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Regeneration and Reuse of Neem Husk Activated Carbon in Hospital Wastewater Treatment

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Abstract:
This work assessed the optimum saturation point for reuse of activated carbon from Neem husk (Azadirachta Indica), activated with phosphoric acid (NHP) for the treatment of wastewater. The prepared adsorbent was used to assess physicochemical parameters such as BOD, COD, microbial load, nitrates, phosphates, chlorides, lead, nickel, cadmium, chromium and zinc in the multi component system. The studies showed that the amount of the studied parameters decreases as the number of cycles of regeneration. The COD and BOD decreased from 60-7%, and 80-60% respectively as the cycle runs from 1- 5. The bacterial and fungal loads were high all through the cycles, at a level of between 92 to 99 % removal even at the 5th cycle. However, the performance of the carbon decreased from 65-18%, 81-5% and 95-49% for adsorption of Cd, Cr and Zn ions respectively as the cycle runs from 1 to 5. It was generally observed that the adsorbents can be reused up to four times before complete saturation.

Keywords: *Neem husk, carbonization, activation, hospital wastewater, adsorption*

1. Introduction

Granular activated carbon (GAC) is commonly used to remove biological and synthetic organic chemicals from wastewater (Andrea, 2004). Once a GAC is used or exhausted, the GAC must be disposed of or recycled in some ways such as land filling, incineration, and thermal reactivation. Replacement and subsequent disposal of spent GAC is expensive (Andrea, 2004). By increasing the service life of the GAC, costs can be decreased. Regeneration of the adsorbent material is of crucial importance in the economic development (Dwivedi *et al.,* 2008). Methods used to regenerate the service life of the GAC include; biodegradation (metabolism and cometabolism), chemical regeneration, and steam regeneration. Regeneration renews the active sites of the adsorbent without damaging the capacity of the adsorbent, making it reusable in several adsorptions and desorption cycles (Dwivedi *et al.,* 2008). The service life of the activated carbon can be increased because the film that forms on the GAC can degrade the adsorbates, thereby reducing competition for GAC adsorption sites and allowing any remaining adsorbates to adsorb onto the GAC to a greater extent (Andrea, 2004). Degradation of adsorbed adsorbates renews the GAC's capacity for adsorption and lengthens the GAC service Life, thereby decreasing operation and maintenance costs (Speitel *et al.,* 1987). The current study uses hot distilled water to wash the used activated carbon to clear the surface and pores of physically bound materials, with the most minimal chemical interaction. This transformed the spent activated carbon into less toxic by-products and the sorption capacity of the carbon is re-established; thus, increasing the useful life of the activated carbon and the costs of water treatment are reduced ((Hajira and Muhammed, 2008). This research work assesses the economies and vis-a-vis the performance of regenerated and reused activated carbon from Neem husks (*Azadirachta Indica*).

2. Materials and Methods

2.1. Preparation of Activated Carbon (NHP)
Neem husk was used to prepare the activated carbon samples. The neem husk was sundried for three days. The sundried sample was properly washed under running tap to remove dust and water-soluble impurities. Excess water accumulated during washing were allowed to drain, in open air for another 12 hours after which they were introduced into in a laboratory oven set at 105 ^{o}C and dried for a 24 hours. The dried samples were gently crushed using a ceramic laboratory mortar and pestle followed by sieving with a <400 µm aperture sieve. 50g of the neem husk samples were placed in large sized ceramic crucibles and carbonized at 350^{o}C in a muffle furnace for 8 hours and activated using H_3PO_4 by the method of Abechi *et al*., (2011). This was then sieved to particle size of 400 µm using laboratory sieves. The fine sieved samples were stored in a clean airtight container for further studies.

2.2. Column Adsorption Studies
Fixed bed columns were prepared by dry packing technique, where cylindrical borosilicate glass columns (diameter - 2.4 cm, length- 32.2 cm, volume- about 150 cm^3) mounted vertically were packed with about 10g each of the prepared activated carbon (i.e. about 12 cm^3 column volume) from the top of the column and allowed to settle by gravitational force. The bottom part of the adsorbent in the column was packed small amounts with nonreactive glass wool, using distilled water, to a column height of approximately 0.5 cm column height to prevent the adsorbents from blocking the tap of the column and returning to the treated water samples. The schematic of the column adsorption setup is presented in Figure 1. The column with the adsorbent was washed with 10 cm^3 of distilled water prior to introduction of the wastewater samples to the column. Approximately 50 cm^3 of the wastewater was transferred into the column containing activated carbon and allowed to have contact with the adsorbent for 30 minutes. The adsorbent was kept submerged throughout the runs to avoid air entrapment in the bed. After the contact time had elapsed, the tap of the column was let open and the treated water (filtrate) allowed to drain and was collected in a beaker, measured and transferred into samples bottles prior to analysis.

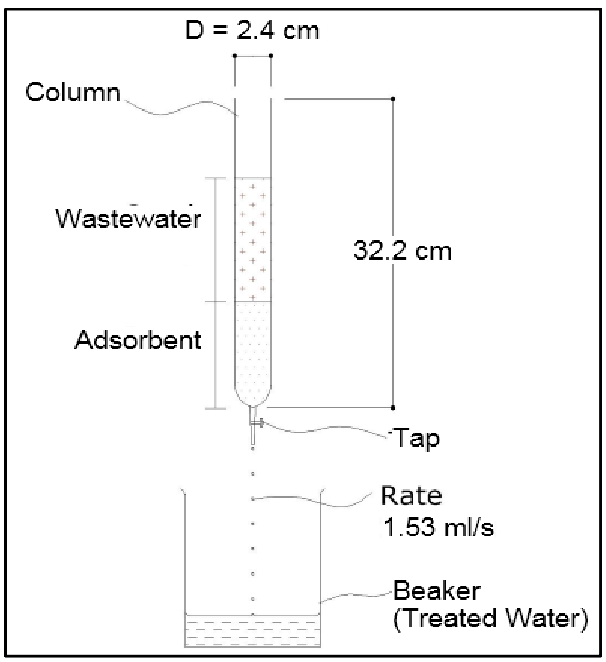

Figure 1: Schematic of laboratory column adsorption filter setup

Regeneration studies was carried out by reusing the adsorbent to determine its treatment efficiency after each adsorption-desorption cycle. After the initial adsorption process, the activated carbon sample was washed with about 100 cm^3 of hot distilled water and allowed to drain properly. After complete draining and cooling, 50 cm^3 of fresh wastewater sample is again introduced into the column and left for 30 minutes contact time. The procedure was repeated four more times and the regeneration data were used to explain the reuse capacity for each adsorbent.

3. Results and Discussion
The effect of regeneration and reuse of the activated carbon (NHP) on BOD, and COD, heavy metals (Cd, Cr, Zn, Ni, Pb) and microbial counts (bacterial and fungal counts) are shown in Figure 2 to 4. Figure 2 present the effect of the reused neem activated carbon on oxygen parameters (BOD and COD).

Biochemical oxygen demand is the amount of oxygen required by bacteria for breaking down to simpler substances, the decomposable organic matter present in any water, waste water or treated effluent. BOD can be used to evaluate the concentration of organic matter present in that kind of sample. This is generally carried out by measuring the amounts of dissolved oxygen (DO) present in any given sample before and after incubation in the dark at 20 degree Celsius for five days. High BOD value is indicative of high pollution statue of the wastewater. The BOD results shows a 80% decrease in value in the first cycle. This performance was recorded even until the fourth reuses (fourth cycle). The performance of the adsorbent dropped at the fifth cycle to a 60% decrease in the BOD value. This is indicate of effective removal of organic waste from the wastewater up to the forth cycle of reuse. It also point to the fact that the regeneration process employed was efficient.

Chemical oxygen demand is the amount of oxygen required for complete oxidation to carbon (IV) oxide and water of organic matter present in a sample of water, waste water or effluent. Figure 2 also shows the COD of the wastewater after exposure to the regenerated and reused adsorbent.

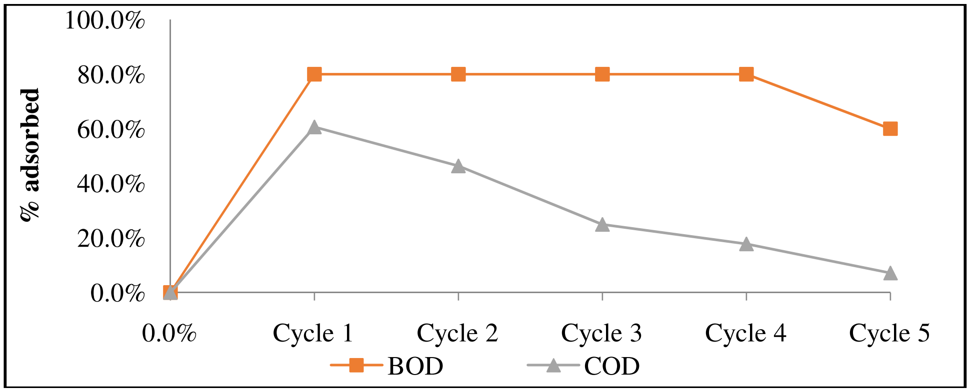

Figure 2: Effect of reuse of AC (NHP) on the DO, BOD and COD

The COD value was reduced by 60.71% after the first cycle. It was observed that the COD value was higher at the subsequent cycles and was highest at cycle five. This shows that the effectiveness of the carbon decreased with reuse of the activated carbon and that the best performance of the adsorbent was obtained at cycle one. The COD was reduced by only 46.43% at the second cycle by 25.0% at the third cycle. The fourth cycle and fifth cycles shows a nearly constant reduction of the COD by only 17.86% and 17.14% respectively.

Figure 3 shows the performance of NHP for metal adsorption. The regeneration and reused of the activated carbon was most effective for Zn, which recorded about 50% recovery even at cycle five. However, the performance of the adsorbent decreased with the cycles and was maximum at cycle one. The amount of Zn removed was higher at all cycles compared with the other metals, showing the adsorbent have greater affinity to the activated carbon than the other metals. Cd, Ni and Pb had more than 50 % removal from the wastewater up to third cycle. Cr had more than 80 % removal in the first two cycles and thereafter reduced by 50% at the third cycle and finally reduced to 5.32% removal at the fifth cycle. The rapid drop in the performance of the adsorbent towards Cr and Cd after the first two cycles suggested chemisorptions of Cr and Cd to the surface of the carbon while adsorption of Zn, Pb and Ni ions onto the adsorbent suggest a physisorption process.

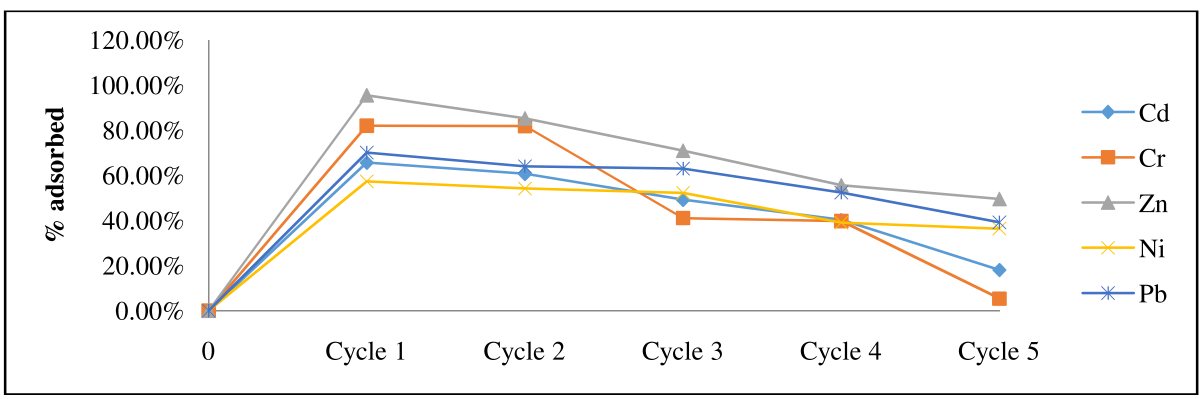

Figure 3: The effect of reuse of AC (NHP) on the heavy metal concentrations

Figure 4 shows the relationship between microbial load and cycles of reuse of the activated carbon. The results generally show that the reuse activated carbon was very effective in reducing microbial load of the wastewater up to fifth cycle. The result suggests that the adsorbent has good antimicrobial properties. The result also shows that the adsorbent is better for reducing the fungal count compared to bacterial count. Generally, it can be deduced that the regeneration process was very effective and that the adsorbent can be exploited for use several time before its life span is exhausted. The economy of regeneration of the carbon is therefore high and that the regeneration process is a successful way to cut cost of preparation activated carbon from Neen husk.

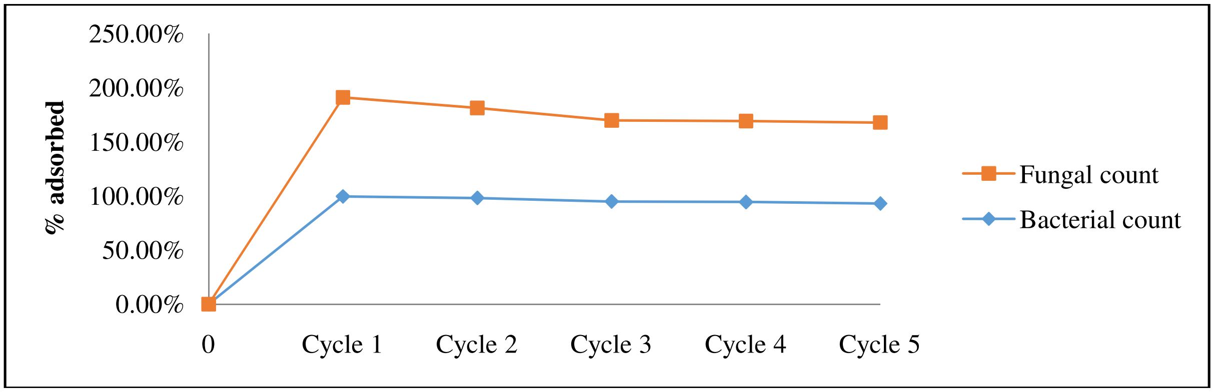

Figure 4: The effect of reuse of AC (NHP) on the microbial load

4. Conclusion

The studies show that the neem husk activated (NHP) is a good adsorbent for wastewater treatment. The result suggested that adsorption of Cr and Cd is a chemisorptions process while adsorption of Zn, Pb and Ni ions onto the adsorbent suggest a physisorption process. The adsorbent shows high effectiveness in its reuse up to a third time of regeneration for most of the metal ions. The results generally show that the reused activated carbon was very effective in reducing microbial load of the wastewater up to fifth cycle. This suggests that the adsorbent has good antimicrobial properties. Generally, the regeneration process was very effective and that the adsorbent can be exploited for use several times before its life span is exhausted. The economy of regeneration of the carbon is therefore high and that the regeneration process is a successful way to cut cost of preparation activated carbon from Neen husk.

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