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REVIEW STUDY ON BIOSORPTION OF TOXIC POLLUTANTS FROM WASTE WATER

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Abstract

Toxic substances removal is necessary to achieve sustainability in wastewater treatment. It can be quite difficult to provide effective care at an affordable price. Adsorption techniques have successfully been shown to be capable of achieving the desired sustainable wastewater treatment. This review shows how several biosorption agents can remove harmful substances from wastewater.

Keywords: adsorption; wastewater,microorganisms,biosorption.

Introduction-

Water is the most valuable natural resource in the world and is necessary for all living things to survive. Nearly 71% of the earth's surface is covered in water, mostly in the form of oceans and other large reservoirs. Because physical processes including precipitation, evaporation, surface runoff, and infiltration frequently result in water entering the ocean. 0.001% of the water in the atmosphere is present as precipitation, clouds, and vapour, and 1.6% of the water is present on the ground. Humanity and other living things both need access to clean, fresh water to survive. However, the freshwater portion of the earth's ecosystem makes up only around 0.5% of the total, with river stations only up 0.01% of the total area. Due to its minimal quantities, this stream of water is therefore of tremendous significance (Khatri & Tyagi 2015). Recent years have seen a sharp increase in the need for clean water due to the rapid growth of businesses and population. According to the most recent report (Mckinsey 2009), several emerging countries will require more water than 50% of the time by the year 2030.

In recent years, due to the presence of untreated wastewaters, pesticides, and chemicals in the environment, water pollution has become the one global problem. Heavy metals and dyes are harmful contaminants that are released into water bodies directly or indirectly as a result of human, agricultural, and industrial activities. Human consumption of these waters spreads dangerous disorder. Typhoid, cholera, diarrhoea, and dysentery are only a few of the water-borne diseases caused by the deadly bacteria and viruses in this contaminated water (Ali 2014; Wang & Yang 2016).

Toxic Nature of Pollutants

Due to water pollution, it is dangerous to have untreated drinking water today. The change in water's physical, chemical, and biological properties is the main source of pollution. Heavy metals and dyes are two examples of both organic and inorganic contaminants that are major contributors to wastewater that pollutes the aquatic environment. Hazardous health difficulties for humans and other living species are caused by toxic heavy metals like copper (Cu), chromium (Cr), lead (Pb), nickel (Ni), mercury (Hg), cobalt and cadmium (Cd), as well as dyes in wastewater (Basaran et al. 2016; Hamidian et al. 2019; Vesali-Naseh et al. 2019; Sahoo et al. 2018). The vast majority of industrial applications consume more synthetic dyes than natural dyes, mostly due to their brilliant colours, ease of application, lower cost of production, and greater resistance to environmental factors. However, these colours are currently becoming more toxic, mutagenic, and carcinogenic (Ngah et al. 2011; Sinha et al. 2018). These heavy metals and dye-containing effluents enter water bodies as runoff from a variety of companies, including those that manufacture paint, smelt metal, mine for ore, process metal, process ore, manufacture batteries, and polish metal. Even if heavy metals have been used as fertilisers for growing vegetation at the microscopic level, high amounts can still have a variety of toxic effects.

Requisite Of Toxic Pollutants Removal-

The most common and dangerous pollutants are heavy metals, dyes, and pigments. They are produced by a range of companies, including those that make batteries, paper and pulp, leather tanning, textiles, and other goods, as well as residential, agricultural, and industrial processes. The accumulation of these hazardous contaminants in various internal organs of the human body causes major health problems for the human race. In order to safeguard the ecosystem and to prevent pollutants from entering food systems, efficient waste disposal is necessary (Kumar et al. 2014).

BIOSORPTION

One of the best methods for excluding contaminants from wastewater has shown to be adsorption. Adsorption is a process that occurs when a liquid or gas solute builds up on a liquid or solid surface, forming an atomic or molecular film. The chemical, physical, and biological systems are examples of the three main systems where this approach is effective. The term "adsorbent" refers to the surface of the solid on which adsorption is taking place, while "adsorbate" refers to the solute that engaged in the adsorption process. Physical adsorption and chemisorption are two different categories for the adsorption process. The weak Van der Waals forces cause the physical adsorption to occur. This type of adsorption has lower enthalpy values and is reversible. The chemisorption process, on the other hand, results from the chemical attraction between the adsorbent and adsorbate. It is irreversible and has a high enthalpy (Hernandez-Eudave et al. 2016). Adsorption is typically thought of as a surface phenomena, although the entire process actually takes place within the adsorbent's pores as well as on its surface. Four processes are included in the adsorption mechanism onto the adsorbent during the removal of the pollutant: advective transport, film transfer, mass transfer, and intraparticle diffusion. In the first step, solute particles are moved from bulk solution on the immovable film layer through axial dispersion or advective movement or diffusion which is called advective transport. In the second step, the solute particles are penetrated and attached to the fixed water film layer, which is termed as film transfer. In the third step, the solute particles are attached to the adsorbent surface which is called the mass transfer. Then the final step, the solute particles are moved into the pores present in the adsorbent surface. Unlike other common technologies, the adsorption technique has some crucial leads (i) cool to handle (ii) the adsorption is reversible, adsorbent used in this process may able to regenerate and reuse via desorption process (iii) inexpensive (iv) choosy adsorption of metal ions or dye molecules (v) efficacious pollutants (metal/dye) ejection even at minimal concentration .

Activated carbon (AC) is the most common sorbent used in wastewater treatment worldwide. Ancient Greeks, Egyptians, Romans, Sumerians, and Phoenicians used sorbents such as charcoal, sand, and clay to decontaminate and desalinate water. A new activated carbon precursor, charcoal, has been identified as a recognized prehistoric adsorbent material in wastewater treatment. Activated carbon is obtained through the process of dehydrating, activating, and carbonizing raw materials. The resulting yield has a huge surface area and a highly porous structure called activated carbon. This versatile sorbent has been used to remove many types of toxic contaminants, especially dyes and metals. Various types of activated carbon are available, including wood activated carbon, hazelnut activated carbon, coconut shell activated carbon, sawdust activated carbon and pulverized carbon activated carbon, and are commercially viable for sorption of toxic pollutants (Anfar et al. 2019). Despite the finer use of activated carbon, inefficiencies and excessive costs can limit its use. Therefore, recently researchers are looking for inexpensive sorbents that can be used to control water pollution. The holding cost aspect plays an important role here.

Biosorption is a powerful technique that uses dead, inert biomass to separate contaminants (heavy metals and dyes) from wastewater. This method is usually referred to as a physicochemical process and involves a number of metabolically independent processes that occur primarily in microbial cells and plant cell walls. Bioadsorption uses several natural substances as bioadsorbents, including physical and chemical adsorption, ion exchange, electrostatic interaction, chelation, complexation, reduction, and attachment of metal ions/dye molecules by precipitation. In general, this biosorption is a rapid and reversible process with several advantages. B. No increase in chemical oxygen demand (COD) of water, no need for additional nutrients, less sludge formation, high efficacy, minimal labor input, ease of use and biosorbent regeneration. The main task of the bioadsorption process is to find bioadsorption materials that can absorb metal ions/dye molecules with good attraction. Various types of biosorbents used to remove toxic contaminants include microorganisms (both living and dead), agricultural or industrial waste, plant material, etc. Fundamental functional groups present in biosorbents include amides, amines, thioethers, imidazoles, carbonyls, sulfonates, carboxyls, sulfhydryls, phenols, phosphodiesters, phosphates and imines, which can potentially bind and separate metal ions/dye molecules. Aqueous solutions (A k see 2005; Ahluwalia & Goyal 2007; Akar et al 2009).

DIFFERENT TYPES OF BIOSORBENTS

Microorganisms

Microorganisms spent as biosorbents for the separation of heavy metals and dyes from waste effluents, which can able to tolerate undesirable circumstances. Different kinds of microbial biosorbents (living or dead) including algae, bacteria, fungi, and yeast present in the environment. Compare to living biomass, dead biomass has been widely used by various researchers for the attaching of metal ions/dye molecules as a result of no need for nutrients and checking of COD and BOD in wastewaters. Thus, the usage of dead microbial biomass is cost-effective.

Algae in waste water treatment-

Algae is one of the eco-friendly and inexpensive biosorbent utilizedfor the treatment of effluent and has established attention owing to the excellent adsorption capacity, limited necessity of nutrients, abundantly obtainable, large extent cultivated across all over the world, the ability to regenerate and recover heavy metal or dye, a reduced amount of sludge disposal and elevated surface area to volume ratio. The major functional groups present in the algae are amino (NH_2^-), carboxyl (COO^-), hydroxyl (OH^-), and sulfate (SO_4^{2-}), which assist as an active site for the biosorption of toxic pollutants (Wang & Chen 2009). Different types algae have been employed as biosorbent by several researchers for the toxic pollutants removal and are involving blue-green algae (*Synechocystis* sp. (Öztürk *et al.* 2009), *Nostoc muscorum* (Dixit & Singh 2013)), green algae (e.g. *Chlorella vulgaris*

(Xie *et al.* 2014), *Scenedesmus obliquus* (Abdel Ghafar *et al.* 2014), *Oedogonium* h. (Gupta & Rastogi 2008), *Scenedesmus quadricauda* (Kızılkaya *et al.* 2012), *Cladophora glomerate* (Lee & Chang 2011), *Ulva lactuca* (El Sikaily *et al.* 2006), *Chaetomorpha linum* (Ajjabi & Chouba 2009) *Caulerpa lentillifera* (Pavasant *et al.* 2006), *Ulva onoi* (Suzuki *et al.* 2005), brown algae (*Sargassum* sp. (Negm *et al.* 2018), *Ulva fasciata* (Nessim *et al.* 2011), *Padina* sp (Khani 2013), *Fucus vesiculosus* (Lebron *et al.* 2019), *Cystroseria* baccata (Herrero *et al.* 2005), and red algae (*Gelidium sesquipedale* Vilar *et al.* 2006).

Bacteria in waste water treatment-

Bacterial biomass is participated in the biosorption as a biosorbent due to its exceptional structure of the body and can be either particularly grown extensively or generated as a by-product of industries. The disadvantages of using this biomass are the limited choices of various constraints including temperature and pH, and the intricate biochemical reactions. Because of their inadequate metal/dye uphold ability, bacteria are not effectively treating the toxic pollutant containing wastewater in huge amounts. Examples of bacteria are *Bacillus sp.* (Wierzba 2015), *Micrococcus sp.* (Bilal *et al.* 2013), and *Pseudomonas sp.* (Garg *et al.* 2012).

Fungi in waste water treatment-

Fungi generally have been propagated by utilizing low-cost culture medium and simple fermentation technologies or spent carbohydrate comprising culture medium. These fungal biomasses have an ability to eliminate heavy metals/dye molecules from aqueous solution and are including *Aspergillus niger* , *White rot fungi* ,*Tremella fuciformis*, and *Auricularia polytricha* . Same like fungi, yeasts are also cultured which are the directly obtainable low-priced resource. Compare to bacteria, it is quite bigger in size. Since the high rate of growth and single-celled nature, these yeast biomasses like *Cunninghamella elegans* (Ambrósio *et al.* 2012), *Candida albicans* (Baysal *et al.* 2008), and *Saccharomyces cerevisiae* (Amirnia *et al.*2015) are to be used as biosorbent in wastewater treatment.

Industrial Wastes and Byproducts-

The different industries, mainly, food manufacturing industries, generate huge capacities of wastes and byproducts. Cost relating to either the treatment of waste or disposal of these wastes is a serious ecological challenge. Spending these cost-free industrial wastes an efficient biosorbent for treating the wastewater may provide a solution to the dual problem with an ecological perspective. Industrial wastes released from industries are including tea industry waste from tea factory (Sulyman *et al.* 2017), peach and apricot stones from juice and jam industry (Rashed 2006), antibiotic waste from antibiotic production complex (Yeddou-Mezenner 2010), fly ash from cement industry (Alinnor 2007), sludge from paper industry (Suryan & Ahluwalia 2012), red mud from aluminum industry (Ahmaruzzaman 2011).

Agricultural wastes in waste water treatment-

Agricultural wastes, mainly comprising cellulose and lignin indicate the best metal ions/dye molecules binding ability. The essential elements present in these wastes are starch, water hydrocarbon, a simple sugar, protein, lignin, lipids, hemicellulose and extractives. These wastes are cheap, easily available, effective, and renewable. Different agricultural wastes like rice husk (Ye *et al.* 2010), wheat bran (Nouri & Hamdaoui 2007), black gram husk (Saeed & Igbal 2003), sugarcane bagasse, etc.,may be used as effectively in waste water treatment.

Conclusion-

One of the top goals for the current generation is the production of portable water from extremely polluted industrial wastewater. Application of the right adsorbents in wastewater treatment has proven to be very effective and cost-effective. An overview of adsorption procedures for pollutant removal was given in the current review. The current review has also offered a synopsis of the advancement of conventional and nano-advanced adsorbents. Additionally, it produces almost no sludge and is widely available, regenerable, and accessible. Therefore, the improvement of the wastewater treatment process employing sorption technology requires the deployment of biosorbents as green technology.On the basis of the references to various biosorbents that were utilised in this review study, we can draw the conclusion that various types of biosorbents may be used in the treatment of waste water.Algal biomass is the most effective and reasonable biosorbent material that can have the capacity to attract heavy metals and dyes from aqueous solutions when compared to all the other biosorbents.

References-

1. Abdel Ghafar, HH, Abdel-Aty, AM, Ammr, NS & Embaby, MA 2014, 'Lead biosorption from aqueous solution by raw and chemically modified green fresh water algae Scenedesmus obliquus', Desalination and Water Treatment, vol. 52, pp. 7906-7914.
2. Ahluwalia, SS & Goyal, D 2007, 'Microbial and plant derived biomass for removal of heavy metals from wastewater', Bioresource Technology, vol. 98, pp. 2243-2257.
3. Ahmaruzzaman, M 2011, 'Industrial wastes as low-cost potential adsorbents for the treatment of wastewater laden with heavy metals', Advanced Colloid Interface Sciences, vol. 166, pp. 36–59.
4. Ajjabi, LC & Chouba, L 2009, 'Biosorption of Cu2+ and Zn2+ from aqueous solutions by dried marine green macroalga Chaetomorpha linum', Journal of Environmental Management, vol. 90, no. 11, pp. 3485-3489.
5. Akar, ST Özcan, AS, Akar, T, Özcan, A, & Kaynak, Z 2009, 'Biosorption of a reactive textile dye from aqueous solutions utilizing an agro-waste', Desalination, vol. 249, pp. 757- 761.
6. Aksu, Z 2005, 'Application of biosorption for the removal of organic pollutants: a review', Process Biochemistry, vol. 40, pp. 997-1026.
7. Ali, I 2014, 'Water Treatment by Adsorption Columns: Evaluation at Ground Level', Separation & Purification Reviews, vol. 43, pp. 175-205. 134 10. Alinnor, I 2007, 'Adsorption of heavy metal ions from aqueous solution by fly ash', Fuel, vol. 86, pp. 853-857.
8. Alinnor, I 2007, 'Adsorption of heavy metal ions from aqueous solution by fly ash', Fuel, vol. 86, pp. 853-857.
9. Ambrósio, ST, Júnior, JCV, da Silva, CAA, Okada, K, Nascimento, AE, Longo, RL & Campos-Takaki, GM 2012, 'A Biosorption Isotherm Model for the Removal of Reactive Azo Dyes by Inactivated Mycelia of Cunninghamella elegans UCP542', Molecules, vol. 17, no.1, pp. 452-462.
10. Amirnia, S, Ray, MB & Margaritis, A 2015, 'Heavy metals removal from aqueous solutions using Saccharomyces cerevisiae in a novel continuous bioreactor–biosorption system', Chemical Engineering Journal, vol. 264, pp. 863-872.
11. Anfar, Z, Ahsaine, HA & Zbair, M 2019, 'Recent trends on numerical investigations of response surface methodology for pollutants adsorption onto activated carbon materials: A review', (Doi.org/10.1080/10643389.2019.1642835).
12. Basaran, G, Kavak, D, Dizge, N, Asci, Y, Solener, M & Ozbey, B 2016, 'Comparative study of the removal of nickel (II) and chromium (VI) heavy metals from metal plating wastewater by two nanofiltration membranes', Desalination and Water Treatment, vol. 57, no. 46, pp. 21870-21880.
13. Baysal, Z, Cinar, E, Bulut, Y & Alkan, H 2008, 'Equilibrium and thermodynamic studies on biosorption of Pb(II) onto Candida albicans biomass, Journal of Hazardous Materials, vol. 161, no. 1, pp. 62-69.
14. Bilal, M, Shah, JA, Ashfaq, T, Gardazi, SMH, Tahir, AA, Pervez, A, Haroon, H & Mahmood, Q 2013, 'Waste biomass adsorbents for copper removal from industrial wastewater-A review', Journal of Hazardous Materials, vol. 263, pp. 322-333.
15. Dixit, S & Singh, DP 2013, 'Phycoremediation of lead and cadmium by employing Nostoc muscorum as biosorbent and optimization of its biosorption potential', International Journal of Phytoremediation, vol. 15, pp. 801-813.

16. El Sikaily, A, Khaled, A, El Nemr, A & Abdelwahab, O 2006, 'Removal of Methylene Blue from aqueous solution by marine green alga Ulva lactuca', Chemistry and Ecology, vol. 22, pp. 149-157.
17. Garg, SK, Tripathi, M, Singh, SK & Tiwari, JK 2012, 'Biodecolorization of textile dye effluent by Pseudomonas putida SKG-1 (MTCC 10510) under the conditions optimized for mono azo dye Orange II color removal in simulated minimal salt medium', International Biodeterioration and Biodegradation, vol. 74, pp. 24-35.
18. Hamidian, AH, Esfandeh, S, Zhang, Y & Yang, M 2019, 'Simulation and optimization of nanomaterials application for heavy metal removal from aqueous solutions', Inorganic and Nano-Metal Chemistry, vol. 49, no. 7, pp. 217-230.
19. Hernandez-Eudave, MT, Bonilla-Petriciolet, A, Moreno-Virgen, MR, Rojas-Mayorga, CK & Tovar-Gómez, R 2016, 'Design analysis of fixed-bed synergic adsorption of heavy metals and acid blue 25 on activated carbon', Desalination and Water Treatment', vol. 57, pp. 9824-9836.
20. Herrero, R, Lodeiro, P, Rey-Castro, C, Vilarino, T & de Vicente, MES, 2005, 'Removal of inorganic mercury from aqueous solutions by biomass of the marine macroalga Cystoseira baccata', Water Resource, vol. 39, pp. 3199-3210.
21. Khani, MH 2013, 'Dynamics and Thermodynamics Studies on the Lead and Cadmium Removal from Aqueous Solutions by Padina sp. Algae: Studies in Single and Binary Metal Systems', Separation Science and Technology, vol. 48, pp. 2688-2699.
22. Khatri, N & Tyagi, S 2015, 'Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas', Frontiers in Life Science, vol. 8, no.1, pp. 23-39.
23. Kumar, KY, Muralidhara, HB Nayaka, YA & Balasubramanyam, J 2014, 'Low-cost synthesis of mesoporous Zn(II)-Sn(II) mixed oxide nanoparticles for the adsorption of dye and heavy metal ion from aqueous solution', vol. 52, pp. 4568-4582.
24. Lebron, YAR, Moreira, VR & de Souza Sandos LV 2019, 'Biosorption of methylene blue and eriochrome black T onto the brown macroalgae Fucus vesiculosus: equilibrium, kinetics, thermodynamics and optimization', Environmental Technology, (Doi.org/10.1080/ 09593330.2019.1626914).
25. Lee, YC & Chang, SP 2011, 'The biosorption of heavy metals from aqueous solution by Spirogyra and Cladophora filamentous macroalgae', Bioresource Technology, vol. 102, vol. 9, pp. 5297-5304.
26. Mckinsey 2009, 'Charting Our Future: Economic frameworks to inform decision-making' Report.
27. Nessim, RB, Bassiouny, AR, Zaki, HR, Moawad, MN & Kandeel, KM 2011, 'Biosorption of lead and cadmium using marine algae', Chemistry and Ecology, vol. 27, pp. 579-594.
28. Ngaha, WSW, Teonga, LC, Hanafiaha, MAKM 2011, 'Adsorption of dyes and heavy metal ions by chitosan composites: A review', Carbohydrate Polymers, vol. 83, pp. 1446-1456.
29. Nouri, L & Hamdaoui, O 2007, 'Ultrasonication-assisted sorption of cadmium from aqueous phase by wheat bran', Journal of Physical Chemistry A, vol. 111, pp. 8456-8463.
30. Öztürk, ù, AslÕm, B & Türker, R 2009, 'Removal of Cadmium Ions from Aqueous Samples by Synechocystis sp.', Separation Science and Technology, vol. 44, 1467-1483.

31. Pavasant, P, Apiratikul, R, Sungkhum, V, Suthiparinyanont, P, Wattanachira, S & Marhaba, TF 2006, 'Biosorption of Cu2+, Cd2+, Pb2+, and Zn2+ using dried marine green macroalga Caulerpa lentillifera', Bioresource Technology, vol. 97, no. 18, pp. 2321– 2329.
32. Rashed, M 2006, 'Fruit stones from industrial waste for the removal of lead ions from polluted water', Environmental Monitoring and Assessment, vol. 119, pp. 31-41.
33. Saeed, A,& Iqbal, M 2003, 'Bioremoval of cadmium from aqueous solution by black gram husk (cicerarientinum)', Water Research, vol. 37, pp. 3472-3480.
34. Sahoo, JK, Kumar, A, Rout, L, Rath, J, Dash, P & Sahoo, H 2018, 'An investigation of heavy metal adsorption by hexa-dentate ligandmodified magnetic nanocomposites', Separation Science and Technology, vol .53, no. 6, pp. 863-876.
35. Sinha, S, Behera, SS, Das, S, Basu, A, Mohapatra, RK, Murmu, BM, Dhal, NK, Tripathy SK & Parhi, PK, 2018'Removal of Congo Red dye from aqueous solution using Amberlite IRA-400 in batch and fixed bed reactors', vol. 205, no. 4, pp. 432-444.
36. Sulyman, M, Namiesnik, J & Gierak A 2017, 'Low-cost adsorbents derived from agricultural by-products/wastes for enhancing contaminant uptakes from wastewater: a review', Polish Journal of Environmental Studies, vol. 26, pp. 479-510.
37. Suryan, S & Ahluwalia, S 2012, 'Biosorption of heavy metals by paper mill waste from aqueous solution' International Journal of Environmental Sciences, vol. 2, no. 3, pp. 1331-1343.
38. Suzuki, Y, Kametani, T & Maruyama, T 2005, 'Removal of heavy metals from aqueous solution by nonliving Ulva seaweed as biosorbent', Water Resource, vol. 39, pp. 1803-1808.
39. Vesali-Naseh, M, Barati, S & Vesali Naseh, MR 2019, 'Efficient copper removal from wastewater through montmorillonite-supported hydrogel adsorbent', Water Environmental Research, vol. 91, no. 4, pp. 332-339.
40. Vilar, VJP, Botelho, CMS & Boaventura, RAR 2006, 'Equilibrium and kinetic modeling of Cd(II) biosorption by algae Gelidium and agar extraction algal waste', Water Resource, vol. 40, pp. 291-302.
41. Wang, J & Chen, C 2009, 'Biosorbents for heavy metals removal and their future', Biotechnology Advances, vol. 27, no. 2, pp. 195-226.
42. Wang, Q & Yang, Z 2016, 'Industrial water pollution, water environment treatment, and health risks in China', Environmental Pollution, vol. 218, pp. 358-365.
43. Wierzba, S 2015, 'Biosorption of lead(II), zinc(II) and nickel(II) from industrial wastewater by Stenotrophomonas maltophilia and Bacillus subtilis', Polish Journal of Chemical Technology, vol. 17, pp.79-87.
44. Xie, Y, Li, H, Wang, X, Ng, IS Lu, Y, Jing, K 2014, 'Kinetic simulating of Cr(VI) removal by the waste Chlorella vulgaris biomass', Journal of the Taiwan Institute of Chemical Engineers, vol. 45, pp. 1773-1782.
45. Ye, H, Zhu, Q & Du, D 2010, 'Adsorption removal of Cd(II) from aqueous solution using natural and modified rice husk, Bioresource Technology, vol. 101, pp. 5175-5179.
46. Yeddou-Mezenner, N 2010, 'Kinetics and mechanism of dye biosorption onto an untreated antibiotic waste', Desalination, vol. 262, pp. 251-259.