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Adsorptive Removal of Arsenic from Water by Adsorbents

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Abstract:
Arsenic pollution in water is a major challenge for water treatment. Sustainable adsorption offer promising alternative to conventional methods. Integrating circular economy principles promotes resource recovery, waste minimization and reuse of treated water. This review highlights various adsorbents used for Arsenic removal and emphasizes the importance of efficient, economical and environment friendly adsorption treatment for long term water quality protection and conservation.

Keywords: ***Arsenic, Removal, sustainability, water treatment***

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Introduction

Arsenic is a naturally occurring element in groundwater caused by geological weathering. Groundwater gets contaminated further by activities such as mining, smelting, and agriculture [1]. Very high concentrations of arsenic are found in wastewaters originating from textile industry, and other anthropogenic activities. These wastewaters have to be treated efficiently to prevent release of high arsenic content into natural water bodies, which eventually can contaminate surface water and groundwater and finally drinking water[2] In natural waters, inorganic arsenic mostly occurs as oxyanions: arsenite (As(III)) and arsenate (As(V)). A strict 10 µg/L limit was recommended by the WHO since skin lesions, cardiovascular illnesses, and numerous malignancies may be caused by chronic exposure to inorganic arsenic (As(III) and As(V)) [3]. Conventional methods, such as ion exchange, reverse osmosis, and membrane filtration, are not feasible for large applications due to low efficiency, generation of secondary pollutants, and high cost. In developing countries, precipitation and adsorption methods are widely used for As removal. Precipitation method requires a large amount of chemicals and creates a volumetric sludge as Arsenic III sulfide, calcium arsenate, or ferric arsenate. So, the adsorption method is the method of choice. The method is simple, cost-effective, and effcient with minimum waste production and can be applied in water containing trace amount of pollutants [4]. The adsorption technique has become a leader owing to its efficacy over a range of arsenic concentrations (µg/L to mg/L) [5], ability to employ both natural and synthetic adsorbents [6], and reusability [7]. The approach consists of two primary steps [8]: physisorption, characterized by weak van der Waals interactions [9], and chemisorption, which entails the creation of stronger chemical bonds [10]. Adsorption of arsenic strongly depends on the system's concentration and pH. At low pH, arsenate adsorption is favoured, whereas for arsenite, maximum adsorption can be obtained between pH 4 and 9. Agricultural wastes as adsorbents has many advantages like low cost, ecofriendly, available in abundance, easy modification, effective, and supports sustainability and circular economy. This paper reviews the various adsorbents used in arsenic removal from water.

Various Adsorbents in Arsenic removal from water

Rice Husk

Md. Akbar Ali assessed Ricehusk for the removal of Arsenic from solution. Rice husk contain cellulose in high amount which has potential to adsorb heavy metal. Acidic modification of rice husk increased capability to adsorb arsenic from solution. The efficiency of acid treated rice husk varied on many parameters like amount of acid treated biochar, equilibrium contact time, concentration of arsenic in waste water, temperature of waste water, and level of pH.The maximum adsorption capacity was found to be 3.32 mg/g, 3.25 mg/g, 2.26 mg/g at 30°C, 40°C and 50°C respectively for acid treated biochar[11]

Red macroalgae

Khanzada et al investigated the potential of hydrochar prepared from red macroalgae for removing As from synthetic wastewater. The hydrochar was produced through 5 h hydrothermal carbonization treatment at 200^0 C, and then, chemically activated with ferric chloride hexahydrate. Hydrochar was then tested in batch experiments to investigate its As removal efficiency. As removal efficiency increased with increasing initial As concentration from 50 to 250 mg/L, and the highest As removal efficiency was 84.75% at a pH of 6, initial concentration of 0.25 mg/L, and adsorbent dose of 1000 mg at 120 min. The Langmuir isotherm model supported the occurrence of homogeneous adsorption over the surface of hydrochar, while the pseudo-second-order model confirmed the chemisorptive nature of the process[12]

Magnetic Fe_3O_4/sugarcane bagasse Activated carbon composite

Joshi et al developed magnetic Fe_3O_4/sugarcane bagasse activated carbon composite for the adsorption of arsenic (III) from aqueous solutions. Batch adsorption experiments were conducted for the adsorption of As(III) onto the composite. The result showed that the composite could remove the arsenic from the water far more effectively than the plain Activated Carbon. The highest percentage of arsenic removal was found at pH at 8, adsorbent dose of 1.8 g/L, and contact time of 60 min. Langmuir model showed the best fit compared to the Freundlich model with a maximal capacity of 6.69 mg/g.[13]

Fe modified W Zeolite

Medina-Ramirez et al studied a low cost zeolite prepared from fly ash modified by chemical treatment with ferrous chloride for arsenite adsorption capacity. The effect of pH, ions coexistence, concentration, temperature and dosage was studied. The Fe-modified W zeolite was stable in the pH range of 3 to 8 and no detriment to its arsenite removal capacity was observed in the presence of coexisting ions commonly found in underground water. The exhausting process proved the adsorption of 0.20 mg g^{-1} of As (III) by the Fe-modified W zeolite and this withstood at least five aging cycles without significant changes of its arsenite adsorption capacity.[14]

Magnetic Fe_3O_4/Douglas fir biochar composites

Navarathna et al employed a modified biochar known as magnetic Fe_3O_4/Douglas fir biochar composites to effectively remove As(III)-contaminated water. Adsorption kinetics data best fitted the pseudo second order model ($R^2 > 0.99$). The Sips isotherm showed the best fit at 25 °C with a 5.49 mg/g adsorption capacity. Experiments were performed on industrial and laboratory wastewater samples in the presence of other co-existing contaminants (pharmaceutical residues, heavy metals ions and oxi-anions). The composite reduced the arsenic concentrations below the WHO's safe limit of 0.2 mg/L for waste water discharge.[15].

Biochar-CuO nanocomposite from Cypress cones

Hamadneh et al studied the removal of arsenite using biochar (BC) and biochar-CuO nanocomposite (BC-CuO-NC) from cypress cones biomass. Arsenite adsorption was studied using the batch technique at different pH, contact time, adsorbent dose, and temperature conditions. BC-CuO-NC demonstrated better adsorption efficiency than BC to 5–6 pH arsenite with a 55.58% removal percentage and a 10 min balance period. According to the Langmuir model, the saturated adsorption capacity of BC and BC-CuO-NC for arsenite reached 22.831 and 36.765 mg/g, respectively. [16]

Orange Peel

Yuan Peng et al converted Orange peels into a low-cost adsorbent. The effects of solution pH, contact time, and concentration of orange peel had been studied. The maximum adsorption capacity calculated from the Langmuir isotherm model was 43.69 mg g^{-1} [17]

Fe(III) loaded saponified Punica granatum peel

Pant et al synthesized Fe(III) loaded saponified Punica granatum peel (Fe(III)-SPGP) to remove arsenic from aqueous solutions. Batch experiments were carried out by altering several factors including pH and contact time, in addition to initial concentration and desorption. The most effective pH for As(III) adsorption using Fe(III)-SPGP was discovered to be 9.0. Pseudo-second-order kinetic model provided the greatest fit and Langmuir isotherm was applied. The maximum adsorption of As(III) that could be adsorbed by Fe(III)-SPGP was 63.29 mg/g. [18]

Neem Bark

Tasrina R. Choudhury et al assessed the adsorption characteristics of arsenic on neem bark, in the laboratory scale using real-life sample. The work investigated the possibility of the use of neem bark adsorption technology without any pretreatment in the removal of arsenic from aqueous media.Adsorption column methods showed the maximum removal of As (III) under the following conditions:initial arsenic concentration, 100 μg/L; neem bark amount, 5 g; average particle size,0.595 mm; treatment flow rate, 1.67 mL/min; and pH, 6.9; respectively. The desorption efficiencies with 1M of HCl after the treatment of groundwater was in the range of 79%.[19]

Fe_3O_4-sunflower straw biochar

Zhao et al analysed an advanced Fe_3O_4@SFBC (Fe_3O_4-sunflower straw biochar) adsorbent for As(III/V) removal. Fe_3O_4@SFBC showed removal efficiency of 86.43% and 95.94% for As(III) and As(V), respectively, at pH 6 and 4. When the SFBC biochar is calcined at 450 °C with an SFBC/Fe mass ratio of 1:5, the adsorption of As(III) and As(V) reached the maximum, which are 121.347 and 188.753 mg/g, respectively. The material was used for five consecutive cycles of adsorption–desorption experiments, and no significant decrease in removal efficiency was observed. [20]

Conclusion

The review showed the different adsorbents used for the removal of Arsenic from water effectively. The removal of arsenic from contaminated water using suitable adsorbent materials offers a promising and effective approach for providing safe and clean water. The adsorption process can efficiently reduce arsenic concentrations and thereby minimize the health and environmental risks associated with arsenic contaminated water. The use of low-cost materials as adsorbents can further make the treatment process economical and sustainable.

References

1.Chen, Q.Y.; Costa, M. Arsenic: A Global Environmental Challenge. Annu. Rev. Pharmacol. Toxicol. 2021, 61, 47–63

2. Katsoyiannis, I.A.; Hug, S.J.; Ammann, A.; Zikoudi, A.; Hatziliontos, C. Arsenic speciation and uranium concentrations in drinking water supply wells in Northern Greece: Correlations with redox indicative parameters and implications for groundwater treatment. Sci. Total Environ. 2007, 383, 128–140.

3. Committee on Medical and Biological Effects of Environmental Pollutants. Arsenic Medical and Biologic Effects of Environmental Pollutants; National Academy of Sciences: Washington, DC, USA, 1977; p. 332

4. Yao, S.; Liu, Z.; Shi, Z. Arsenic removal from aqueous solutions by adsorption onto iron oxide/activated carbon magnetic composite. J. Environ. Health Sci. Eng. 2014, 12, 58

5. Jekel, M.; Amy, G.L. Interface Science in Drinking Water Treatment—Theory and Application Arsenic removal during drinking water treatment. Interface Sci. Technol. 2006, 10, 193–206.

6. Hao, L.; Liu, M.; Wang, N.; Li, G. A critical review on arsenic removal from water using iron-based adsorbents. RSC Adv. 2018, 8, 39545–39560.

7. Li, D.; Yadav, A.; Zhou, H.; Roy, K.; Thanasekaran, P.; Lee, C. Advances and Applications of Metal-Organic Frameworks (MOFs) in Emerging Technologies: A Comprehensive Review. Glob. Chall. 2024, 8, 2300244.

8. Ho, Y.S. Review of second-order models for adsorption systems. J. Hazard. Mater. 2006, 136, 681–689.

9. Rouquerol, F.; Rouquerol, J.; Sing, K. Adsorption by Powders and Porous Solids: Principles, Methodology and Applications; Academic Press: Cambridge, MA, USA, 1999.

10. Masel, R.I. Principles of Adsorption and Reaction on Solid Surfaces; Wiley: Hoboken, NJ, USA, 1996.

11. Md. Akbar Ali. Removal of Arsenic from wastewater by acid treated Rice Husk, Int. res. j. eng. tech, 2019, Vol 6 (5), 7242.

12. Khanzada, A. K., Rizwan, M., Al-Hazmi, H. E., Majtacz, J., Kurniawan, T. A., & Mąkinia, J. Removal of arsenic from wastewater using hydrochar prepared from red macroalgae: Investigating its adsorption efficiency and mechanism. Water, 2023, 15(21), 3866.

13 Joshi, S., Sharma, M., Kumari, A., Shrestha, S., & Shrestha, B. Arsenic Removal from Water by Adsorption onto Iron Oxide/Nano-Porous Carbon Magnetic Composite. Applied Sciences, 2019, 9(18), 3732

14. Medina-Ramirez A, Gamero-Melo P, Ruiz-Camacho B, Minchaca-Mojica JI, Romero-Toledo R, Gamero-Vega KY. Adsorption of Aqueous As (III) in Presence of Coexisting Ions by a Green Fe-Modified W Zeolite. Water. 2019; 11(2):281

15. Navarathna, C. M., Karunanayake, A. G., Gunatilake, S. R., Pittman, C. U., Perez, F., Mohan, D., et al. Removal of Arsenic(III) from water using magnetite precipitated onto Douglas fir biochar. J. Environ. Manage.2019, 250, 109429.

16. Hamadneh, I., Al-Mobydeen, A., Hannoon, F., Abu Jaber, A., Albuqain, R., Alsotari, S., & Al-Dujaili, A. H. Arsenite adsorption on biochar-based nano copper oxide composites using Mediterranean cypress cones: Equilibrium, kinetic and thermodynamic studies. Desalination and Water Treatment, 2021, 221, 260–273

17. Peng, Yuan & Xiao, Hong & Cheng, Xian & Chen, Hong. Removal of Arsenic from Wastewater by Using Pretreating Orange Peel. Advanced Materials Research.2013,773. 889-892.

18. Pant, B. D., Adhikari, S., Shrestha, N., Baral, J., Paudyal, H., Ghimire, K. N., Pokhrel, M. R., & Poudel, B. R. Iron-loaded Punica granatum peel: An effective biosorbent for the excision of arsenite from water. Heliyon,2024, 10(17).

19. Choudhury, Tasrina. Arsenic (III) Removal from Real-Life Groundwater by Adsorption on Neem Bark (Azadirachta indica). International Research Journal of Pure & Applied Chemistry.2014, 4. 29-42.

20. Zhao Y, Shi H, Tang X, Kuang D, Zhou J, Yang F. Performance and Mechanism of As(III/V) Removal from Aqueous Solution by Fe_3O_4-Sunflower Straw Biochar. Toxics. 2022; 10(9):534

