مجلة الدراسات التربوية والعلمية - كلية التربية - الجامعة العراقية
العدد الرابع والعشرون - المجلد الرابع - علوم الكيمياء - تشرين ثاني 2024 م
doi.org/10.52866/esj.2023.04.24.13

Utilizing the adsorption method to remove pollutants from water review

Basma Esam. Jasim[1]*, Suraa Reaad [2], Nibras Abdul Ameer[1]
1Department of chemical industrial,
institute of Technology-Baghdad-Middle Technical university, Iraq.
2Department of Pharmaceutical chemistry,
College of Pharmacy, AL-Nahrain University, Iraq
*basmaisam@mtu.edu.iq:

Abstract :

The removal of toxic substances from industrial processes is a significant challenge for the environment and society. Heavy metal ions are one of the most common water pollutants, posing significant dangers to soil, water, animals, and humans due to their high toxicity. A recent literature survey highlights the importance of addressing this problem whether when they are in low or high concentrations, the process of searching for techniques to remove these pollutants has become a very necessary task as a result of the development of the danger of these substances with the great technological development and with the increased need and diversity of use of this type of Metals, whether in the form of ore or others, in modern industries, which prompted those authorities and organizations concerned with preserving the environment have to impose strict restrictions and laws different laboratories and factories, forcing them to find ways to treat waste industrial products before being released into the environment so that toxic substances do not exceed the permissible limits this prompted workers in this field to encourage researchers to devote their efforts to Finding effective and economically inexpensive methods as possible to eliminate the danger of this type of contaminants by passing the familiar traditional methods whose use usually requires providing Sophisticated and expensive technologies. So we can say adsorption on the surfaces of solid materials is one of the methods Effective in this type of treatment and as a result of the importance of this topic, we decided to shed light in this research on the most important sources of water pollution and the most important methods used in water purification, especially the adsorption method.

Keywords: adsorption, Chemical Adsorption, Pollution, Physical Adsorption, water treatment.

استخدام طريقة الامتزاز لإزالة الملوثات من المياه

بسمة عصام جاسم 1، سرى رياض حمودي2 ، نبراس عبد الامير عبود 1
.قسم الصناعات الكيميائية، المعهد التكنولوجا، بغداد، الجامعة التقنية الوسطى، العراق1
قسم الكيمياء الصيدلانية، كلية الصيدلة، جامعة النهرين2

مستخلص:

تمثل إزالة المواد السامة من العمليات الصناعية تحديًا كبيرًا للبيئة والمجتمع. تعد أيونات المعادن الثقيلة من أكثر ملوثات المياه شيوعًا، وتشكل مخاطر كبيرة على التربة والمياه والحيوانات والإنسان بسبب سميتها العالية وتسلط الدراسات الحديثة للأدبيات الضوء على أهمية معالجة هذه المشكلة سواء كانت بتراكيز منخفضة أو عالية فإن عملية البحث عن تقنيات لإزالة هذه الملوثات أصبحت مهمة ضرورية جداً نتيجة تطور خطورة هذه المواد مع التطور التكنولوجي الكبير ومع زيادة الحاجة والتنوع استخدام هذا النوع من المعادن سواء على شكل خام أو غيره في الصناعات الحديثة، مما دفع تلك الجهات والمنظمات المعنية بالحفاظ على البيئة إلى فرض قيود وقوانين صارمة على المعامل والمصانع المختلفة، مما اضطرها إلى إيجاد طرق معالجة مخلفات المنتجات الصناعية قبل إطلاقها في البيئة بحيث لا تتجاوز المواد السامة الحدود المسموح بها، مما دفع العاملين في هذا المجال إلى تشجيع الباحثين على تكريس جهودهم لإيجاد طرق فعالة وغير مكلفة اقتصاديا قدر الإمكان للقضاء على خطر هذا النوع من النفايات والملوثات من خلال تمرير الطرق التقليدية المألوفة والتي يتطلب استخدامها عادة توفير تقنيات متطورة ومكلفة. لذا يمكننا القول أن الامتزاز على أسطح المواد الصلبة يعد من الطرق الفعالة في هذا النوع من المعالجة ونتيجة لأهمية هذا الموضوع قررنا أن نلقي الضوء في هذا البحث على أهم مصادر تلوث المياه و أهم الطرق المستخدمة في تنقية المياه وخاصة طريقة الامتزاز.

الكلمات المفتاحية: الامتزاز، الامتزاز الكيميائي، التلوث، الامتزاز الفيزيائي، معالجة المياه.

Introduction

Natural water contains various dissolved and suspended organic and inorganic substances, with their concentrations varying based on the water's nature and presence. Pollution occurs due to changes in the environment's basic components' proportions, either due to human intervention or natural phenomena, resulting in increased or decreased levels of these components. [1].

Water pollution is a significant issue due to its significant role in daily life, as it is the secret of life for everyone on the ground, and its essential role in various industries, where different industries require vast amounts of water, resulting in varying quality and purity standards. [2].

Excreta in water can cause changes in its color, taste, turbidity, odor, acidity, density, viscosity, and gaseous content, causing harm to health, life, and the environment. It is not suitable for domestic, industrial, and agricultural use. Organic pollutants pose a high risk due to their long-term effects, some of which are considered carcinogenic, and their interaction with organisms' organic compounds. [3].

Factory techniques for economical water purification include physical, chemical, and biological processes, depending on water specifications and impurity quality. Understanding water pollution sources is crucial before addressing purification methods [4] .

Sources of Water Pollution

Water pollution occurs when human activities alter the water's composition or condition, making it less suitable for human use. This includes foreign substances, such as bacteria, algae, or parasites, which alter the water's natural properties. Contaminated water is not suitable for drinking, domestic consumption, agriculture, or industry, and is therefore not suitable for legitimate life uses. [5-7].

Rivers are one of the most important sources of water, so putting any kind of pollutants in them will change the rivers' environment and affect the aquatic life, and these changes may be physical changes such as an increase in river water temperature, an increase in turbidity, changes in the level of dissolved oxygen or Biological such as

an increase in the unwanted growth of some organisms such as algae, or it may be chemical changes as a result of adding chemicals to the water. And the degree of impact of these pollutants depends on the type and quantity of these pollutants and the characteristics of the water receiving them, Domestic Pollutants, Agricultural Pollutants, Industrial Pollutants, Thermal Pollutants [8-10] and radiational pollutants [11, 12].

Water Pollution Treatment Methods

Domestic and industrial wastewater constitute a major source of water pollution, and therefore it is necessary to subject it to a treatment to reduce chemical and biological pollutants before it is released to water sources. The wastewater treatment process is divided into three main stages [13].

They are: The primary treatment stage, which includes the removal of floating objects and solid plankton by mechanical methods.

While the secondary treatment stage includes the use of biological treatments such as biological filtration and the use of life processes that depend on microorganisms such as bacteria analyzing organic impurities [14]. As for the last stage, which is: Tertiary treatment: It is an advanced stage of treatment procedures that are carried out on the water resulting from secondary treatment and by methods based on chemical-physical foundations that can outperform the biological methods used or reach the same quality at a lower cost [15]. The most important chemical methods used in this field are:

1. Chemical Oxidation
2. Ion Exchange
3. Reverse Osmosis Pressure
4. Adsorption

The adsorption method is one of the most important methods currently used to reduce environmental pollution because it is a simple and inexpensive method when compared with other chemical methods, so it has become necessary to shed light on this method by explaining it in a simple way.

Adsorption

Adsorption is the process of gathering a substance in the form of molecules, atoms, or ions on the surface of another substance; the substance that undergoes adsorption on the surface is known as a [Adsorbate] [16]. While the surface on which adsorp-

tion occurs is known as the [Adsorbent] surface, there are numerous examples of adsorption, such as the adsorption of acetic acid on animal charcoal, in which acid particles collect on the surface of coal particles, and hydrogen adsorption on the surfaces of some metals such as nickel [17]. Adsorption is classified into two types: unimolecular adsorption, which is the creation of a single partial layer on the adsorbent surface; and multimolecular adsorption, which is the formation of many molecular layers on the adsorbent surface [18].

Adsorption results in a decrease in free energy (ΔG) and entropy (ΔS) of the adsorbent surface. This is due to the molecules being restricted by their bonding to surface atoms, resulting in a loss of degrees of freedom compared to their previous state [19].The thermodynamic relationship [20] states that as free energy (ΔG) and entropy (ΔS) drop, the enthalpy (ΔH) content (heat) decreases.

$\Delta G = \Delta H - T\Delta S$ …. [1]

According to this relationship, the enthalpy ΔH is negative, that is, in general, adsorption is exothermic [Exothermic] This does not prevent some types of adsorption from being [Endothermic] [21] .The process opposite to the process of adsorption is called (desorption) and it is the process of separation of the adsorbed particles on the adsorbent surface and their return to the solution, desorption occurs usually when the temperature rises to the extent sufficient to break the bonding strength between the adsorbent and the adsorbate [22].As for the process of penetration of the adsorbate particle to the adsorbent surface and its diffusion in it is called (sorption). Adsorption can be classified according to the type and strength of the bond between the particles of the adsorbent material and the adsorbate material and the heat that accompanies the adsorption process into [23]:

1- Physical Adsorption

Adsorption Waals Vander, or Physisorption, is a physical attraction between an adsorbent surface and molecules adsorbed on it. It is similar to condensation and can cause multiple layers of material. The energy released is close to the enthalpy of condensation and less than 40 kJ/mol. The adsorbent atom or molecule moves within a limited area, making it not localized.. [24].

2- Chemical Adsorption

Chemisorption is a chemical force between adsorbed atoms or molecules and the adsorbing surface, occurring under specific conditions on a surface. This type of adsorption is characterized by specificity, thermal changes, and energy release exceeding 100 kJ/mol. It is localized, meaning molecules cannot move from their adsorption site. Chemisorption is non-reversible and limited to a monolayer, and may not occur on other surfaces or under the same conditions. It is characterized by thermal changes and localized adsorption. [25].

Physical adsorption occurs at temperatures close to or below the boiling points of the adsorbent material, while chemical adsorption occurs at temperatures higher than the boiling point. The temperature effects directly affect the occurrence of adsorption, as seen in the case of hydrogen gas adsorption on nickel metal surface. [26].

Factors Affecting on Adsorption Process

1. Effect of contact time

Contact time is a crucial parameter in adsorption processes, determining the adsorbent's optimal time to absorb the maximum number of heavy metals. Research indicates that the removal percentage of pollutants increases with contact time, possibly due to the bio sorbent's larger surface area at the medium's opening for metal ion adsorption. [27].

2. **Effect of pH**

The effect of the PH on the adsorption capacity varies with the different adsorbent surfaces and the nature of the adsorbate material, So the changes in the PH that lead to an increase in the solubility of the adsorbate in the solution reduce the amount of adsorption, on the contrary, the changes that lead to a decrease in the solubility of the adsorbent molecules [28].

3. The Nature of Adsorbent

Adsorption is affected by the nature of the adsorbent surface and the presence of polar groups on the surface. It is also affected by the surface area, the size of the pores, and their distribution on the surface. Many studies have proven that porous surfaces provide a larger surface area for adsorption compared to non-porous surfaces, this depends on the size of the adsorbed particle and the shapes of the pores and their sizes [29].

4. The Nature of Adsorbate

The nature of the adsorbate in terms of shape, size, polarity, presence of effective groups, molecular weight, and solubility influences the interaction between the adsorbent surface and the adsorbate particles; the difference in this interaction between the surface and the adsorbed particles results in the selective adsorption of one component of the solution without the other [30].

5. Solvent Effect

The solvent affects the behavior of the adsorption process through its interaction with the solute in the solution. The less soluble the substance in the solvent, the greater its adsorption on the surface of the adsorbent [31].

6. Concentration Effect

Adsorption in a solution increases with concentration, sometimes stopping when one layer forms on the surface. In other cases, adsorption may continue from multiple layers on the surface, resulting in a higher amount of adsorbent material than single-layer adsorption. The relationship between adsorbate amount and equilibrium concentration is known as the isotherm of adsorption. The shape of this isotherm can predict the relationship between adsorption amount and adsorbent substance concentration in the solution. [32, 33].

7- Adsorption Isotherm

Adsorption isotherms, including Freundlich and Langmuir isotherms, are crucial in environmental protection and adsorption techniques research, predicting a material's adsorption capacity.

8- The Freundlich Adsorption Isotherm is a method used to study the adsorption of substances by a substance.

The Freundlich isotherm is an empirical model that takes into account the adsorbent's monomolecular layer interference with the solute, assuming a heterogeneous surface for a single component system, as previously explained.

$$Qe = KF\ Ce1/n \quad (2)$$

The linear form of the Isotherm is;

$$\boldsymbol{ln\ qe = ln\ KF + 1/n\ ln\ Ce} \quad (3)$$

In the equation, KF and n are known as the Freundlich constants, with n representing the adsorption technique's favorability and KF representing the adsorption capacity. KF and n may be calculated by graphing ln qe against ln Ce [35].

9-Langmuir Adsorption Isotherms

The Langmuir isotherm posits that equilibrium occurs when the adsorbent is saturated with monolayer adsorbate compounds, as shown in the following equation:

$$Qe = \quad Ce/\ 1 + b\ Ce \quad (4)$$

The linearized form of the Isotherm is:

$$Ce/Qe = 1/Qm\ b + (\ 1/Qm\ )\ Ce \quad (5)$$

Where Qe is the amount of adsorbed adsorbate per unit mass of the adsorbent (mg/l). Ce = the adsorbate equilibrium concentration (mg/l), b = a constant linked to the affinity between the adsorbate and the adsorbent, and Qm = the monolayer's saturation ability as defined theoretically [36].

10- Applications of Adsorption

Adsorption has the following applications: Gas masks keep harmful gasses from entering coal miners' equipment. Charcoal is used to eliminate air traces from evacuation equipment. Silica gel pellets are used to absorb moisture in pharmaceuticals and plastic bottles. Animal charcoal is used to remove color from cane juice, leaving a clear liquid solution. Catalysts are used to bind reactants to the surface of materials, allowing for quicker reactions and higher reaction rates. These approaches assist manage humidity, eliminate colorants, and increase the efficiency of chemical processes [37].

11- Conclusion

The adsorption process by adsorbents, especially the solid kind, emerges among the potential technologies for treating water. This process is thought to be one of the most efficient ways to treat and remove organic pollutants in wastewater treatment. Because of its straightforward design and potential for cheap initial cost commitment, it offers advantages over other approaches. Researchers have paid close attention to the adsorption method, which is commonly employed to clean water for both organic and inorganic pollutants. The quest for inexpensive adsorbents with binding properties to remove water pollutants has became more intense in the last few years. Natural materials and agricultural wastes that are readily available locally can be employed as inexpensive adsorbents.

12- References

1. 1-Briffa, J., Sinagra, E., & Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans.

Heliyon, *6*(9), e04691.

2. Mohammed, A.J., Jasim, B.E. Nano chitosan adsorption of o-Nitroaniline ***AIP Conference Proceedings***This link is disabled., 2023, 2475, 040011
3. Aloke, C., Uzuegbu, I. E., Ogbu, P. N., Ugwuja, E. I., Orinya, O. F., & Obasi, I. O. (2019). Comparativ e assessment of heavy metals in drinking water sources from Enyigba Community in Abakaliki Local Government Area, Ebonyi State, Nigeria. *African Journal of Environmental Science and Technology*, *13*(4), 149-154.
4. 4- Engwa, G. A., Ferdinand, P. U., Nwalo, F. N., & Unachukwu, M. N. (2019). Mechanism and health effects of heavy metal toxicity in humans. *Poisoning in the modern world-new tricks for an old dog*, *10*.
5. 5-N. A.A. Aboud, B. E. Jasima, A. M. Rheimab, (2021).Methylene Orange dye removal in aqueous solution using synthesized CdO-MnO2 nanocomposite: kinetic and thermodynamic studies,Chalcogenide Letters 18 (5), 237-243.
6. AMR, N. A. A. Abouda, B. E. Jasima ,Adsorption study of phosphate ions pollution in aqueous solutions using microwave synthesized magnesium oxide nanoparticles2021)).Digest Journal of Nanomaterials and Biostructures 16 (No. 3), p. 801 - 807
7. Pietrzak, S., Wójcik, J., Baszuk, P., Marciniak, W., Wojtyś, M., Dębniak, T., & Lener, M. R. (2021). Influence of the levels of arsenic, cadmium, mercury and lead on overall survival in lung cancer. *Biomolecules*, *11*(8), 1160.
8. Schweitzer, L., & Noblet, J. (2018). Water contamination and pollution. In *Green chemistry* (pp. 261-290). Elsevier.
9. S Reaad, BE Jasim, NAA Aboud, AS Hussain (2023).Activated Carbon Nanoparticles as Adsorbent to Remove the Cadmium Ion from Aqueous Solution: Thermodynamic Study.
10. Al-Mustansiriyah Journal of Science 34 (2), 44-49 Mitiku, A. A. (2020). A review on water pollution: causes, effects and treatment methods. *Int J Pharm Sci Rev Res*, *60*(2), 94-101.
11. Hasan, M. K., Shahriar, A., & Jim,

K. U. (2019). Water pollution in Bangladesh and its impact on public health. *Heliyon*, *5*(8), e02145.

12. Khatun, R. (2017). Water pollution: Causes, consequences, prevention method and role of WBPHED with special reference from Murshidabad District. *International Journal of Scientific and Research Publications*, *7*(8), 269-277.
13. Zajda, M., & Aleksander-Kwaterczak, U. (2019). Wastewater treatment methods for effluents from the confectionery industry–an overview. *Journal of Ecological Engineering*, *20*(9).
14. Mathuram, M., Meera, R., & Vijayaraghavan, G. (2018). Application of locally sourced plants as natural coagulants for dye removal from wastewater: a review. *J. Mater. Environ. Sci*, *2508*, 2058-2070.
15. Hussain, A., Madan, S., & Madan, R. (2021). Removal of heavy metals from wastewater by adsorption. *Heavy Metals—Their Environmental Impacts and Mitigation*.
16. AA, Q. N., Mohammed, R. H., & Lawal, D. U. (2021). Removal of heavy metal ions from wastewater: a comprehensive and critical review. *NPJ Clean Water*, *4*(1).
17. Zaimee, M. Z. A., Sarjadi, M. S., & Rahman, M. L. (2021). Heavy Metals Removal from Water by Efficient Adsorbents. *Water*, *13*(19), 2659.
18. Ajibade, F. O., Adelodun, B., Lasisi, K. H., Fadare, O. O., Ajibade, T. F., Nwogwu, N. A., ... & Wang, A. (2021). Environmental pollution and their socioeconomic impacts. In *Microbe mediated remediation of environmental contaminants* (pp. 321-354). Woodhead Publishing.
19. Sulaymon, I. D., Mei, X., Yang, S., Chen, S., Zhang, Y., Hopke, P. K., & Zhang, Y. (2020). PM2. 5 in Abuja, Nigeria: Chemical characterization, source apportionment, temporal variations, transport pathways and the health risks assessment. *Atmospheric Research*, *237*, 104833.
20. Masindi, V., & Muedi, K. L. (2018). Environmental contamination by heavy metals. *Heavy metals*, *10*, 115-132.
21. Briffa, J., Sinagra, E., & Blundell, Reffects on humans. *Heliyon*, *6*(9), e04691.

22. Wadhawan, S., Jain, A., Nayyar, J., & Mehta, S. K. (2020). Role of nanomaterials as adsorbents in heavy metal ion removal from waste water: A review. *Journal of Water Process Engineering*, *33*, 101038.
23. Gao, X.; Guo, C.; Hao, J.; Zhao, Z.; Long, H.; Li, M. Adsorption of heavy metal ions by sodium alginate-based adsorbent—A review and new perspectives. Int. J. Biol. Macromol. 2020, 164, 4423–4434.
24. Zhu, Y., Yi, B., Yuan, Q., Wu, Y., Wang, M., & Yan, S. (2018). Removal of methylene blue from aqueous solution by cattle manure-derived low temperature biochar. *RSC advances*, *8*(36), 19917-19929.
25. Helmenstine, A.M. What Adsorption Means in Chemistry. 2019. Available online: https://www.thoughtco.com/definition-ofadsorption-605820.
26. Ray, S., & Das, G. (2020). Process equipment and plant design. *NY: Elsevier*.
27. Singh, N. B., Nagpal, G., & Agrawal, S. (2018). Water purification by using adsorbents: a review. *Environmental technology & innovation*, *11*, 187-240.
28. Anastopoulos, I., Pashalidis, I., Orfanos, A. G., Manariotis, I. D., Tatarchuk, T., Sellaoui, L., & Núñez-Delgado, A. (2020).
29. Removal of caffeine, nicotine and amoxicillin from (waste) waters by various adsorbents. A review. *Journal of Environmental Management*, *261*, 110236. 29- Sočo, E., Papciak, D., Michel, M. M., Pająk, D., Domoń, A., & Kupiec, B. (2021). Characterization of the Physical, Chemical, and Adsorption Properties of Coal-FlyAsh–Hydroxyapatite Composites. *Minerals*, *11*(7), 774.
30. Al-Senani, G. M., & Al-Fawzan, F. F. (2018). Adsorption study of heavy metal ions from aqueous solution by nanoparticle of wild herbs. *The Egyptian Journal of Aquatic Research*, *44*(3), 187-194.
31. Obulapuram, P. K., Arfin, T., Mohammad, F., Khiste, S. K., Chavali, M., Albalawi, A. N., & Al-Lohedan, H. A. (2021). Adsorption, Equilibrium Isotherm, and Thermodynamic Studies towards the Removal of Reactive Orange 16 Dye Using Cu

(I)-Polyaninile Composite. *Polymers*, *13*(20), 3490.

32. Alam, S., Ullah, B., Khan, M. S., Khan, L., Shah, L. A., Zekker, I., & Zahoor, M. (2021). Adsorption Kinetics and Isotherm Study of Basic Red 5 on Synthesized Silica Monolith Particles. *Water*, *13*(20), 2803.
33. Kalam, S., Abu-Khamsin, S. A., Kamal, M. S., & Patil, S. (2021). Surfactant Adsorption Isotherms: A Review. *ACS omega*, *6*(48), 32342-32348.
34. Naser Ettish, M., Abuzalat, O., Wong, D., El‐Sayyad, G. S., & Elsayed, M. A. (2022). Adsorption isotherm, kinetics, and thermodynamic studies of O, O‐diethyl ‐O‐(3, 5, 6 ‐trichloropyridin‐2‐yl) phosphorothioate (chlorpyrifos) on cinnamon verum–based activated carbon. *International Journal of Chemical Kinetics*, *54*(2), 104-120.
35. Patanjali, P., Chopra, I., Mandal, A., & Singh, R. (2021). Kinetics and isotherm studies for adsorptive removal of methylene blue from aqueous solutions using organoclay. *Indian Journal of Chemical Technology (IJCT)*, *28*(1), 86-93.
36. Ojediran, J. O., Dada, A. O., Aniyi, S. O., David, R. O., & Adewumi, A. D. (2021). Mechanism and isotherm modeling of effective adsorption of malachite green as endocrine disruptive dye using Acid Functionalized Maize Cob (AFMC). *Scientific reports*, *11*(1), 1-15.
37. Dada, A. O., Adekola, F. A., Odebunmi, E. O., Dada, F. E., Bello, O. M., Akinyemi, B. A., ... & Umukoro, O. G. (2020). Sustainable and low-cost Ocimum gratissimum for biosorption of indigo carmine dye: kinetics, isotherm, and thermodynamic studies. *International Journal of Phytoremediation*, *22*(14), 1524-1537.
38. Baby, R., Saifullah, B., & Hussein, M. Z. (2019). Palm Kernel Shell as an effective adsorbent for the treatment of heavy metal contaminated water. *Scientific reports*, *9*(1), 1-11.