Hong Kong Student Science Project Competition 2023

Template of Extended Abstract (Investigation)

(Word Limit: 1,600 words, Pages: 3 pages only)

Team Number:

Project Title: Fan 'trash' tic Bagasse

Project Type: Investigation

***To our best knowledge, there <u>are / ~~are no~~</u> * similar works in the field*; (if there are,) related research links are as below:**

https://iopscience.iop.org/article/10.1088/1757-899X/107/1/012045

The enhancement our project made / the difference with related research are:

Our project has tested for the metal ion adsorption and regeneration of nanocellulose. We have produced biofilms from the nanocellulose by adding differing combinations of PVA, glycerol and citric acid to improve their mechanical properties. Their tensile strength, flexibility and water absorption ability were also examined.

Please delete if not applicable. The competition values the originality of works. Students must do enough literature research to ensure that their works are unique and list relevant reference materials before starting research or invention.

I. Background

- Provide background information of project and/or state the problem to tackle
- Provide highlights of the **literature review** with the support of pertinent and reliable references
- Provide an overview of work and mention the **research gap that the project is trying to fill**

The amount of bagasse being discarded in landfills every year is 123 million tons. Landfills take up a lot of land, which is already scarce in Hong Kong, and they create many harmful environmental problems such as the production of greenhouse gasses that intensify global warming, or even leakage of heavy metals into the soil and water. We aim to synthesize nanocellulose from bagasse waste to effectively adsorb heavy metal ions and create biofilm as a replacement for plastic cling film to reduce water and waste pollution.

To produce nanocellulose from sugarcane bagasse, HNO_3(aq), NaOH(aq) and NaOCl(aq) were added respectively to the ground bagasse powder (Wulandari W.T., Rochliadi A, Arcana I. M., 2016 ; Sabara R, Mutmainnah A, Kalsum U, Afiah I. N., Husna I, Saregar A, Irzaman, Umam R 2022). Nanocellulose synthesized from sugarcane bagasse can act as an adsorbent for the removal of heavy metal ions like Pb^{2+}, Hg^{2+} and Cu^{2+} ions from its aqueous solutions (Anish J.T. , Jain N, Joshi H.C. , Prasad S, 2008).

Other research that synthesised nanocellulose from other cellulosic materials like ours. However, for the production of biofilm, instead of the PVA, they used starch. We believe that our project lasts longer as using starch in the biofilm may cause it to grow moldy, whereas our biofilm will be more sustainable for the long term. Also, from another research paper (Amin M R, Chowdhury M A, Kowser M, 2019), the biofilm is synthesized from corn starch which is food, while our biofilm is synthesized from sugarcane bagasse which is food waste, alleviating solid waste pollution problems. Our biofilm also has a stronger tensile strength than the corn starch-based biofilm.

II. Objectives

- State the **aim(s)** of project

Our project aims to upcycle waste sugarcane bagasse which will be used to synthesize nanocellulose, and investigate the effectiveness of nanocellulose, bagasse powder and unrefined sugarcane bagasse as adsorbents to remove three heavy metal ions (Hg^{2+}, Pb^{2+} and Cu^{2+}). We also aim to recover Cu^{2+} ions from the adsorbents and regenerate the adsorbents for more rounds of adsorption. Besides, by mixing PVA, glycerol and citric acid of different proportions with nanocellulose, we aim to produce biofilms which can be used as packaging materials.

III. Hypothesis

- Propose an explanation for a phenomenon and stating how the **hypothesis** can be tested by experiments

Nanocellulose can adsorb three heavy metal ions (Pb^{2+}, Hg^{2+} and Cu^{2+} ions) effectively and it can be tested by gravimetric analysis and colorimetric analysis. Nanocellulose synthesized can be made into biofilm by mixing with PVA, glycerol and citric acid of different proportions and its quality can be tested via tensile strength test, water absorption ability test and flexibility test.

IV. Methodology

☐ List out the materials used
☐ Describe the **experimental protocol** including the set-up of **control experiment** (if any), **repeated experiment** (if any), and its scientific theory
☐ Indicate with the support of reasons, the **analysis** used in the investigation

Materials used: unrefined sugarcane bagasse, ground bagasse powder, 0.5M HNO_3(aq), 3.5% NaOCl(aq), 17.5% NaOH(aq), 0.1M HgCl(aq), 2M Na_2CO_3(aq), 0.1M $Pb(NO_3)_2$(aq), 1M KI(aq), 0.01M $CuSO_4$(aq), 0.1M ethane-1,2-diamine, 10% polyvinyl alcohol (PVA), glycerol, citric acid, deionized water

Experimental protocol:

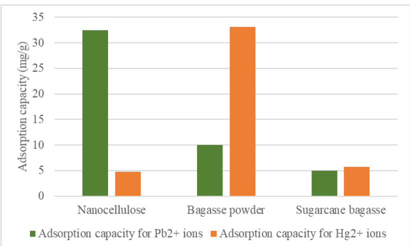
Metal ion adsorption: We prepared samples of sugarcane bagasse, bagasse powder and nanocellulose, and added $HgCl_2$(aq) to each and stirred. The mixture was filtered, and Na_2CO_3(aq) was added into the filtrates. The formed $HgCO_3$(s) precipitate was filtered and dried, and the steps were repeated with $Pb(NO_3)_2$(aq). We applied quantitative gravimetric analysis and measured the masses of precipitate to calculate the percentage decrease in mass of Hg^{2+} and Pb^{2+} after adsorption by the three adsorbents, and compared them with the control, which is the same Na_2CO_3(aq) added to $HgCl_2$(aq) without adsorbents.
$CuSO_4$(aq) was added to the three adsorbents respectively and stirred. After filtration, ethane-1,2-diamine was added into the filtrates, which turned the pale blue solution purple with the formation of a purple complex $[Cu(H_2NCH_2CH_2NH_2)_2]^{2+}$. The absorbance of the solutions was measured using a colorimeter via the application of quantitative colorimetric analysis to obtain results compared with the control $CuSO_4$(aq) with ethane-1,2-diamine added.

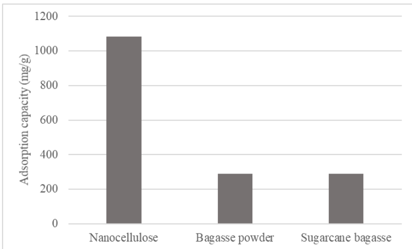
Cu^{2+} recovery: Cu^{2+} ions adsorbed by the three adsorbents along with nanocellulose with acid hydrolysis were recovered by adding H_2SO_4(aq) via ion exchange, and the mixture was filtered and washed. After drying, colorimetric analysis was repeated using the regenerated adsorbents twice more to increase the reliability of the tests and to test whether the regenerated nanocellulose can be used repeatedly in metal ion adsorption.

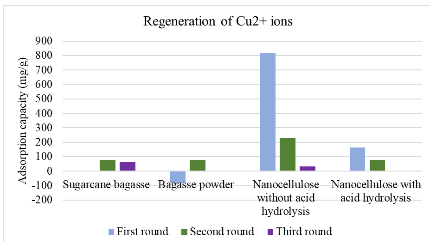
Biofilm production: Nanocellulose was mixed with varying concentrations of PVA, glycerol and citric acid, then heated and stirred. The mixture was air-dried to form sheets. Scores were given to each blend based on flexibility based on our observations. We tested the tensile strength of all 10 blends by using a spring balance to measure the force needed to rip the biofilms apart and calculated their tensile strength with a tensile strength formula for quantitative analysis. We also tested their water absorption ability by soaking the biofilms in water for 10 minutes, weighing them before and after, and measuring their percentage increase by mass.

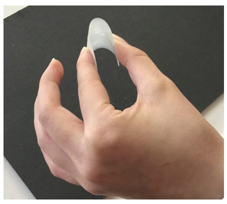
V. Results

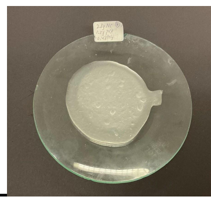
☐ Present the **data** with figures, tables or photos
☐ **Data analysis** (if any, with emphasis on data reliability and the reproducibility based on statistics)
☐ Interpret the results and its implication
☐ Discuss **limitation** and compare with existing related works (if any)
☐ Discuss the importance or impact of the research and how it is applicable to real problems











Nanocellulose is the best adsorbent for Cu^{2+} ions, with an adsorption capacity of 1082 mg/g. Nanocellulose is also the best at adsorbing Pb^{2+} ions with its highest adsorption capacity of 32.50 mg/g. We also found that nanocellulose without acid hydrolysis is the most effective at adsorbing Cu^{2+} ions multiple rounds after regeneration, with the highest adsorption capacity of 359 mg/g, so it is the best option for repeated uses in adsorbing heavy metal ions. We created 10 blends of biofilms which were made by blending synthesized nanocellulose with different combinations of PVA, glycerol and citric acid and the result suggested that blend 9 with a combination of nanocellulose to PVA to glycerol at the ratio 10:6:1, is the best on average with the fourth highest tensile strength of 1.59 MPa, the lowest water absorption ability of 27.3% and the highest flexibility among all blends. This means the biofilm is durable while being appropriately water resistant so it is less likely to be damaged by wetting. Hence, blend 9 is the best biofilm to make packaging materials like cling wrap.
For limitations, the pigment in sugarcane bagasse and bagasse powder may have contaminated the solution used in colorimetric analysis leading to inaccurate reading. Besides, marks for flexibility of

the films were given by observations which may not be accurate. Also, some nanocellulose may be lost from being stuck onto filter papers, making the mass used in metal ion adsorption smaller than expected and leading to subpar results.

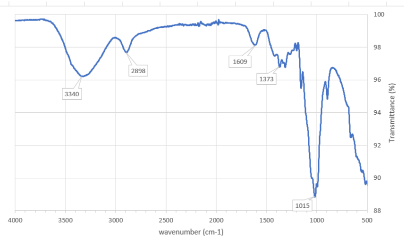
VI. If your team will compete the Sustainable Development Award, please indicate the specific sustainable development goal the project is related to, and provide justification for competing for this award. *(Word limit: 300 words)*

We have fulfilled 6 out of the 17 sustainable development goals. Nanocellulose synthesized from sugarcane bagasse is effective in removing heavy metal ions from wastewater even when the metal ions are at low concentration, in contrast with the current wastewater treatment method of carbonate precipitation that only works in high concentrations, achieving goal 6: clean water and sanitation. This also achieves goal 14: life below water, by improving the living environment of marine life. Also, our project aims to upcycle food waste in producing nanocellulose to reduce the amount of solid waste in landfills. This helps us achieve goal 12: responsible consumption and production. Thirdly, we achieved goal 11: sustainable cities and communities by producing biodegradable film that show properties of being a good alternative for packaging materials. Also, we hope to achieve goal 13: climate action. Our plastics are biodegradable, hence reducing the need for incineration and landfills. It can reduce greenhouse gas emissions like carbon dioxide as well as air pollutants like nitric oxides. Hence reducing the severity of global warming and climate change while improving the air quality, achieving goal 15: life on land by protecting the terrestrial ecosystems from toxic pollutants and preserving their habitats by reducing landfills. Through this, we are mitigating the negative impacts heavy metal pollution and full landfills have on our current environment and society. More importantly, we are encouraging a more sustainable way of life by relieving the burden of resolving these issues off of our future generations, otherwise these environmental problems may accumulate and increase to levels beyond control. This way, we can ensure a brighter future not just for us, but for generations to come.

VII. If your team will compete the Social Innovation Award, please list the target group or social issue the project focuses on, and provide justification for competing for this award. *(Word limit: 300 words)*

VIII. Conclusion

- ☐ Make a **data-driven** conclusion of the project and the way forward of the research
- ☐ Justify if the proposed project meets the objective(s)



In part 1, after characterisation by infrared spectroscopy, we have successfully synthesized 6.33 g of nanocellulose from bagasse waste as the absorption peaks observed in nanocellulose synthesized are similar to those in reference paper. In part 2, we found that nanocellulose is the best adsorbent for Cu^{2+} ions and Pb^{2+} ions, proving the nanocellulose synthesized from sugarcane bagasse can be greatly utilized for removing toxic metal ions from substances. We also found that nanocellulose is the most effective at adsorbing Cu^{2+} ions multiple rounds even after regeneration, and thus is the best option for repeated uses in adsorbing heavy metal ions. In part 3, among the 10 blends of nanocellulose all with different combinations of PVA, glycerol and citric acid, blend 9 with a combination of nanocellulose to PVA to glycerol at the ratio 10:6:1, seems to be the best on average with the fourth highest tensile strength of 1.59 MPa, the lowest water absorption ability of 27.3% and the highest flexibility. Hence, we believed blend 9 is the best biofilm to make packaging materials like cling wrap.

We would like to further investigate the biodegradability of our biofilm and find ways to lower the cost. Also, we would love to use different raw materials to make bioplastics and compare their tensile strength, water absorption ability and biodegradability, to find out the best one to make bioplastics. We would like to use more accurate equipment, such as the universal testing machine to measure the tensile strength.

□ Our project is developed based on previous project and the enhancement is below: