REMOVAL OF ZINC ION FROM AQUEOUS SOLUTION USING MUSA SAPIENTUM: AN EXPERIMENTAL APPROACH

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Abstract

Due to their poisonous composition and inability to biodegrade, heavy metals have become a considerable cause of water contamination. This study utilised banana peel as a biosorbent to extract heavy metals from polluted water. The primary issue with banana peel bioadsorbent is that activated carbon obtained from biomass has a relatively poor adsorption capacity compared to its commercial equivalent. Additionally, the large quantity of wasted banana peels complicates disposal. By transforming banana peels into bioadsorbent, it is anticipated that the present effort would solve issues associated with banana peel disposal. The goals of this study are to create a biosorbent from banana peels and evaluate its ability to absorb heavy metals. In addition, we optimised the pH, solution temperature, adsorbent dosage, contact time, and solid-liquid ratio in order to determine the biocapacity of adsorbents to remove Ni. Due to their ease of processing, wide availability, and environmental friendliness, it is strongly recommended that inexpensive raw materials be widely employed as bioadsorbent in wastewater operations.

Paper Identification

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Introduction

Heavy metal ions are utilised in a range of industrial processes, including metal finishing, electroplating, painting, dying, photography, surface treatment, and printed circuit board fabrication. The bulk of heavy metal ions are well-known to be toxic and carcinogenic, and when they are untreated and released into the environment, they constitute a threat to human health as well as considerable damage to the aquatic ecosystem (1–4). Nickel is the fifth most common element, behind iron, oxygen, magnesium, and silicon. Heavy metals (HMs) are elements having a bigger atomic mass and greater density, such as cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), silver (Ag), chromium (Cr), copper (Cu), iron (Fe), and platinum (Pt). Heavy metal contamination of water is one of the most critical environmental concerns affecting people, animals, and plants (5). Since heavy metals are not biodegradable, even little amounts are hazardous. Metals and metalloid ions were divided into three types. In the first group are metals like mercury, cadmium, and lead, which are hazardous in minute quantities. The second group of metals (bismuth, indium, arsenic, thallium, and antimony) are less dangerous, and the third group consists of essential metals such as zinc, cobalt, copper, iron, and selenium, which are required for a variety of biochemical and chemical processes in the body but are only toxic in excess quantities. (7) Hyperaccumulator plants may retain high amounts of hazardous metals that could impair human and animal health by poisoning the food chain.

Reported heavy metal ion removal techniques include precipitation reduction, solvent extraction (8,9), and membrane procedures (10). However, these techniques have significant drawbacks, including insufficient metal removal and harmful sludge production. Bio-adsorbent-based removal of heavy metals by means of a novel technique represents a significant advance (11,12). Bioadsorption is the capacity of biological materials to absorb heavy metals from wastewater via metabolically mediated or physicochemical mechanisms. This phenomenon, known as bioadsorption, appears to be a cost-effective alternative to conventional technologies for the treatment of vast volumes of wastewaters with low pollutant concentrations, as it does not generate chemical sludge, is more selective, more efficient, and simple to run (13,14).

The use of fruit peels as adsorbents is more economically and ecologically advantageous since these materials can be obtained at a reduced cost, reducing the buildup of agro-waste, allowing for the renewal of the adsorbent, and allowing for the extraction of metals from adsorbents. The primary remnant is banana peel, which comprises 30–40% of the fruit's weight and is one of the most eaten fruits (15). Banana peel (hence BP) is a typical byproduct that is rich in cellulose and minerals. Large quantities of BP generate substantial disposal challenges and resource waste. It has been demonstrated that a range of functional groups, including as carboxyl, hydroxyl, and amide groups, located on the BP surfaces are critical to the biosorption processes. At 41.37%, it includes carbon as well (16). By recovering it as sorbent, it is possible to dispose of BP in an attractive manner. Because of its porous structure and variety of surface groups, purified and treated BP has been used as a sorbent to remove dissolved heavy metals from wastewater (17). Due to its limited absorption capacity, pure BP must still be chemically treated with alkaline and acid. Several research groups have utilised unprocessed and chemically treated banana stalks and BP in this study for the removal of Zn, a dangerous heavy metal ion, from aqueous solutions and industrial wastes (18,19). In the current work, fresh BPs were used as raw materials, and they were then treated with acidic and basic solutions of varying concentrations to develop efficient bioadsorbent. As a result, BP bioadsorbents with oxygen-containing surface functional groups were developed and tested for their ability to remove heavy metals.

Materials and Methods

Banana peel adsorbent creation: The banana peel (BP) was acquired from a nearby market and cleaned with distilled water twice or thrice to eliminate contaminants and dust. Then, it was sliced into little pieces and let to naturally dry in sunlight-exposed open air. In order to reduce moisture and facilitate crushing, the peels were roasted at 120°C. The particles with a diameter greater than 0.150 mm were then removed using a crushing process and a single sieve. The completed mass was then placed in a desiccator until required.

Bioadsorbent amendment using various chemicals:

For the activation of bio-adsorbent, referred as ABP, the solid support is combined with 1 N nitric acid solution in a weight-to-volume ratio of 1/2 so that it may undergo a 24-hour thermochemical treatment at 120 °C. The surplus acid was then removed from the combination using distilled water, and the waste acid was removed by filtering the mixture overnight in a 1% solution of $NaHCO_3$. The strong support was then dried in an oven at 105°C (20). For the activation, 200 g of the BP are combined with 1 litre of 0.1 M caustic soda solution (referred to as BBP) and let to sit for 24 hours before being washed with distilled water until a neutral pH is reached (21,22). Following that, the NaOH-treated material was dried in an oven at 105 °C.

Preparation of Zinc solution:

Zinc sulphate pentahydrate ($ZnSO_4{\bullet}5H_2O$), an analytical grade sulphate salt, was used to make Zn(II) solution. Distilled water was utilised to create the $ZnSO_4{\bullet}5H_2O$ aqueous solution. From this stock solution, test samples at various concentrations for studies on various parameters were created.

Experimental Set-up and Analysis:

The adsorption of zinc from aqueous solution was examined using the batch technique at room temperature. The starting concentrations of Zn (II) were varied between 5, 10, 20, 30, 40, 50, 70, 100, and 150 mg/L. In each adsorption experiment, a 100 ml flask containing 100 ml of the required amount of Zn(II) aqueous solution was injected. The pH of BP, AKP, and BKP was adjusted with the addition of 0.1 N (or 1 N) HNO_3 and 0.1 N (or 1 N) NaOH. These 100 ml flasks were shaken at 200 rpm for one hour.

In the batch experiments, the experimental conditions comprised the impact of pH, the dosage and size of the biosorbent, the initial concentration of Zn(II), the contact length, the agitation speed, the temperature, and the peel pretreatment. The effect of the adsorbent mass was evaluated by varying the BP weight between 0.1 and 1 g. Additionally, the zinc adsorption capability of BP at varied contact periods with Zn ions solutions was examined (15 min, 30 min, 1 h, and 2 h). In both instances, the initial concentration of metal ion solutions was 50 mg/L, the pH was 4 and the temperature was 25 degrees Celsius.

% Removal and Metals Uptake Capacity Assessment

The Ni ion uptake was calculated using the concentration difference technique (19). The quantity of metal ion (mg) that is absorbed per g (dry weight) of BP is known as the adsorption capacity, or q. The volume of the utilised metal ions solution is V(L), the initial concentration of metal ions is Ci (mg/L), the equilibrium concentration of metal ions in solution is Ce, and the weight of the adsorbent is W(g).

The following equations were used to calculate the %metal uptake by the sorbent and adsorbent capacity at equilibrium q_e (mg = g).

%Adsorption=(Ci-Ce)100/Ci

Results and Discussion:

Effect of Biosorbent Particle Size:

The particle sizes of the biosorbent had a substantial effect on its sorption capacity, since they altered the total surface area accessible for the sorption of metal ions. According to the effect of sorbent particle size on sorption capacity, q (mg=g), smaller particles removed more Zn(II) than bigger particles.

As seen in Figure 3, finely powdered biomass absorbed Zn(II) ions more rapidly. With smaller particles of biosorbent, equilibrium was reached faster than with larger particles. This was likely due to the increase in total surface area, which provided the metal ions with more sorption sites (24,25,26).

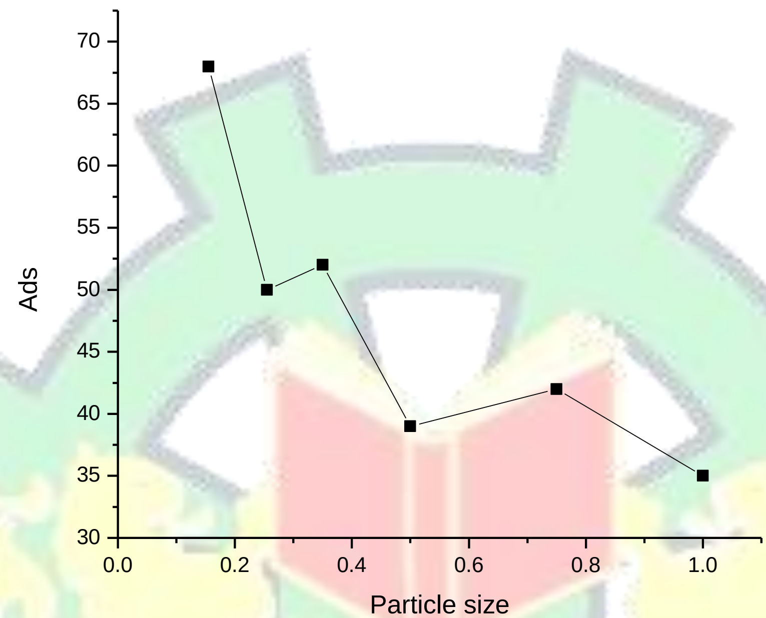


Figure 1: Effect of particle size on adsorption of Zn ions.

The impact of primary treatments: To determine the effect of pretreatment on Musa Sapientum waste biomass, 25 mg/L of Ni(II) was shaken for two hours at 200 rpm with 0.1 g/L of pretreated bio-adsorbent with a particle size of 0.155 mm at a pH of 6 with 0.1 g/L of pretreated bio-adsorbent with a particle size of 0.155 mm. Figure 2 depicts the sorption q values of untreated, physically and chemically changed Musa sapientum waste biomass. Due to the removal of mineral matter and the introduction of new sorption sites on the biomass surface during the boiling process, the sorption capacity of the biomass has increased. Heating biomass decreased the uptake of metals due to the loss of intracellular absorption. (24).

Two elements are crucial in determining the sorption capacity of a certain biomass following acidic pre-treatment-Due to the ionisation of organic and inorganic groups, the polymeric structure of biomass surfaces exhibits a negative charge (25–27), and at a certain concentration, acids can increase the surface area and porosity of the initial sample, enhancing the absorption capacity of biomass (23,28). Similar to how the bio-adsorbent absorption capacity was influenced by two parameters following basic pretreatment. In addition to removing lipids and proteins that cover up reactive sites and purifying the biomass, it may also damage autolytic enzymes (27,29–33). In addition, after a specific alkali concentration, the number of protein amino groups that may participate in metallic ion binding significantly reduced. Theoretically, deproteinization ought to decrease metal retention (23–24, 27, 28–33).

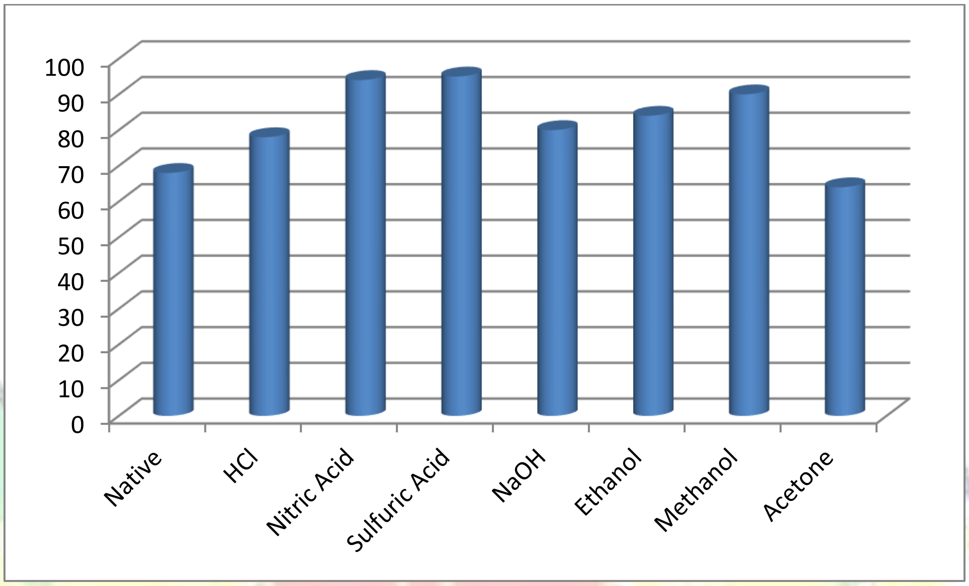
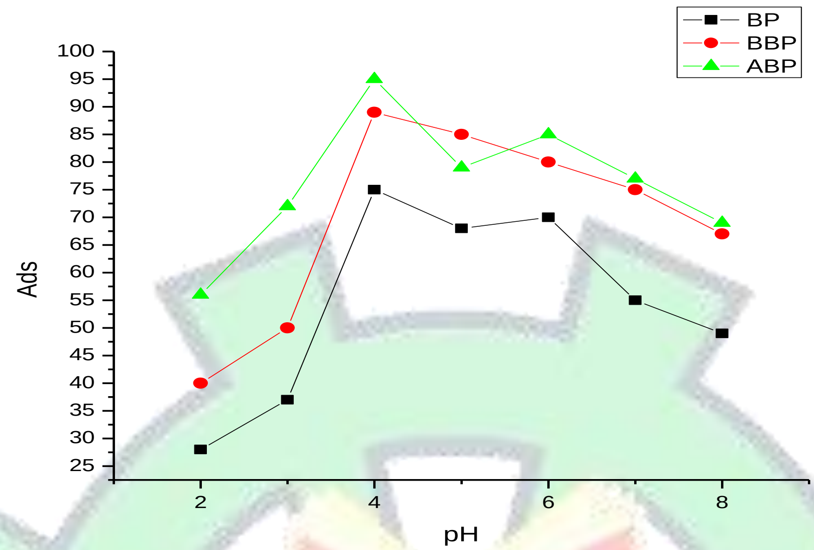


Figure 2: Effect of pre-treatment on adsorption of Zn ion

Result of pH:

Banana peel used in an experiment to test the effect of pH on zinc absorption. Mix 100 ml of a 25 mg/L Zn ion solution with 0.1 g of dried banana peel and 0.1 g of powdered banana peel that has been chemically changed (particle size: 0.160 mm). Using 1 N HNO_3 or 1 N NaOH to adjust the pH between 3 and 10, samples were shaken at 200 RPM for eight hours at room temperature. Additionally, it influences the dissociation of functional groups and the surface charge of adsorbents (20, 21). The adsorption capacity of Musa sapientum waste biomass increased as the pH of the solution rose. Due to the fact that the surface active sites of the adsorbent were protonated, the competition between Zn ion and H^+ for the same surface active sites led to a negligible zinc absorption. At a constant biomass concentration (0.05 g/L), Zn ion absorption increased when pH rose from 4 to 6. (Fig. 3). It can be observed that the Zn ion's adsorption efficiency is at its lowest at pH- 3 and increases to 95% at pH 6. The uptake of Zn ions decreased as pH rose. Below pH- 6, low adsorption percentage removal is anticipated and can be attributed to a number of factors, including (a) repulsion between the sorbent's positive charge and free Zn ions, (b) competition between free Zn ions and H^+ for the sorbent's active sites, and (c) a decreased ability to form complexes with metal ions due to protonation of surface functional groups.



. Figure 3: Effect of pH on adsorption of Zn ion

Effect of agitation speed:

Fig. 4 shows the impact of agitation speed on the removal of Cu ions by BP, ABP, and BBP. A constant agitation speed of between 50 and 200 rpm was used. For BP, ABP, and BBP, other variables including pH (pH 4), contact duration (20 min), and temperature (25 degree celsius) were held constant. As the agitation speed rose, more Zn ions were adsorbed (mg/g). With 200 rpm of agitation speed, the best results for the removal of Zn ions were discovered. The agitation speed used for the rest of the trials was 200 rpm.

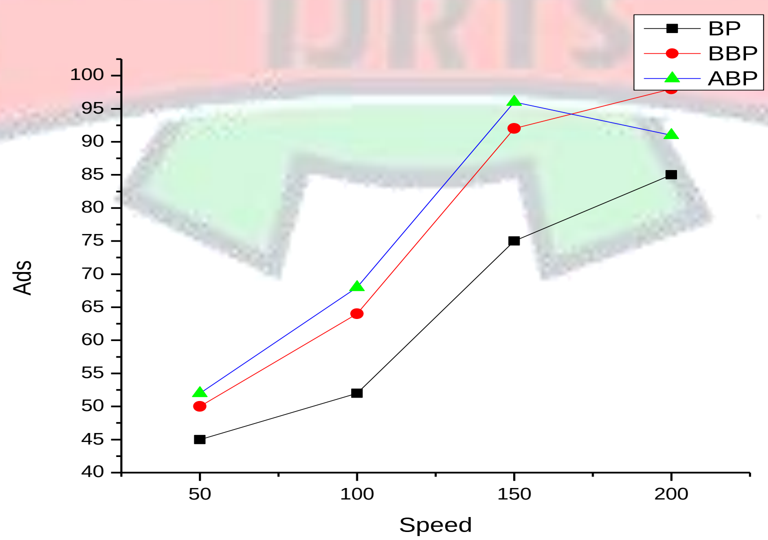


Figure 4: Effect of speed on adsorption of Zinc

Effect of adsorbent dose:

The mass of modified and unmodified BP and its impact on the expulsion of Zn ions from aqueous solution were shown in Figure 3. The dosages of adsorbent for 100 mL of zinc ion solution ranged from 0.1 to 1 g. Other factors like temperature (25 degree celsius), contact duration (20 min), and pH (pH 4) were held constant. The findings demonstrate that when adsorbent mass grows, Zn ion removal percentage correspondingly rises, however adsorption capacity falls (Fig. 4).

This is because there are more active sites available for interaction with metal ions as a result of increasing the dosage of modified and unmodified BP. Consequently, an increase in the proportion of metal ions removed from the aqueous solution. On the other hand, aggregation of modified and unmodified BP inside greater doses of adsorbent can lead to unsaturation of active sites, which can lead to a reduction in adsorption capacity. This aggregation reduces the adsorbent's overall surface area.

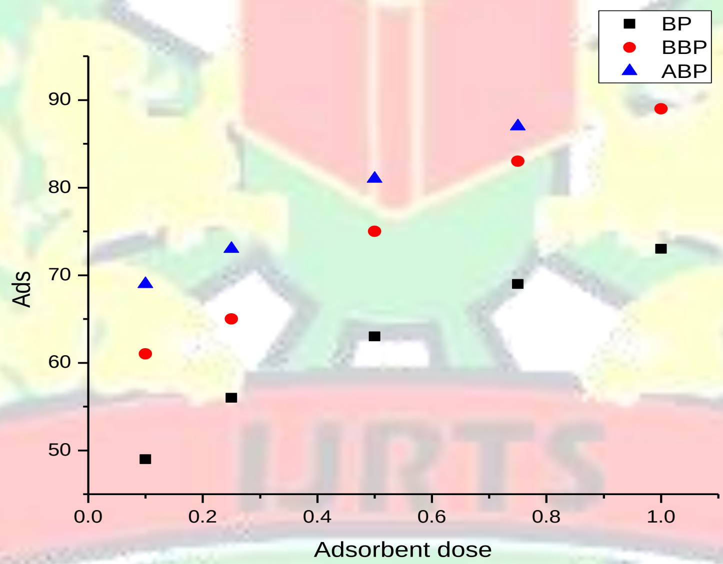


Figure 5: Effect of adsorption dose on adsorption of Zn ions

Effect of contact time:

The impact of contact duration on the removal of copper by banana peels is depicted in Figure 5. The curve has a classic saturation curve form. The Zn ion was rapidly adsorbed, and the three support ports activated by caustic soda (NaOH) and sulfuric acid attained saturation in roughly the first five minutes. The adsorption is significantly slower for the natural support (Snat), though, and saturation is attained in approximately 10 minutes. This is explained by the initial vacancy of the adsorption sites, which makes it simple for metallic ions to readily occupy them and provide a high adsorption rate. After this first period, a slower diffusion of dissolved species through the pores of the material might be the cause of the sluggish adsorption.

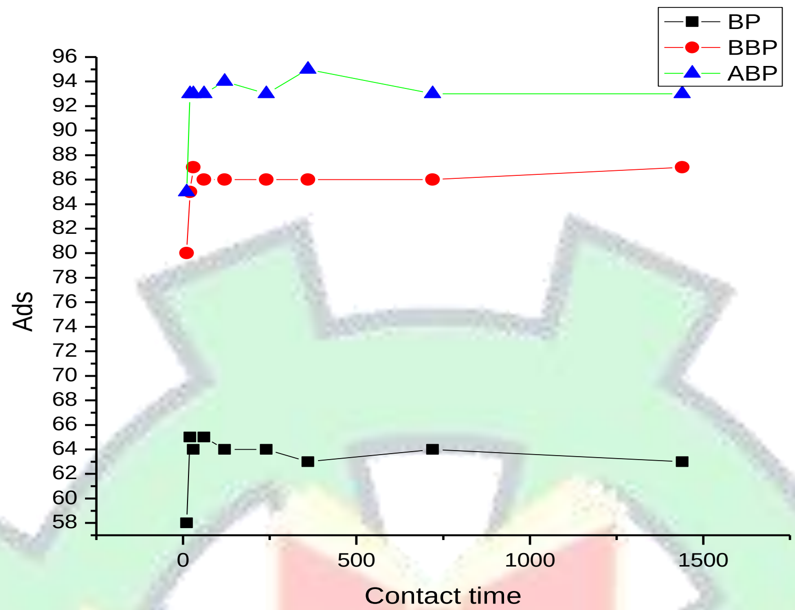


Figure 6: Effect of contact time on adsorption of Zn ions

Effect of temperature:

Figure 7 illustrates the influence of temperature on banana peel adsorption of Zn(II). The optimal temperature for Zn(II) adsorption was 35 °C. The fact that the adsorption capability of Zn(II) increased as the solution temperature rose indicates that the process was endothermic. Temperature rise accelerated the movement of Zn(II) ions from the solution onto the empty sites of banana peel and decreased the thickness of the peel's surface layer.

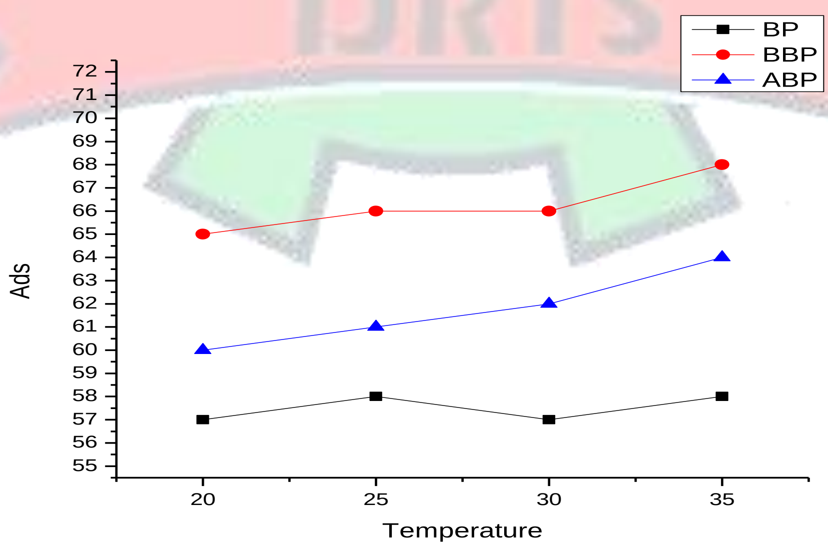


Figure 7: Effect of temperature on adsorption of Zn ions.

Conclusion

We have created a bio-adsorbent based on banana trash that can remove zinc ions from aqueous solutions. We have a wide range of reaction parameters, such as adjusting the pH, solution temperature, adsorbent dose, contact time, and solid-liquid ratio. The removal of cadmium from banana peel has been proven to be very effective, economically feasible, and inexpensive.

References:

1. Benguella, B.; Benaissa, H., Cadmium removal from aqueous solution by chitin: kinetic and equilibrium studies. Water Res., 36: (2002), 2463–2474.
2. Bernard A., Cadmium & its adverse effects on human health. Indian J Med Res 128(4): (2008), 557–564.
3. Bhatti, H.N.; Khalid, R.; Hanif, M.A., Dynamic biosorption of Zn(II) and Cu(II) using pretreated Rosa gruss an teplitz (red rose) distillation sludge. Chem. Eng. J., 148: (2009), 424–443.
4. Yang, J., Zheng, Y. A., Gou, X., Pu, K., Chen, Z., Guo, Q., ... & Zhou, Y. (2020). Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. International journal of infectious diseases, 94, 91-95.
5. Fairbairn, D. J., Elliott, S. M., Kiesling, R. L., Schoenfuss, H. L., Ferrey, M. L., & Westerhoff, B. M. (2018). Contaminants of emerging concern in urban stormwater: Spatiotemporal patterns and removal by iron-enhanced sand filters (IESFs). Water Research, 145, 332-345.
6. Odobašić, A., Šestan, I., & Begić, S. (2019). Biosensors for determination of heavy metals in waters. Biosensors for environmental monitoring.
7. Cullaj, A., Hasko, A., McBow, I., & Kongoli, F. (2004). Investigation of the potential of several plants for phytoremediation of nickel contaminated soils and for nickel phytoextraction. European Journal of Mineral Processing & Environmental Protection, 4(2).
8. Chatterjee S, Sivareddy I, De S, Adsorptive removal of potentially toxic metals (cadmium, copper, nickel and zinc) by chemically treated laterite: Single and multicomponent batch and column study. J. Environ. Chem. Eng., 5(4), (2017), 3273–3289.

9. Deng, S.; Ting, Y.P. Characterization of PEI-modified biomass and biosorption of Cu(II), Pb(II) and Ni(II). Water Res., 39: (2005), 2167–2177
10. Dow, J.M.; Rubery, P.H., Chemical fraction of the cell walls of mycelial and yeast like of Mucor rouxii: Acomparative study of the polysaccharide and glycoprotein components. J. Gen. Microbiol., 99: (1977), 29–41.
11. Goksungur, Y.; Uren, S.; Guvenc, U., Biosorption of Cd and Pb ions by ethanol treated waste baker's yeast biomass. Bioresour. Technol., 96: (2005),103–109.
12. Hanif, M.A.; Nadeem, R.; Bhatti, H.N.; Ahmad, N.R.; Ansari, T.M., Ni (II) biosorption by Cassia fistula (Golden Shower) biomass. J. Hazard. Mater., 39: (2007), 345–355.
13. Hanif, M.A.; Nadeem, R.; Zafar, M.N.; Akhtar, K.; Bhatti, H.N., Kinetic studies for Ni(II) biosorption from industrial waste water by Cassia fistula (golden shower) biomass. J. Hazard. Mater., 145: (2007), 501–505.
14. Iftikhar, A.R.; Bhatti, H.N.; Hanif, M.A.; Nadeem, R. Kinetic and thermodynamic aspects of Cu(II) and Cr(III) removal from aqueous solutions using rose waste biomass. J. Hazard. Mater., 161: (2009), 941–947.
15. Mohammed, R. R., & Chong, M. F. (2014). Treatment and decolorization of biologically treated Palm Oil Mill Effluent (POME) using banana peel as novel biosorbent. Journal of environmental management, 132, 237-249.
16. Sari, S. N., & Melati, A. (2019). Facile preparation of carbon nanofiber from banana peel waste. Materials Today: Proceedings, 13, 165-168.
17. Ahmad, T., & Danish, M. (2018). Prospects of banana waste utilization in wastewater treatment: A review. Journal of environmental management, 206, 330-348.
18. Deshmukh, P. D., Khadse, G. K., Shinde, V. M., & Labhasetwar, P. (2017). Cadmium removal from aqueous solutions using dried banana peels as an adsorbent: kinetics and equilibrium modeling. Journal of Bioremediation & Biodegradation, 8(03), 1-7.
19. Moreno-Castilla, A.; Carrasco-Marin, F.; Maldonado-Hodar, F.J.; Rivera-Utrilla, J., Effects of non-oxidant and oxidant acid treatments on the surface properties of an activated carbon with very low ash content. Carbon, 36: (1997), 145–151.
20. Moreno-Castilla, A.; Carrasco-Marin, F.; Maldonado-Hodar, F.J.; Rivera-Utrilla, J., Effects of non-oxidant and oxidant acid treatments on the surface properties of an activated carbon with very low ash content. Carbon, 36: (1997), 145–151.
21. Muraleedharan, T.R.; Venkobachar, C., Mechanism of cobalt biosorption. Biotechnol. Bioeng., 33: (1990), 823–831.

22. Nakhla, G.; Lugowski, A.; Patel, J.; Rivest, V., Combined biological and membrane treatment of food processing waste water to achieve dry-ditch criteria: Pilot and full scale performance. Bioresour. Technol., 97: (2006), 1–14.
23. Nuran, A., Zeynep, E., and Necla, B., Removal of Cu (II) Ions by Activated Poplar Sawdust (Samsun Clone) from Aqueous Solutions, J. Hazard. Mater., vol. 137, 2006, 909.
24. Pavasant, P.; Apiratikul, R.; Sungkhum, V.; Suthiparinyanont, P.; Wattanachira, S.; Marhaba, T.F., Biosorption of Cu2þ, Cd2þ, Pb2þ and Zn2þ using dried marine green macroalga Caulerpa lentillifera. Bioresour. Technol., 97: (2006), 2321–2329.
25. Prasad, M.N.V.; Hagemeyer, J., Heavy Metal Stress in Plants from Molecule to Ecosystems; Springer, (1999), 11–37.
26. Romero-Cano L.A., García-Rosero H., Gonzalez-Gutierrez L.V., BaldenegroPérez L.A., Carrasco-Marín F., J. Clean. Prod. 162 (2017), 195.
27. Rosales E., Meijide J., Tavares T., Pazos M. and Sanromán M.A., Process Saf. Environ. Prot., 101 (2016), 61.
28. Ross, S.M. Toxic Metals in Soil Plant Systems; Wiley: Chichester, (1994), 1–45.
29. Shakoor S., Nasar A., J. Taiwan Inst. Chem. Eng. 66 (2016), 154.
30. Sheng, P.X.; Ting, Y.P.; Chen, J.P.; Hong, L., Sorption of lead, copper, cadmium, zinc, and nickel by marine algal biomass: characterization of biosorptive capacity and investigation of mechanisms. J. Colloid Int. Sci., 275 (1): (2004), 131–141.
31. Sternberg, S.P.K.; Dom, R.W., Cd removal using cladophora in batch, semi batch and flow reactors. Bioresour. Technol., 81: (2004), 249–255.
32. Sudha R., Srinivasan K., Premkumar P., Ecotoxicol. Environ. Saf. 117 (2015), 115.
33. Torab-Mostaedi M., Asadollahzadeh M., Hemmati A., Khosravi A., J. Taiwan Inst. Chem. Eng. 44 (2) (2013), 295.