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HEAVY METAL ADSORPTION CAPACITY OF ACTIVATED CARBON FROM ORANGE AND SOUR SOP SEEDS

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ABSTRACT

The activated carbon produced from Orange and Soursop seeds were used as adsorbents to remove Cobalt and Mercury ions from aqueous solutions. The samples were dried, powdered and activated by the use of 50% orthophosphoric acid by chemical activation method. Moisture content, ash content and percentage yield were characterized and the effects of initial ion concentration and time were evaluated using Atomic Absorption Spectroscopy (AAS). The results of characterization showed that soursop seed has higher percentage yield and ash content (28.5 and 5.53%) while orange seeds have higher moisture content (62.0%). Adsorption decreases with increase in time and concentration. Soursop seed activated carbon showed a better adsorbent of Cobalt while that of orange seeds showed a better adsorbent of Mercury. The study has shown that both adsorbents had the potential for heavy metal removal from aqueous solutions. The results from the study can be used for the development of efficient, clean and cheap technology for treating effluents. It is therefore recommended that bio char materials from other different sources be investigated for their capacity in removal of heavy metals from contaminated water.

Keywords: Adsorption, Activation, Adsorbent, Effluents, Concentration, Heavy metals

Introduction

Human vulnerability to the effects of heavy metals found everywhere in the universe has become a great environmental concern. Heavy metals such as Lead, Arsenic, Mercury, Cadmium, Cobalt, and Aluminum find their way to the underground water through leaching thereby producing dangerous toxins for our ecosystem. When heavy metals are assimilated, they accumulate primarily in the brain, liver, kidney, nervous and reproductive system. In 2021, Lopez-Botella and his colleagues linked sperm DNA damage and lower sperm quality that affects male fertility to heavy metal exposure. A recent review in 2024 by Ferahmandian and his group revealed that cadmium in humans leads to a 31% of increase in lung cancer. Heavy metal poisoning affects adults and children alike causing behavioral and cognitive problems; according to the study by Gudadhe et al. in 2024. Several studies pointed to many health issues like Alzheimer's disease, Amyotrophic Lateral Sclerosis, Parkinson's disease, Hemolytic Anemia, Lung embolism, Asthma, Respiratory Failure, Heart Disorders, Nausea and Dizziness. De Carvalho et al. in 2023 linked heavy metal exposure to skin diseases.

Routes of human exposure to heavy metals include ingestion, inhalation and dermal contact. Laoye and his group in their 2025 study stated that anthropogenic heavy metals are derived from industrial activities including mining, smelting and refining of ores, steel production, other metallurgical operations, product finishing and surface coating such as paints and electroplating. Obasi and his colleague in their 2022 study added pesticides, wood and leather treatment chemicals as contributing to human problems. Uncontrolled disposal of industrial effluents pose health issues. Abdullahi and Sani in 2020 reported welding operations as an environmental concern.

Conventional methods for removing heavy metals from industrial effluents include precipitation, coagulation, solvent extraction, electrolysis, membrane separation, ion exchange, adsorption, reverse osmosis and use of zeolite composites. These methods suffer with high capital and regeneration cost of the materials. Hence, there is a need for a new, innovative and cost-effective method for the removal of toxic substance from waste water. Adsorption involves the use of porous materials such as activated carbon, zeolites or biosorbents to capture heavy metal ions from waste water. Adsorption has advantage of low cost, minimizing sludge, efficiency, adsorbent regeneration and possibility of metal recovery. Activated carbons are amorphous materials characterized by expanded surface areas, porosity and availability of appropriate active centers which promote adsorption. A study carried out by Sardella and colleagues in 2015, reported that 98% adsorption capacity was achieved using grape seeds. Orange (*Citrus sinensis)* and Sour sop (*Annona muricata)* seeds are plant waste materials which can be easily gathered for preparation of low cost and effective activated carbon for adsorption of heavy metals from wastewater. Heavy metals that pollute the environment mostly spread through water. It is therefore important to control the environmental pollution caused by heavy metals by limiting heavy metals content in waste water. Adsorption process by using activated carbon to eliminate or reduce heavy metals from waste water will be the answer. This research addresses the critical gap of selecting the best activated carbon with the best capacity for adsorption of heavy metals. This study tends to evaluate the heavy metal adsorption capacity of activated carbon produced from orange and soursop seeds by producing and characterizing active carbon from orange and soursop seeds and to determine the heavy metal adsorption capacity of these activated carbons. The study also aims to compare the adsorption capacities of the two active carbons and carry out adsorption tests on the effects of concentration and time.

Materials And Methods

The materials used in this study include orange and soursop seeds, distilled water, Mercuric nitrate, Cobalt chloride and orthophosphoric acid. The apparatus includes pH meter, atomic absorption spectroscopy, weighing balance, muffle furnace, air drying oven, grinding machine, Fourier Transform Infrared Spectrometer (FTIR). The samples (orange and soursop) were brought from Eke Oko market in Anambra state. Reagents for the project were procured from the chemical market in Onitsha, Anambra State, Nigeria.

Preparation of Sample

The seeds were removed from the fruits washed and dried, and then ground to small particle size. The powder was sieved with 3.0 mm mesh and retained in 1.0 mm mesh size. 400g of ground samples were carbonized in a muffle furnace at $300^{\circ}C$ for 50 minutes (soursop seeds powder) and 30 minutes (orange seed powder) reducing them to 289g and 246g respectively.

Characterization of Activated Carbon.

The samples were characterized by determining the percentage yield, ash content and moisture content. The activated carbon was further analyzed for functional group using the Fourier Transform Infrared Spectrometer (FTIR)

50% orthophosphoric acid (H_3PO_4) was prepared and samples were impregnated in it which were heated and stirred until they formed slurry. The sample slurry were washed with distilled water individually to a pH of 6.7 for orange slurry and 6.8 for soursop slurry. They were further dried in an oven at a temperature of 105ºC for 4 hours.

Preparation of Aqueous Solutions for Adsorption.
Stock solutions of Cobalt Chloride ($CoCl_3$) molecular weight (164.28) and Mercuric Nitrate Hg (No_3) .$2H_2O$, molecular weight (342.62) were prepared by dissolving 0.28g of Cobalt Chloride and 0.17g of Mercuric Nitrate into 100ml distilled water.

Adsorption Test
Effect of Time
2.0 g of the soursop seed activated carbon and orange seed activated carbon were added to 20, 40, 60 & 80 ppm of aqueous solution of Mercuric Nitrate and Cobalt Chloride respectively. These were heated in the oven for 30 mins at 80ºC, 60 mins at 100ºC, 90 mins at 120ºC and 120 mins at 140ºC respectively. These samples were then allowed to cool and then filtered with a filter paper and their filtrates were sent to the Atomic Absorption Spectroscopy for analysis and the time for adsorption was recorded for the two samples.

Effect of Concentration:
Concentrations of 20, 40, 60 and 80 ppm of the metals (Hg and Co) and 2g of each samples were added and heated in the oven 80ºC, 100ºC, 120ºC and 140ºC respectively. The samples were allowed to cool, filtered and the filtrates sent into Atomic Absorption Spectroscopy for analysis. The concentrations for adsorption for the two samples were recorded.

Results and Discussion

Table 1. The properties of activated carbon of orange and soursop seeds.

Properties	**Orange Seeds**	**Soursop Seeds**
Mass (g)	400	400
Mass of activated carbon (g)	183	210
Moisture content %	62.0	60.5
Ash content %	3.52	5.53
Ph	6.7	6.8
Yield %	25.5	28.5

Table 1. shows that orange seed has a high moisture content (62.0) while soursop seed is higher in ash content and total yield (5.53 and 28.5% respectively). This agrees with Wigmans work (1989) which stated that plant samples with high carbonization time have high percentage yield and ash content.

Table 2. The Rate of Adsorption of Mercury by activated carbon from Orange seeds

Time (mins)	**Concn ppm**	**Initial Concn ppm**	**Final Concn ppm**	**Concn Absorbed ppm**	**Rate of Adsorption ppm/mins**	**Percentage Absorbed %**

30	20	99.905	0.696	99.209	3.31	99.3
60	40	99.905	0.571	99.334	1.66	99.4
90	60	99.905	0.391	99.514	1.11	99.5
120	80	99.905	0.460	99.445	0.83	99.6

Table 3. The Rate of Adsorption of Mercury by activated carbon from Soursop seeds

Time (mins)	**Concn ppm**	**Initial Concn ppm**	**Final Concn Ppm**	**Concn Absorbed ppm**	**Rate of Adsorption ppm/mins**	**Percentage Absorbed %**
30	20	99.906	2.009	97.896	3.26	98.0
60	40	99.906	1.050	98.855	1.65	98.9
90	60	99.906	0.132	99.773	1.11	99.9
120	80	99.906	0.100	99.805	0.83	99.9

Table 4. The Rate of Adsorption of Cobalt by activated carbon from Orange seeds.

Time (mins)	**Concn ppm**	**Initial Concn ppm**	**Final Concn ppm**	**Concn Absorbed ppm**	**Rate of Adsorption ppm/mins**	**Percentage Absorbed %**
30	20	100.63	10.369	90.261	3.01	89.7
60	40	100.63	25.901	74.729	1.25	74.3
90	60	100.63	41.290	59.343	0.66	59.8
120	80	100.63	56.639	33.991	0.28	33.8

Table 5. The Rate of Adsorption of Cobalt by activated carbon from Soursop seeds.

Time (mins)	**Concn ppm**	**Initial Concn ppm**	**Final Concn ppm**	**Concn Absorbed ppm**	**Rate of Adsorption ppm/mins**	**Percentage Absorbed %**
30	20	100.63	7.110	93.500	3.12	92.9
60	40	100.63	46.201	54.400	0.91	54.1
90	60	100.63	84.202	74.300	0.83	73.8
120	80	100.63	96.320	54.100	0.45	53.8

Table 6. Comparison of the Rates of Adsorption of Mercury and Cobalt by activated Carbon from Orange and Soursop seeds

Time (min)	**Conc ppm**	**Rate of Adsorption of Mercury**		**Rate of Adsorption of Cobalt**		**Rate of Adsorption by Activated carbon from Animal Bone**	
		OS	**SS**	**OS**	**SS**	**Hg**	**Co**
30	20	3.01	3.21	3.31	3.26	3.32	3.25
60	40	1.25	0.91	1.66	1.65	1.66	1.60
90	60	0.66	0.83	1.11	1.11	1.11	1.12
120	80	0.28	0.45	0.83	0.83	0.83	0.83

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Tables 1,2,3,4 and 5 shows that with increase in time and concentration, there is a corresponding decrease in the rate of adsorption. This result disagrees with Balci et al (1992) which states that "as the time and concentration of plant adsorbent increases, the metal ions removal should increase progressively".
Further comparing the activated carbon from the orange seeds and soursop seeds, it was observed that activated carbon from soursop is a better adsorbent for cobalt while that of orange seeds is better adsorbent for Mercury.
Comparing both activated carbon (from orange and soursop seeds) with the activated carbon from animal bone (control), it was observed that the activated carbon from the animal bone is better in absorbing both Mercury and Cobalt.
FTIR results showed that activated carbon from both orange and soursop seeds have adequate active adsorption sites and therefore are potentials for removing specific heavy metals.

Conclusion

From the result, it can be concluded that adsorption using activated carbon from orange and soursop seeds can be effectively used in the removal of heavy metals in industrial waste water. It is recommended that Biochar materials should be further investigated for their capability in the removal of metals from waste water.

Abbreviations

SS – Soursop seed
OS – Orange Seed
Hg –Mercury
Co –Cobalt
Ppm –parts per million

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