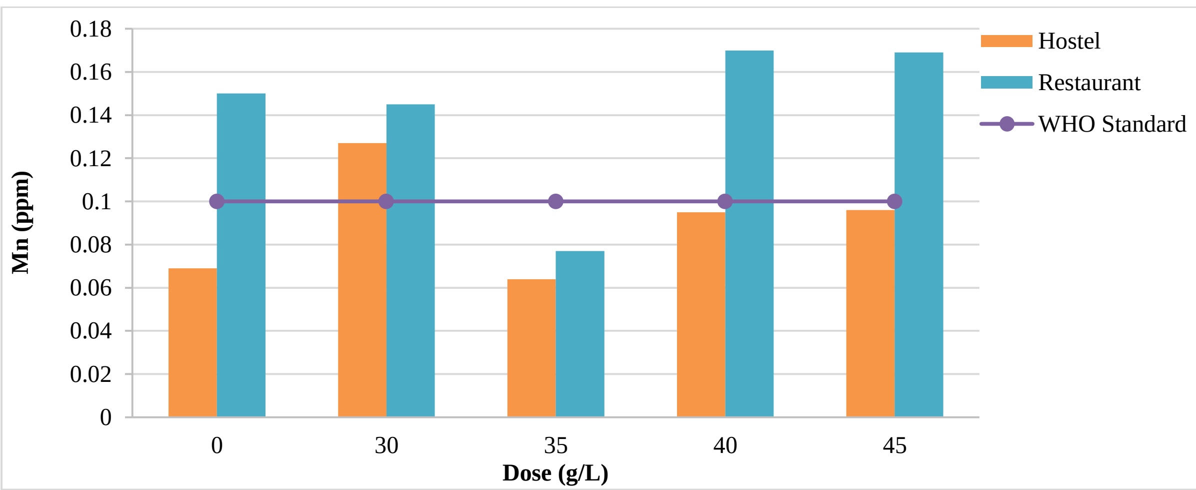

Figure 10. Effect of Adsorbent Dosage on Manganese (Mn) Content

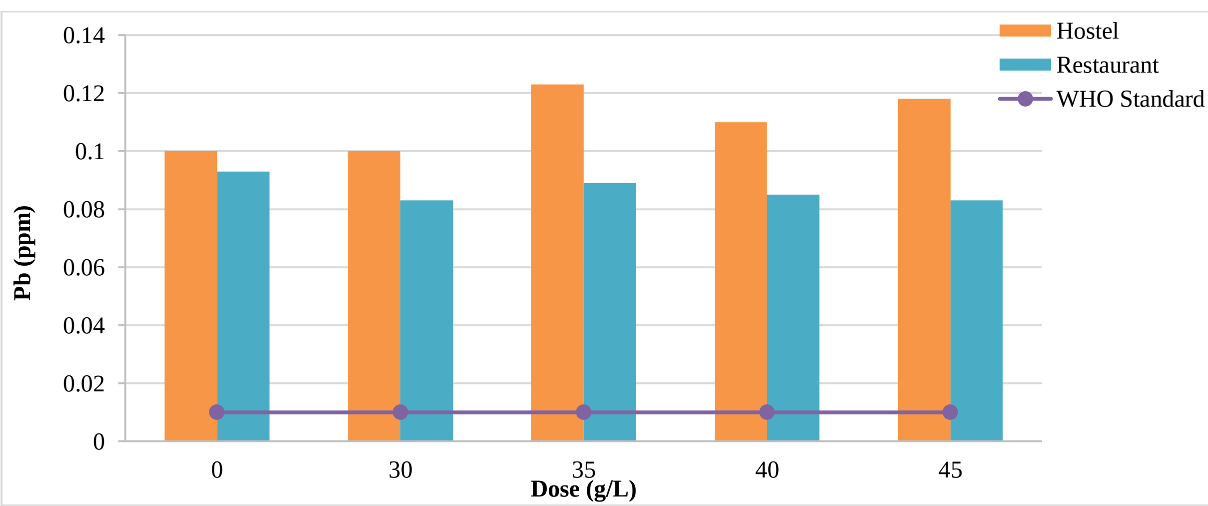

Figure 11. Effect of Adsorbent Dosage on Lead (Pb) Content

Effect of adsorbent dosage on lead (Pb) content

Figure 11 shows the results of both samples (Hostel and Restaurant) using different doses of activated carbon for the treatment of Lead (Pb) on the wastewater sample. The doses were varied from 30g to 45g of activated carbon. The Pb value of the wastewater samples for the Hostel and Restaurant before treatment were 0.100mg/L and 0.093mg/L. The effect of adsorbent dosage on the adsorption of Pb was examined as a function of varying the adsorbent dosage 30g, 35g, 40g, and 45g and keeping all other parameters constant (T_{room} = 23°C, RPM = 100, V=400 ml) with the help of magnetic shaker. It was observed from Figure 11 that as the adsorbent dosage increases, the Pb removal increases, which can attribute to the increased adsorbent surface area.

Effectiveness of rice husk adsorbent

The result of the effect of dosage on both samples on the water parameters which were tested during the research, as compared with the WHO standard for drinking water. The maximum percentage removal of DO, COD, BOD, TDS, and TSS, with rice husk is up to 21%, 58%, 72%, 21%, and 57% respectively.

DECLARATIONS

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Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Authors' contribution

Michael O. Ojedele performed the experiments, analysed the data obtained and wrote the manuscript. Ochuko M. Ojo and Hephzibah A. Abe designed the experimental process and revised the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare no competing interests in this research and publication.

CONCLUSION

The selected low-cost activated carbon is a promising material for the preparation of rice husk adsorbent by using diluted sulfuric acid (H_2SO_4) as the activating agent. From the research carried out, the following conclusion can be drawn from the effect of the different doses of the adsorbent on Hardness, pH, BOD, COD, DO, TDS, TSS, Lead, Manganese, Chromium, and Iron of the treated water samples. The maximum percentage removal of DO, COD, BOD, TDS, and TSS, with rice husk is up to 21%, 58%, 72%, 21%, and 57% respectively. The municipal wastewater treatment with rice husk-based activated carbon can be discharged into the water bodies and can be used for irrigation purposes.

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