Investigation of modified sawdust for the remediation of wastewater containing nitrate and other pollutants

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1. Abstract

Sawdust is widely regarded as an active ingredient in water purification and has been extensively researched all over the world. This study aims to investigate which method of modification to the sawdust was most effective in reducing the concentration of harmful pollutants. A predetermined amount of sawdust was treated with different concentrations of sodium hydroxide and sodium carbonate. A colorimeter and UV-spectrophotometer were used to analyse the results obtained. The results showed that sodium hydroxide treated sawdust was generally more effective in removing pollutants and organic dyes than sodium carbonate treated sawdust. Reasons for these results will be discussed later on.

2. Introduction

Recently, there has been growing interests and investments in the research on the effectiveness of sawdust for water filtration and remediation. According to *(Ansari et al., 2015),* horizontal roughing filters were presented as being inefficient in the removal of nitrate and other pollutants in water. This horizontal roughing filter was presented to be unsuccessful in removing large amounts of pollutants in wastewater, and hence should not be chosen as a viable method for water purification.

Moreover, according to (*Hayrynen et al., 2009*), nanofiltration is shown to perform poorly in the removal of nitrates and other pollutants. The retention of nitrate is around 90%; therefore, nanofiltration is not a preferred method for water purification. According to (*Karenen et al. , 2014*), chemically modified pine sawdust was shown to be effective in the removal of nitrate from 5-70 degrees celsius, with roughing filter and nanofiltration as possible alternatives. However, when the temperature exceeds or falls below this range, the removal of nitrate is shown to decrease moderately. Therefore, our project will also analyse the optimal temperature, if any, for our modified sawdust in the removal of pollutants in wastewater and remediation.

In the discussion on the most effective source for the sawdust, according to (*Sciban et al., 2006*), sawdust obtained from oak and black locust hardwood are shown to be most effective in the removal of pollutants and remediation. It further states that sodium hydroxide specifically, modified sawdust is significantly more effective than unmodified sawdust in the remediation and removal of pollutants in wastewater.

3. Objective and hypotheses

3.1 Objective

The main objectives of the experiment are as follows:

1. Investigate the ability of modified sawdust for the remediation of nitrate from wastewater
2. Investigate whether sawdust treated with NaOH or Na_2CO_3 is more effective in water treatment
3. Investigate the difference between modified and unmodified sawdust in removing nitrate, heavy metal ions and organic dyes

3.2 Hypotheses

1. *Chemically modified sawdust will be more effective in the removal of nitrate and other pollutants (organic dyes, anions and heavy metal ions) than unmodified sawdust*
2. *Our method of modifying the sawdust will make it versatile in adsorbing various pollutants (organic dyes, anions, heavy metal ions)*

5. Experimental Procedures

5.1 Modification of sawdust

1g of sawdust was treated with 3 ml of sodium hydroxide and sodium carbonate of 5 M each. The treatment is done by first washing the sawdust with deionised water, before treating the sawdust with the respective chemicals. Then, the sawdust is heated at 70 degrees celsius for 2 hours before being left to dry overnight. This ensures that the sodium hydroxide and sodium carbonate are being absorbed by the sawdust as much as possible. The sawdust is also washed thoroughly with acetone.

The above procedure is repeated for 5g of sawdust with 1 ml and 3 ml of 5M sodium hydroxide and sodium carbonate.

5.2 Preparation of stock solution (polluted water)

As stated above, the ability of the modified sawdust in purifying water containing these common pollutants: nitrate, copper (II), iron (III), zinc, green and blue dyes (malachite green and methylene blue) will be tested.

Nitrate, copper (II), iron (III), and zinc ions were obtained from the salts $Zn(NO_3)_2.10H_2O$, $CuSO_4.10H_2O$, $Fe(NO_3)_2.9H_2O$ and $ZnSO_4.10H_2O$ respectively. The mass of each salt needed was calculated using their molar masses, and they were each added to 1 litre of deionised water to form a 50 PPM stock solution.

5.3 Preparation of dyes

The methylene blue polluted water was further divided into varying concentrations from 1 to 5 ppm and while the malachite green one was split into different concentrations from 1 to 6 ppm. Then, the UV-spectrophotometer was used to plot calibration curves.

6. Mixing of sawdust and stock solution

A total of forty-two beakers were used for this section. Each type of sawdust, six in total, were used alongside the test water of different pollutants, seven in total. Each type of sawdust was divided exactly into seven equal portions by mass, and each type of sawdust was added to the various types of water containing the different pollutants.

This allowed us to conclude which factor, or combination of factors, best improved the ability of the sawdust to absorb and purify the polluted water. We were also able to measure the effectiveness of the type of sawdust in purifying each type of pollutant, to conclude if any sawdust was particularly useful in treating certain pollutants.

7. Results collection

A colorimeter was used to analyse the effectiveness of the sawdust. This is done by measuring the initial against the final concentrations of the pollutants. The difference between the results can be attributed to the sawdust absorption capabilities.

A UV-spectrophotometer was used to measure the data for dyes.

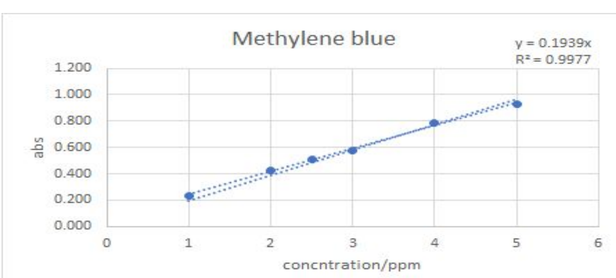
8. Results and discussion

8.1 Dyes

Before treatment

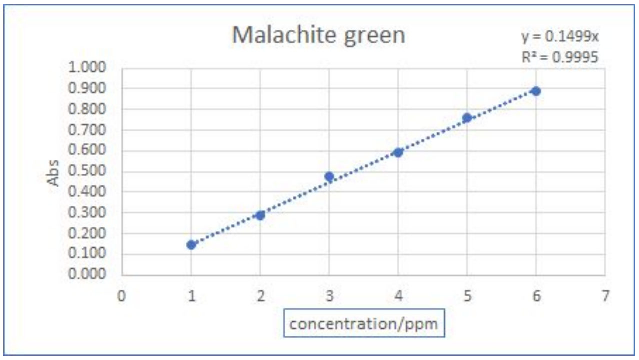
Methylene Blue

5 ppm	4 ppm	3 ppm	2 ppm	1 ppm
0.912	0.798	0.576	0.420	0.240
0.910	0.796	0.565	0.425	0.236



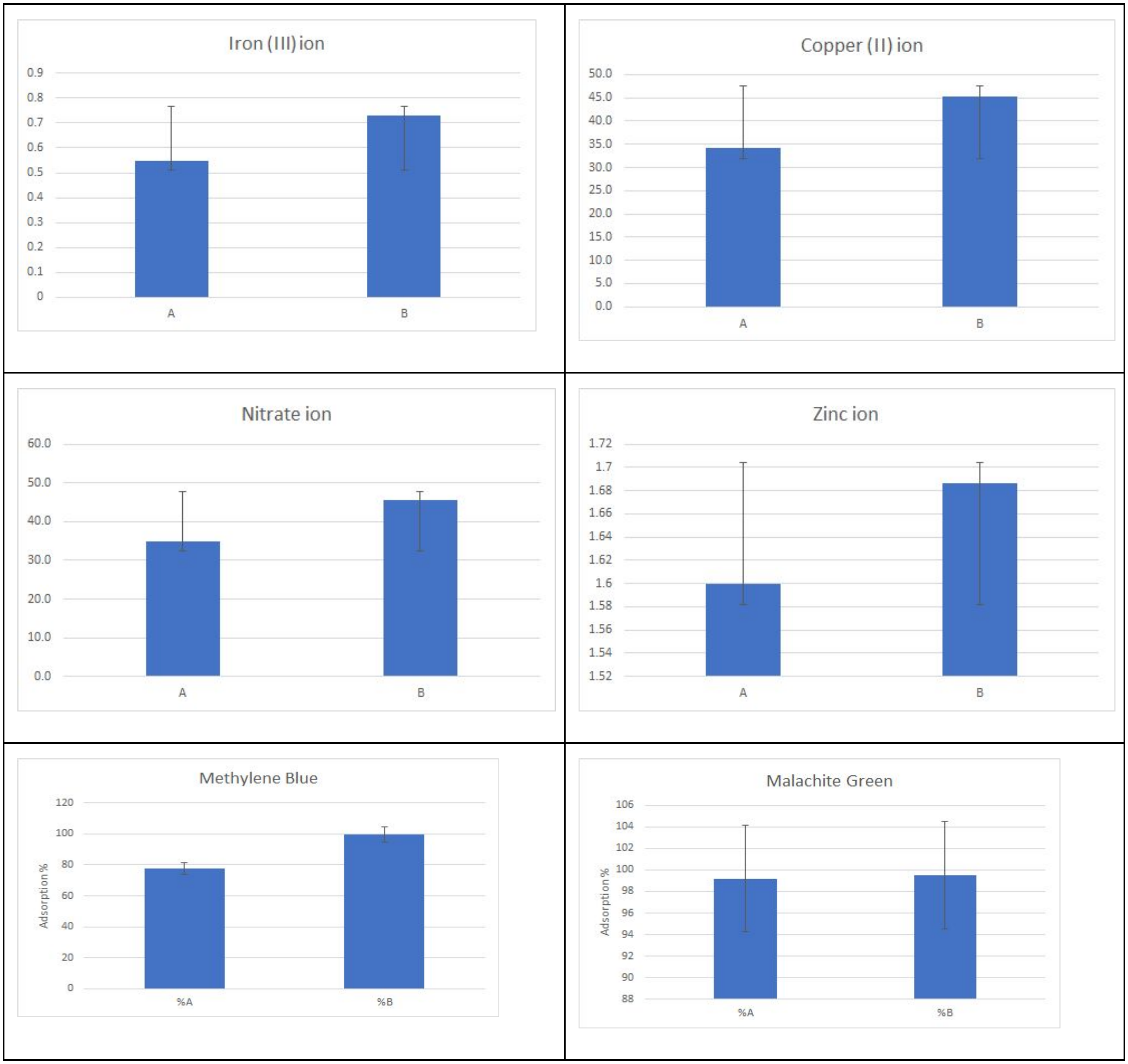
Malachite Green

5 ppm	4 ppm	3 ppm	2 ppm	1 ppm
0.794	0.635	0.391	0.316	0.170
0.729	0.560	0.411	0.268	0.130



8.2 After treatment

	A: 1g sawdust 3ml NaOH (aq)			B: 1g sawdust 3ml Na2CO3(aq)		
initially 50PPM	average concentration/PPM	percentage absorbed	standard deviation	average concentration/PPM	percentage absorbed	standard deviation
Fe^{3+}	13.75	72.5	0.057	36.5	27.0	0.0410
Zn^{2+}	40.0	20.0	0.041	42.5	15.0	0.0290
Cu^{2+}	34.2	31.6	0.690	45.2	9.60	0.860
NO^{3-}	34.8	30.4	1.96	45.5	9.00	2.04
methylene blue	11.1	77.8	0.1775	0.403	99.19	0.0525
malachite green	0.192	99.6	0.0925	0.250	99.5	0.105



%A: Percentage adsorption for sawdust treated with 1g sawdust with 3ml NaOH for individual pollutants, with respect to the original concentrations

%B: Percentage adsorption for sawdust treated with 1g sawdust with 3 ml Na_2CO_3 of individual pollutants, with respect to the original concentrations

8.3 Data analysis

Pollutant	Sample A (NaOH)	Sample B (Na_2CO_3)
Iron (III)	✓	
Zinc	✓	
Nitrate	✓	
Copper (II)	✓	
Methylene Blue		✓
Malachite Green	✓	

8.4 Discussion:

NaOH treated sawdust was shown to remove an average of 55% of all the pollutants. For the case of sodium carbonate treated sawdust, it was shown to remove an average of 43% of the pollutants. Apart from methylene blue, NaOH treated sawdust performed better than Na_2CO_3 treated sawdust in removing pollutants from the water.

Purpose of cellulose and lignin in water purification:

Cellulose:

Cellulose (Fig 1.1) can not only act as an effective filter due to its small pores, but it can also help in water purification by acting as an ion exchanger according to (Mathew, 2016). This is due to sawdust cellulose nanofiber having a large surface area and OH^- ion that can convert to anionic or cationic anchoring sites for water contaminants once modified. This explains why the polluted water treated with modified sawdust showed a large decrease in pollutant concentration, or by 53% on average.

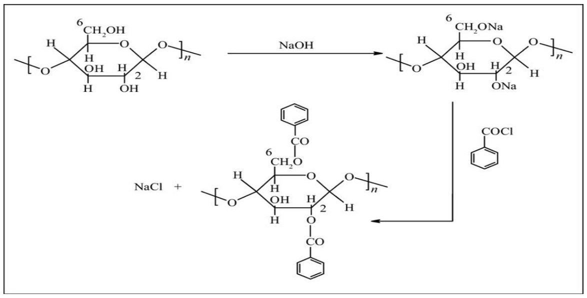


Fig 1.1

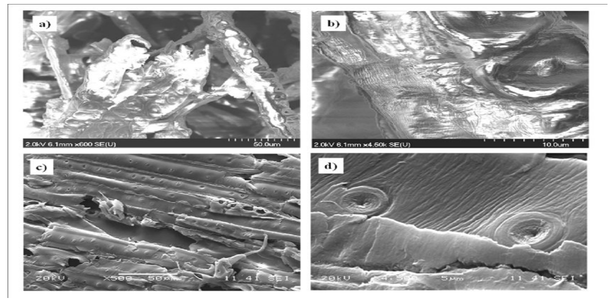


Fig 1.2

Lignin:

Lignin (Fig 1.2) is one of the most abundant natural polymers after cellulose. Due to its typical structure, it can be converted into different products for miscellaneous uses, one of which is water purification. Lignin-based hydrogels have recently come into prominence due to its efficiency in water purification, and research has shown that lignin-based hydrogels are even more effective in removing pollutants from wastewater, according to (Thakur et al., 2017).

9. Limitations

- Due to our packed schedules, we were unable to obtain five results for the effectiveness of each type of sawdust on each pollutant.
- Besides, since we were unable to collect five results for each pollutant, we were unable to plot the Mann-Whitney graph to determine if our results were significantly more effective.

9.1 Conclusion

Within the limits of our experiment,

- From our experiment conducted, sodium hydroxide (55%) is generally more effective in removing pollutants tested than sodium carbonate (43%) when used to treat sawdust, apart from Zn^{2+} and methylene blue.

- Sawdust is also shown to be an effective medium for water purification of heavy metal ions and organic dyes.

9.2 Future work

- The amount of sawdust and NaOH or Na_2CO_3 added can be optimised to treat polluted water more effectively
- Obtain five replicates for each test to increase the reliability of results
- Test absorption of PO_4^{3-} ions (colorimeter limit)

10. References

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