

Removal of Arsenic using Low Cost Biosorbent Tamarind Bark

Pagala Bangaraiyah, Popuri Ashok Kumar

Abstract: The present work focuses the potentiality of agricultural waste, Tamarind bark for removal of arsenic from industry effluent. One parameter model was performed to evaluate time, dosage, concentration of arsenic ion and pH. The process conditions were determined as contact time 50 minutes, dosage 0.85gm, metal ion concentration 0.1g/l and pH was 4. The experimental values are analysed with adsorption isotherms to know the capacity of biosorbent. The data well explained Langmuir model compared to Freundlich model. The mechanism involved in biosorption was tested by using kinetic expressions of first and second order, but the given values are best suited to second order kinetics. The maximum removal of arsenic using low cost biosorbent of tamarind bark was found to be 68%.

Keywords: Arsenic metal, tamarind bark, biosorption, adsorption isotherm, kinetics

I. INTRODUCTION

The appearance of toxic metals in ground and surface water bodies causes serious problem to human and environment. So, there is a need of research on finding the new method for removal of these contaminants [1]. The metals like Fe, Zn, Cr, Cu and Arsenic are the most toxic non biodegradable metals accumulate in the water bodies. The toxic metals appear even at low concentrations in the drinking water leads to adverse affects on human beings [2].

Arsenic is a dangerous heavy metal found in ground and various industrial activities like electroplating, metallurgical and petroleum refining. The ground water contaminated with arsenic have a great impact on environment [3]. The presence of arsenic in water causes to kidney problems, skin cancer, lungs and neurological problems to mankind [4].

The heavy metal arsenic and other metals are removed by many different methods such as dialysis, precipitation, filtration and extraction. These techniques are suffering with lot of problems like sludge formation, high cost, less removal rate etc. Because of these drawbacks the above methods are not suitable recovery of toxic metals. So, the alternative technology to this is biosorption [5]. This method is a new technology for reducing the metal ions. It minimizes the sludge formation, cost and residual metal ion precipitation. In biosorption process the biosorbent selected for removal of heavy metal was a low cost easily available agricultural waste dead biomass [6]. The objective of present work is to find the biosorption capacity of agricultural waste biosorbent tamarind bark for reducing arsenic metal using biosorption method. The various factors affecting the biosorption process were also evaluated.

Revised Manuscript Received on November 15, 2019

Pagala Bangaraiyah, Chemical Engineering, VFSTR, Vadlamudi-522213, A.P., India,

Popuri Ashok kumar, Chemical Engineering, VFSTR, Vadlamudi-522213, A.P., India,

II. MATERIALS AND METHOD

A. Preparation of biosorbent and stock solution

Tamarind tree bark was taken from kavoor of Karnataka state. This was cleaned and dried in at a temperature of 40° C for 5 hrs and crushed to make powder. The powder was sieved using sieve shaker and gets the uniform size of 120µm. The stock solution was prepared by using sodium arsenate hydrate solution. The required concentrations were prepared with serial dilution [7].

B. Experimental method

The biosorption of arsenic using tamarind bark experiments were performed in one parameter method. The various process conditions of t time, dose, initial concentration of metal and pH are evaluated. The sample was taken at constant conditions of pH-5, dosage 0.85gm, concentration 0.1g/l and temperature of 32°C into a conical flask for getting optimum contact time. Then biosorbent was added and agitated for a period of one minute[8]. The agitated sample was filtered and analyzed with spectrophotometer to get the concentration after biosorption of arsenic. The arsenic removal was estimated by

Percentage removal of arsenic = $\frac{C_i - C_o}{C_i} * 100$

Here, C_i and C_o were concentrations of before and after sorption.

III. RESULTS AND DISCUSSION

A. Contact time

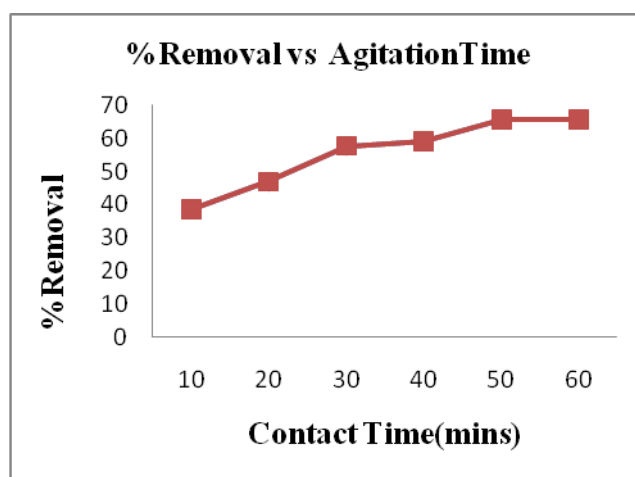


Figure. 1 Contact Time with percentage removal

From Figure.1, the removal of arsenic was raised with raise in contact time from 10 min to 50 minutes. This was due to surface area available for sorption was more at initial stage. After this the active sites

Removal of Arsenic Using Low Cost Biosorbent Tamarind Bark

were got saturated and hence no change in percentage removal of arsenic was noticed. So, the maximum arsenic removal was occurred at 50 minutes [10,11].

B. Effect of Initial concentration

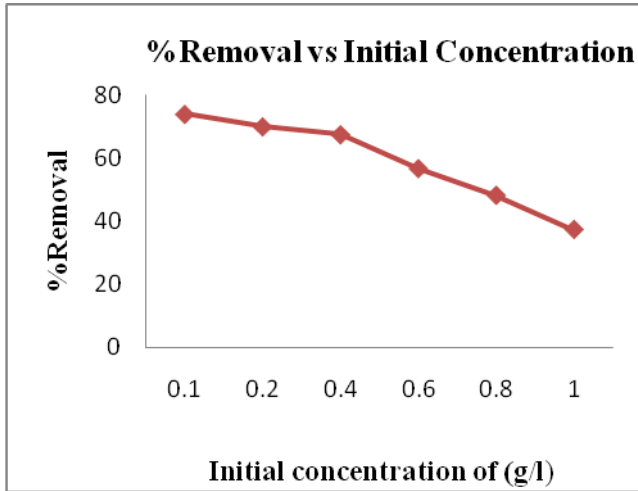


Figure.2 Metal Ion Concentration With Percentage Removal

The influence of arsenic concentration on biosorbent was estimated by taking concentration range of 0.1 to 1 g/l. From figure.2, it was clearly noticed that at 0.1 g/l concentration the percentage arsenic removal was more compared to the concentration at 1 g/l. This was as a result of more active sites at low concentration. As concentration increased the number of available active sites were less, hence removal of arsenic was low [11]. So, the maximum arsenic removal was identified at 0.1g/l.

C. Effect of Dosage

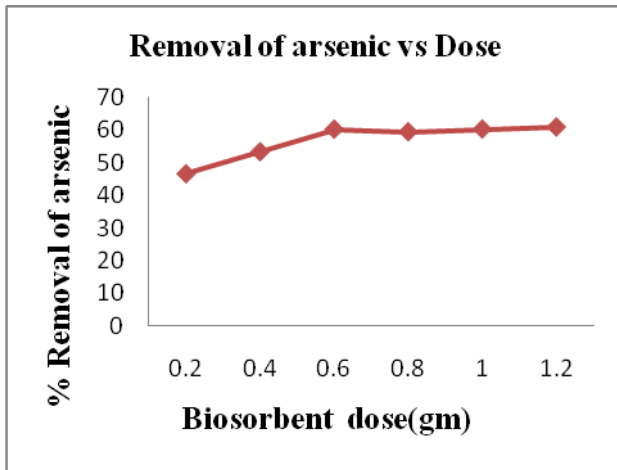


Figure.3 Change of biosorbent dose

The percentage removal was influenced with biosorbent dose and was one of the important parameter in evaluation. From figure.3, as biosorbent dosage increased from 0.2gm to 0.8gm, the arsenic removal was raised from 46% to 62%, because of more number of binding sites available for sorption. If biosorbent dosage increased the beyond 0.8gm, there was no change in percentage removal of arsenic due to less number of sorbate ions compared to active surface area available for sorption[12]. So, the optimum dosage was 0.8gm.

D. Effect of pH

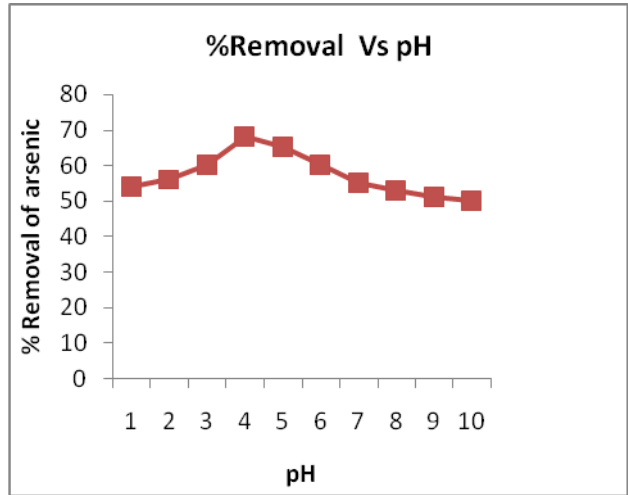


Figure.4 Removal of arsenic with Initial P^H

The solution pH considered as an important parameter due to great influence of percentage removal of arsenic with ph. The figure.4 presented that as pH increase from 1 to 2, there was less percentage removal of arsenic metal, because of adsorbate faced the H⁺ ions on biomass. As pH increases beyond 2, there was great increase in removal of arsenic because of deprotonation of the active sites on biosorbent surface [13]. When pH was increased more than 4, there was decrease in percentage removal of arsenic metal due to precipitation.

E. Adsorption isotherms

The adsorption isotherms explain the mechanisms involved in biosorption process between biosorbent and sorbate. Here two models were tested to find the mechanism; those are 1. Freundlich isotherm 2. Langmuir isotherm.

F. Freundlich isotherm

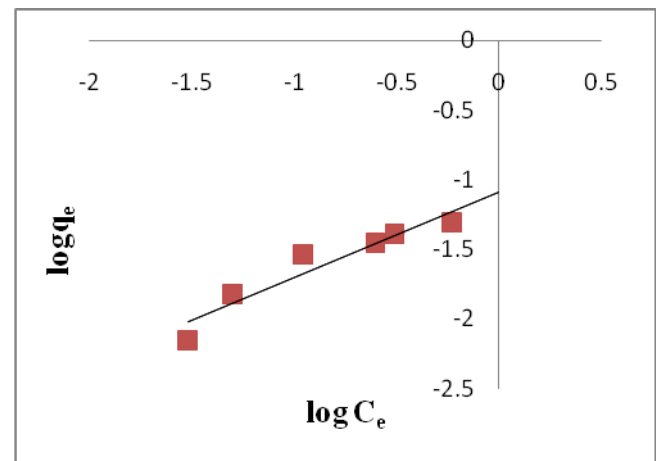


Figure.5 Freundlich model

This model assumes heterogeneous surface of the biosorbent and equation was represented by

$$\log Q_e = \log k_f + 1/n \log C_e$$

Here Q_e – equilibrium biosorption capacity, C_e – concentration at equilibrium, k_f and n constants. From figure.5, the data were not well correlated to Freundlich model [14].

G.Langmuir isotherm

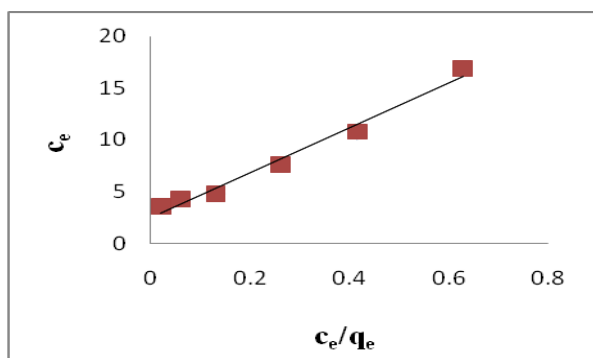


Figure.6 Langmuir isotherm

The Langmuir model was as follows

$$C_e / q_e = 1 / q_o b + C_e / q_o$$

Here, C_e concentration at equilibrium, q_e biosorption capacity, Q_o and b constants. A plot of C_e / q_e Vs C_e gives slope of $1/Q_o$. The Langmuir constants b and Q_o were estimated. From figure.6, the given values were best correlated to Langmuir model than Freundlich model [15].

H. kinetic mechanisms

The sorption rate of adsorbate onto the adsorbent was described by kinetics. It was also determine the controlling mechanism involved in biosorption process. Here two mechanisms were tested to analyse the data. First order 2. Second order mechanisms [16-17].

The 1st order rate expression

$$\log(q_e - q_t) = \log q_e - k_d t$$

Here, q_e adsorption rate at equilibrium, q_t adsorption rate at any time and k_d was the rate constant. From figure.7, it was observed that R^2 value is not very close to 1. So, the given data were not best suited to first order kinetics [17-18].

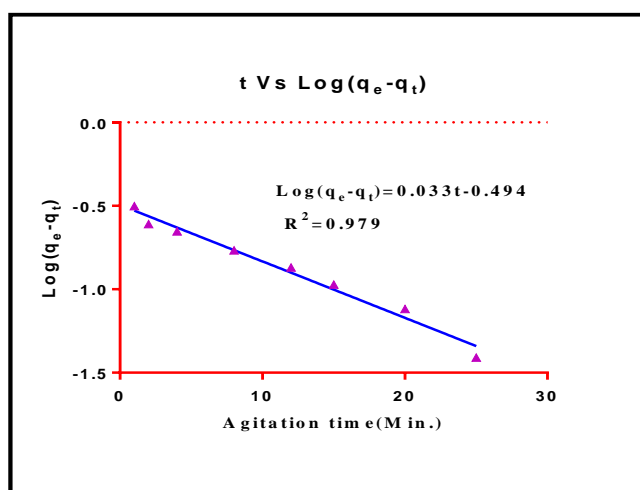


Figure.7 First order kinetics

The second order equation was presented as

$$t/q_t = 1 / k_s q_e^2 + 1/q_e$$

Here q_t - rate of adsorption at any time, q_e -rate of adsorption at equilibrium and k_s was second order rate constant. From figure.8, it was noticed that R^2 value is very close to 1. So,

the given data were best followed the second order compared to first order kinetic mechanism [19-21].

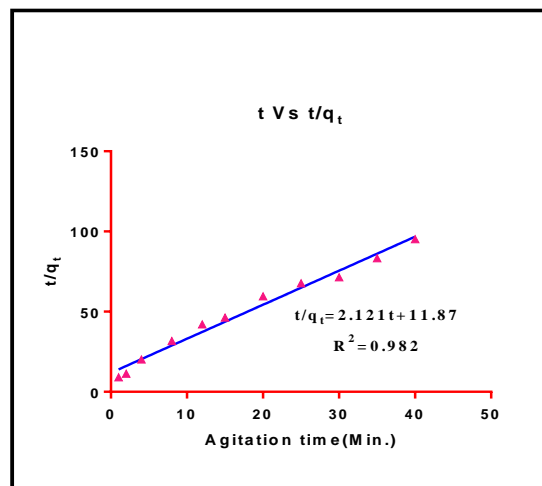


Figure.8 Second order kinetics

IV. CONCLUSION AND FUTURE SCOPE

The results showed that the tamarind bark biosorbent was favourable for biosorption of arsenic. The process conditions, which were influencing the biosorption, were found to be contact time 50minutes, dosage 0.85gm, metal ion concentration 0.1g/l and pH 4. The experimental values were analysed with Freundlich and Langmuir models and are well suited to Langmuir model. The biosorption mechanism was tested with two kinetic mechanisms. The experimental values were well followed to second order kinetics. The maximum percentage removal of arsenic using tamarind bark was found to be 68%. In this work evaluation of thermodynamic parameters are not done and also optimization of process parameters. In future there is a scope for optimization and also for multiple metal recoveries.

REFERENCES

1. Nisha, G., Aayush, K., Mahavir, Y., & Archana, Tiwari., "Adsorptive removal of lead and arsenic from aqueous solution using soya bean as a novel biosorbent: equilibrium isotherm and thermal stability studies" Applied Water Science, 2018, 8(98), pp.1-12.
2. Sibi, G., "Biosorption of Arsenic by Living and Dried Biomass of Fresh Water Microalgae - Potentials and Equilibrium Studies" Journal of Bioremediation & Biodegradation, 2014, 5, pp.249-252.
3. Catherine, N. H., Bohumil, V., & Daniel, C., "Biosorption of arsenic (V) with acid-washed crab shells." Water research, 2007, 41(11), pp.2473-2478.
4. Kamsonlian, S., Suresh, V., Ramanaiah, C. B., Majumder, S., & Chand, A. K., "Biosorptive behaviour of mango leaf powder and rice husk for arsenic(III) from aqueous solutions" International Journal of Environmental Science and Technology, 2012, 9, pp.565-578.
5. Sidhu, M., Sama, P., Parmar, J., & Sheelendra, B.M., "Biosorption of Arsenic (III) from drinking water by using low cost biosorbents derived from peels of Oranges, Turnip and Peanut shells" International Journal of Pharmaceutical Research & Drug Development, 2014, 1, pp.66-69.
6. Xue W.N., & Peng, Y.B., "Biosorption of Arsenic (III) from Aqueous Solutions by Industrial Fermentation Waste Aspergillus niger" Applied Mechanics and Materials, 2014, 1, pp.791-794.

- Srinivasulu, M, & Rao, A.S., "Absorption and emission spectra of Pr³⁺-doped mixed alkali fluorophosphate optical glasses". Journal of Materials science letters Nanoscience and Nanotechnology, 2001, 2, pp.737-740.
7. Sivaprakash, B., & Rajamohan, N., "Equilibrium and Kinetic Studies on the Biosorption of As (III) and As (V) by the Marine Algae *Turbinaria conoides*" Research Journal of Environmental Sciences, 2011, 5, pp.779-789.
 8. Pennesi, C., Vegliò, F., Totti, C., Romagnoli, T., & Beolchini, F., "Nonliving biomass of marine macrophytes as arsenic (V) biosorbents" Journal of Applied Phycology, 2012, 24, pp.1495–1502.
 9. Karlapudi A.P., Venkateswarulu T.C., Tammineedi J., Kanumuri L., Ravuru B.K., Dirisala V.R., & Kodali V.P, Role of biosurfactants in bioremediation of oil pollution-a review, Petroleum, 2018, 4, 241-249.
 10. Jaafarzadeh, N., Mengelizadeh, N., Takdastan, A., Farsani, M.H., Niknam, N., Aalipour, M., Hadei, M., & Bahrami, P., "Biosorption of heavy metals from aqueous solutions onto chitin" International Journal of Environmental Health Engineering, 2015, 4(7), pp.1-8.
 11. Yamani, J.S., Miller, S.M., Spaulding, M.L., & Zimmerman, J.B., "Enhanced arsenic removal using mixed metal oxide impregnated chitosan beads" Water Research, 2012, 46, pp. 4427-4434.
 12. Slavomír, E., Martin, U., Jaroslav, S., Pavol, L., & Edgar, H., "Biosorption of arsenic and cadmium from aqueous solutions" African Journal of Biotechnology, 2007, 6(16), pp. 1932-1934.
 13. Ramos-Vargas, S., Ruth Alfaro, C.V., Rafael, H.A., & Raúl, C.M., "Removal of Fluoride and Arsenate from Aqueous Solutions by Aluminum-Modified Guava Seeds" Applied Science, 2018, 8, pp.1807-1813.
 14. Pankaj, G., Debasish, D., & Tarun, K. M., "Equilibrium and kinetics study on removal of arsenate ions from aqueous solution by CTAB/TiO₂ and tarch/CTAB/TiO₂ nanoparticles : a comparative study" Journal of Water Health , 2016, 15 (1), pp. 58-71.
 15. Mohebrad, B., Bonyadi, Z., Dehghan, A., & Rahmat, M.H., "Arsenic removal from aqueous solutions using *Saccharomyces cerevisiae*: Kinetic and equilibrium study" Environmental Progress & Sustainable Energy, 2018, 5(2), pp. 1-5.
 16. Budinova, T., Petrov, N., Razvigorova, M., Parra, P., & Galiatsatou, J., "Removal of Arsenic(III) from Aqueous Solution by Activated Carbons Prepared from Solvent Extracted Olive Pulp and Olive Stones" Industrial & Engineering Chemistry Research, 2006, 45(6), pp.1896-1901.
 17. Michael, A.S., & Annadurai, G., "Arsenic Adsorption from Aqueous Solution Using Chitosan Nanoparticle". Research Journal of Nanoscience and Nanotechnology, 2012, 2, pp.31-45.
 18. [Kumar, P.R., Madhusudhanrao, V., Rao, B.N., Venkateswarlu, M., & Satyanarayana, N., Enhanced electrochemical performance of carbon-coated LiMPO₄ (M = Co and Ni) nanoparticles as cathodes for high-voltage lithium-ion battery, Journal of Solid State Electrochemistry, 2016, 20, 1855–1863.
 19. Sudhir, M.S., Mohan, P.M., & Nadh, R.V., Simple and validated ultraviolet spectrophotometric method for the estimation of Febuxostat in bulk and pharmaceutical dosage forms, Oriental Journal of Chemistry, 2013, 29(1), 235-240.
 20. Suresh, G., Venkata Nadh, R., Srinivasu, N., Kaushal, K., Novel coumarin isoxazoline derivatives: Synthesis and study of antibacterial activities, Synthetic Communications, 2016, 46(24), 1972-1980.

AUTHORS PROFILE



Bangaraiah Pagala is an Associate Professor at Vignan's Foundation for Science, Technology & Research, India. He obtained B. Tech, M.Tech and Ph.D in Chemical Engineering from Sri Venkateswara University, Tirupati. He has been conducting research in various fields, namely effluent treatment, adsorption, biosorption and process instrumentation.



Ashok Kumar Popuri is an Associate Professor at Vignan's Foundation for Science, Technology & Research, India. He obtained B. Tech in Chemical Engineering from Sri Venkateswara University, Tirupati and M.Tech in Chemical Engineering from IIT, Kharagpur and Ph. D in Chemical Engineering from Sri Venkateswara University, Tirupati. He has been conducting research in various fields, namely effluent treatment, waste heat recovery adsorption, coagulation and process simulation.