Paya Lebar Methodist Girls' School (Secondary)

To Investigate the Removal of Heavy Metal Ions by Different Adsorbents

By: Megan Seow, Jael Leong & Isabel Lim

ABSTRACT

An investigation was performed to find out which adsorbent is better at removing heavy metal ions from aqueous solutions. This can help assist in cleaning up water contaminated with heavy metal ions more easily and efficiently. We experimented using two kinds of adsorbents, sawdust and activated carbon, to remove three types of heavy metal ions, Cu^{2+}, Fe^{2+} and Zn^{2+} ions (of compounds copper(II) nitrate, iron(II) sulfate and zinc nitrate respectively) from water over the course of seven days. Based on all our data collected, activated carbon was shown to be the best adsorbent at removing the three heavy metal ions from water.

INTRODUCTION

Heavy metal pollution has become one of the most serious environmental problems today. The treatment of heavy metals is of special concern due to their recalcitrance and persistence in the environment. If successful, our experiment can help remove ions from polluted water more easily and effectively, using commonly available items that are not very costly as well. Since adsorption is the best technique for removing heavy metal ions with more economical and environmental benefits, this will reduce the negative impact of water contaminated with heavy metal ions on people and the environment. Our main aim is to find out which adsorbent, sawdust or activated carbon, adsorbs the most amount of heavy metal ions, copper nitrate, iron sulfate and zinc nitrate, in water. This can help us understand which adsorbent can be used to clean up water contaminated with these heavy metal ions more easily and efficiently.

THEORETICAL BACKGROUND

Heavy metals are natural elements on the earth's crust and they are metallic chemical elements with a relatively high density and is toxic even at low concentration. Heavy metal poisoning could occur from drinking contaminated water sources (e.g. water in lead pipes), high ambient air concentrations near emission sources, or consuming food laced with those ions. Heavy metals can enter a water supply by industrial and consumer waste, or even from acid rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater.

Heavy metals are dangerous because they tend to bioaccumulate and cannot be degraded or destroyed in an organism. Bioaccumulation is the increase in concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things when they are taken up and stored faster than they are broken down (metabolized) or excreted. Activated carbon has a high surface area, a microscopic structure and a high degree of surface reactivity that make it versatile in adsorbents. It is particularly effective in the adsorption of organic and inorganic pollutants from aqueous solutions.

In a study done by Bulut and team, they experimented on the removal of heavy metals from aqueous solution by sawdust adsorption and concluded that sawdust is a good adsorbent of heavy metal ions Pb(II), Cd(II) and Ni(II). In their experiment, Therefore we decided to investigate the removal of Cu(II), Zn(II) and Fe(II).

CHEMICALS & APPARATUS NEEDED FOR THE EXPERIMENT

- 200 mL of distilled water
- Copper nitrate (2 sets of 5 g each)
- Iron sulfate (2 sets of 5 g each)
- Zinc nitrate (2 sets of 5 g each)
- Activated carbon (2 sets of 2 g each)
- Sawdust (2 sets of 2 g each)
- 720 mL of sodium hydroxide
- Nitric acid
- 12 beakers (6 for 1 M NaOH; 6 for distilled water)
- 1 measuring cylinder
- 8 metal rods
- 8 boiling tubes
- 8 filter funnels
- 16 pieces of filter paper
- 1 electronic weighing scale

PROCEDURE

1. To 8 beakers containing 25 mL of distilled water each, add 3 drops of nitric acid to each beaker and mix well.
2. Weigh 5 g of each metallic salt (i.e. 2 sets of copper(II) nitrate, 2 sets of zinc nitrate and 2 sets of iron(II) sulfate). Add them into 6 beakers and mix them well.
3. Get 8 containers and label them as: ($Cu(NO_3)_2$ + sawdust), ($Cu(NO_3)_2$ + activated carbon), ($FeSO_4$ + sawdust), ($FeSO_4$ + activated carbon), ($Zn(NO_3)_2$ + activated carbon), ($Zn(NO_3)_2$ + sawdust), (control + sawdust), (control + activated carbon).
4. Add 2 g of sawdust to each of the 4 solutions and 2 g of activated carbon to the other set of 4 solutions.
5. Mix the suspensions well in their containers by shaking them for approximately 5 minutes.
6. Leave them to set for 7 days.
7. Filter the mixtures and collect the filtrates (Refer to **Fig 1 and 2**).
8. Pour 1 mol/L of sodium hydroxide solution in excess into each beaker containing the filtrates (Refer to **Fig 3**)
9. Stir the mixtures for about 5 minutes, ensuring that all the heavy metal ions have reacted with the sodium hydroxide.
10. Stir the mixtures for about 5 minutes, ensuring that all the heavy metal ions have reacted with the sodium hydroxide.
11. Pour ~20 ml of sodium hydroxide into the beakers which were originally containing the filtrates from Step 9 to ensure that all the metal hydroxides have been filtered. Leave it to dry.
12. Weigh the filter papers with the residue.
13. Subtract the masses of the filter papers from the results. Also, subtract the mass of the residue collected for control from the other results.
14. Repeat the experiment twice to collect the results of three trials in total.

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RESULTS & DISCUSSION

Chemical Equations:

$Cu(NO_3)_2(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + 2NaNO_3(aq)$

$FeSO_4(aq) + 2NaOH(aq) \rightarrow Fe(OH)_2(s) + Na_2SO_4(aq)$

$Zn(NO_3)_2(aq) + 2NaOH(aq) \rightarrow Zn(OH)_2(s) + 2NaNO_3(aq)$

Calculation of the maximum mass of precipitates if all the heavy metal ions from each chemicals were adsorbed using mole calculations:

No. of moles of $Cu(OH)_2$ = 0.03 mol (3 s.f.)
Mass of $Cu(OH)_2$ = **2.61 g** (3s.f)
No. of moles of $Fe(OH)_2$ = 0.03 mol (3s.f.)
Mass of $Fe(OH)_2$ = **2.96 g** (3s.f)
No. of moles of $Zn(OH)_2$ = 0.03 mol (3 s.f.)
Mass of $Zn(OH)_2$ = **2.62 g** (3s.f)

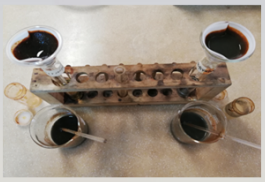

Fig. 1 Experimental set-up of the filtration of mixtures pt. 1

Fig. 2 Experimental set-up of the filtration of mixtures pt. 2

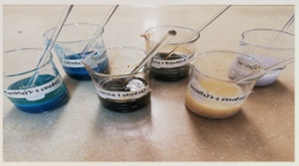

Fig. 3 Addition of sodium hydroxide to the filtrates

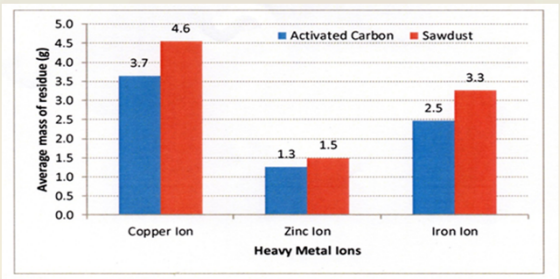

Fig.4 Average data collated represented on a bar chart (Data from Trial 2 of the Copper ions were anomalous and consequently removed from the calculation of the average mass)

Based on our results we can conclude that activated carbon is a better adsorbent than sawdust (refer to Fig 4). With reference to Fig 4, it shows that the average mass of residue from the mixture with activated carbon as the adsorbent is less than the average mass of residue from the mixture with sawdust as adsorbent for all of the samples (excluding the control). Since the residue is the precipitate from the reaction between the remaining heavy metal ions in the solution (i.e. those that were not adsorbed onto the adsorbents) and sodium hydroxide, the smaller amount of residue collected for samples with activated carbon implies that the activated carbon had adsorbed more heavy metal ions than the sawdust.

Our results are derived after subtracting the amount of residue of our control samples, which was 0.4 g instead of 0 g. The 0.4 g of residue could be due to carbon dioxide from the air that dissolved into the mixture and hence when we added the sodium hydroxide, sodium carbonate could have formed which could have contributed to the mass of 0.4 g. This could be because the containers we used were not airtight or that the amount of nitric acid we added at the start was too little. Assuming that this happened to all of our experiments, we subtracted the control mass to get a more accurate data.

CONCLUSION

In conclusion, the objective of this research project has been met. Activated carbon is a better adsorbent of Cu^{2+}, Fe^{2+} and Zn^{2+} ions than sawdust. There is still much room for improvement in a number of areas such as the efficiency of the experiment as too much experimental time was lost from waiting for gravity filtration to complete, especially when there is too much residue on the filter paper. In the event that vacuum filtration set-ups can be accessed in future experiments, this would most likely bring about an improvement in the efficiency that the experimental results can be obtained, which in turn may allow faster progress in our research. Also, for future work, to ensure that the sets of residue collected are strictly from the compounds that we have added at the start and not from the carbonates due to carbon dioxide dissolving in water, more nitric acid can be added at the start of the experiment along with using airtight containers to contain the mixtures. With more reliable results, we can potentially assist people in removing heavy metal ions from polluted water and reduce the negative impact of heavy metal ions in water on people and the environment.

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