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Studies on Some Heavy Metals Removal inIndustrial and Drinking Water: A review

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***Abstract*— In order to learn many new concepts and details in our field of study, we analyzed and investigated a number of prior studies in this work. The majority of these studies were conducted within the last five years, and they covered techniques for removing heavy metals from aqueous media by measuring various physical and chemical properties like initial concentration pH, and how these properties affect heavy metals in this study, we used heavy metals like Copper, Zinc, and Lead. Zn = 80.7% in sewage water, Cu = 97.10% in drinking water, and lead (Pb) = 100% in industrial medium. Natural zeolite was the most effective adsorbent material utilized in the removal procedure, along with silica and live bacteria. Adsorbents are used to remove heavy metals from aquatic media. The effectiveness of these materials in removing these heavy metals from polluted water has been confirmed. This removal is done according to certain conditions, such as pH, temperature, etc., and the removal efficiency varies from one metal to another. This is what we will confirm in this chapter by discussing various references and modern scientific articles in which heavy metals were investigated from polluted water using different adsorbent materials.**

***Keywords*— Drinking Water, Pollution, groundwater, Heavy Metals, Toxic ions.**

I. INTRODUCTION

Water is the basic element in our lives, whether surface or underground [1- 2]. The proportion of freshwater constitutes only 2.8% of the total water on the planet, as water is exposed to various types of deterioration. Population expansion, industrial development, and rapid social progress in recent years have caused an increase in the level of pollution of water sources. Human uses for water like by industries , agricultures , and domestic uses have a direct impact on water quality. Rivers and lakes locate near cities and industrial complexes have become polluted graveyards, due to discharged liquid waste. Therefore, the polluted water became incapable of self-purification [3- 7] .

In 1961, the World Health Organization defined water pollution as: “It is any change that occurs in the natural, chemical and biological characteristics of water, which leads to a change in its condition directly or indirectly, whereby the water becomes less suitable for the natural uses for which it is intended, whether for drinking, domestic or agricultural consumption.” Or something else” [8-10].

The presence of ions from metallic elements in the environment is a result of industrial activities, as most of them were found to be highly toxic and not decomposable, and this is a cause for concern, especially if they exceed the permissible limit. Also, the lack of decomposition of these metals necessarily leads to their accumulation and increased concentration in water. The problem of water pollution with heavy metals is a major problem facing the world. Therefore, previous study resorted to treating the polluted water in various ways and had to treat it before it entered the water bodies. The treatment was done using various physical and chemical methods to remove the heavy metals, such as biosorption, ion exchange, and chemical precipitation, adsorption, and other methods, as each treatment method has performance, characteristics and different impacts on the environment [11-14].

Many absorbent materials (natural and prepared) have been used to remove these heavy metals. Natural adsorbents include clay, zeolite, ores, and other natural materials that are characterized by their low cost and abundance. They also have a great potential to modify and enhance their abilities in the adsorption process. As for industrial adsorbents, its adsorbent is a material prepared from agricultural products, waste, household remains, industrial waste, and sewage sludge. All types of adsorbents have special properties such as porosity, pore structure, and the nature of the adsorbent surface [11, 15, 16].

In this study, several methods were used to remove heavy metals from aquatic media (industrial and drinking water) with different methods and adsorbents. The study aims to discussed removing the largest heavy metal from polluted water using the best methods and removal material.

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II. Removal of heavy metals from drinking water

Various human activities are the main reason behind the increase in the concentration of heavy metals in the environment, which causes many serious health problems when humans are exposed to them and these metals accumulate in their bodies as shown in figure 1 [17-18].

Heavy metals are considered carcinogenic and harmful when they exceed the permissible limit in the environment, as they directly affect humans, animals, plants and cause many diseases [19- 21].

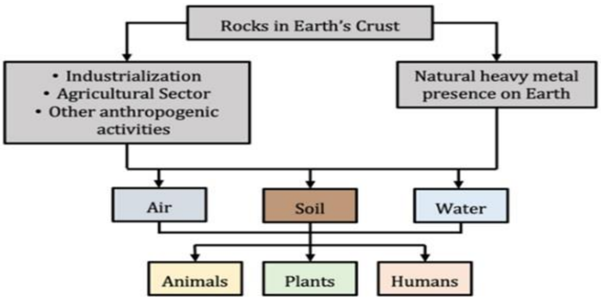

Fig. 1: The heavy metal sources and their pathways into the environment and humans.

Analytical Study No. (1)

According to Maman, et al. (2017) [22] , copper (Cu) occurs naturally in various forms in the environmental matrices. The significant additional contribution of Cu is from industrial and domestic sources , and it can have serious environmental impacts and health problems.
This work was done to evaluate the ability of two clay materials to remove copper from water through absorption. After studying the basic physical and chemical properties, the information of this study was summarized in the following Table.1.

Table.1 The evaluation of two clay materials from the Niger River Valley in eliminating copper from drinking water.

The minerals studied in this article	Copper Cu (II)
Removal of heavy metals from	Drinking water
Removal method	Adsorption
Removal material	(10T and 11LP are two clay materials)
Removal ratio	**T10** **LP11** **Rivers**: 62.8% 44.08% **Wells**: 64.49% 57.11% **Tap:** 65.47% 4.44%
Technologies Used for Detection	IR, XRD, SEM, ATG
Adsorption isotherm	Langmuir, Frendlich
pH	pH < 7

Study Result

In removing copper from drinking water, the capacity of both substances 11LP and 10T was determined. The capacity of each of them consisting of kaolin was estimated between 60.99% and 61%. It has a major role in removing copper, and the most compatible isotherm is Freundlich. This is because it contains organic materials. Impurities of kaolinite 11LP are better than 10T, but the absorption rate may have contributed to better adsorption of copper.

Analytical Study No. (2)

Wołowiec et al. (2019) [23] studied the ability of waste generated as a by-product from water treatment plants to absorb heavy metals and metals from water. Water treatment residues have great adsorption capacities due to their large specific surface areas and chemical compositions. Absorption capacity is also affected by absorption conditions as shown on Figure 2.

The results showed that water treatment residues may be a suitable material for developing an effective adsorbent to remove heavy metals and metals from water. The most important points were identified in the following Table 2.

Table .2 Inductively shows the removal of heavy metals and metals from water using drinking water treatment waste.

The minerals studied in this article	Pb (II). Cr (III). Cr (VI). A s (V)
Removal of heavy metals from	Drinking water
Removal method	Adsorption
Removal material	Water treatment waste
Removal ratio	Pb(II),Cr(III), Cr(VI) 91% As 81%
Technologies Used for Detection	FTIR, XRD, SEM
Adsorption isotherm	Langmuir, Frendlich
pH	Variable depending on the type of metal

Study Result

The ability of waste generated as a by-product from water treatment plants to absorb heavy metals and metals from water. Water treatment residues have great adsorption capacities due to their large specific surface areas and chemical compositions.

Analytical Study No. (3)

Petrovič, A., & Simonič, M. (2016) [24] studied the ability of this installed Chlorella sorokiniana cell to remove ions from drinking water solutions. The effects of the initial metals, contact times and temperatures on the bio-efficiency and removal efficiency of the tested metals were examined at initial pH values, and the study is summarized in the following Table 3.

Table. 3 Shows the removal of heavy metal ions from drinking water by one type of living cell.

Minerals studied in this article	Nickel (Ni), Copper(Cu) and Cadmium, Cd
Removal of heavy metals from	Drinking water
Removal method	Bio sorption
Removal material	Chlorella sorokiniana cell
Removal ratio	Cu 96.12% Ni 52.96% Cd 65.63%
Technologies used for Detection	FTIR, XRD, SEM
Adsorption isotherm	Redlich-Peterson, Dubinin, Freundlich, Langmuir Radushkevich
pH	(5-7)

Study Result

This study showed that C. sorokiniana cells immobilized in Ca. alginate. can be an effective absorbent material for the removal of Cu, Ni, and Cd, but the efficiency of bio sorption for nickel is less efficient compared to the efficiency of bio sorption for the other two metals.

Analytical Study No. (4)

Muneeb Muhammad et al. (2017) [25] studied the preparation of a new adsorbent material, magnetic graphite nanostructures from watermelon waste as shown in figure 2. The absorbent material was characterized by various useful techniques and was used to remove heavy metals from water. The prepared absorbent is characterized by high absorption capabilities and can be used efficiently to remove heavy metals from water. Table 4. summarizes the most important points of the study.

Table 4. Shows the removal of heavy metals from drinking water by magnetic carbon nanostructures.

Minerals studied in this article	As, Cr, Pb, Zn
Removal of heavy metals from	Drinking water
Removal method	Biosorption
Removal material	Magnetic carbon nanostructures prepared from biomass
Technologies used for Detection	FTIR, XRD, SEM, EDX
Adsorption isotherm	Freundlich, Langmuir
pH	AS PH= [1-9] Cr PH= [1-7] Cr Pb PH= [1-10] Pb Zn PH= [1-8] Zn

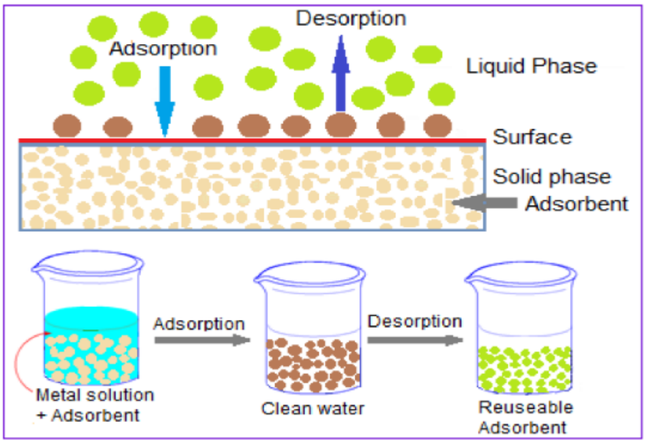

Fig. 2: The mechanism of metal ions adsorption – desorption process in water.

Study Result

The removal of heavy metals from water samples was studied using a biosorbent prepared from watermelon peel and characterized by a surface area analyzer. It was concluded from data that was prepared from adsorbents that watermelon waste has high adsorption capacities and can therefore be used as an effective adsorbent for the removal of heavy metals. The best isothermal model is Freundlich.

Analysis of the articles studied above

These articles (1-4) were studied from 2016 to 2019 to remove group of metals, including (copper, lead, zinc, arsenic... and other metals mentioned) in drinking water and minerals. The most widely metals discussed in these articles was copper, and the danger of these metals has been discussed previously in different countries, such as Niger, Poland, Pakistan and Saudi Arabia

The study was conducted to reduce the harm of these metals, This study discussed only two methods for the removal process, which are biosorption and adsorption, two of the most commonly used methods. The effect of pH on them was studied, whose values ranged from (1-10).

The acidic and moderate medium were always the most important isotherms for adsorption used in the study because they are the most widely used mathematical designs due to their simplicity and their ability to describe equilibrium data in a wide range of concentrations. This was done using detection techniques, most of which are SEM, XRD, and IR.

Standard solutions of elements were used to determine the concentrations of heavy elements in the atomic absorption device. As a result of these elements, the removal rates fluctuated between the metals, including Cd = 64.61%, Pb = 90%, and As= 80% where the largest removal rate was for copper with a value of (Cu =97.10%).

III. Removal of Heavy Metals from Industrial Water

Analytical Study No. (1)

Sdiri Ali (2019) [26] studied the effects of silicates on the removal of heavy metals from aqueous solutions by determining the effect of this substance on the performance of limestone samples in removing these impurities. The results of the study showed that natural limestone can be used to remove heavy metals with high efficiency from polluted water. It was found that samples containing a high percentage of silicates are characterized by greater efficiency. The study is summarized in the following Table 5.

Table 5. Showing the effects of limestone on removing heavy metals from prepared aqueous solutions

Minerals studied in this article	Copper, zinc, lead, cadmium
Removal of heavy metals from	Prepared aqueous solutions
Removal method	Ion exchange, adsorption
Removal material	Limestone (silicates)
Removal ratio	Cu= 37-77 %, Cd= 14.5-59%, Zn= 7-73% Pb≤100 %
Technologies used for Detection	XRD, XRF
pH	5

Study Result

It was concluded that silicates have a positive effect on the effectiveness of removing the metals. Limestone was used due to its low-cost for removing mineral contaminants from aqueous solutions.

Analytical Study No. (2)

Wierzba Slawomir (2015) [27] studied the bio sorption of lead, zinc and nickel for the Botswana region. They were examined under different experimental conditions in industrial wastewater using two types of live bacterial biomasses. The results were positive and these biomasses were included as an effective adsorbent. This is summarized in the following Table 6.

Table 6. Showing the removal of some heavy metals by biomass from water Industrial.

Minerals studied in this article	Lead Pb(II) , Zinc Zn(II) , Nickel Ni (II)
Removal of heavy metals from	Industrial water
Removal method	Bio sorption
Removal material	Stenotrophomonas maltophilia, bacillus subtilis
Removal ratio	Pb< 80%
Technologies used for Detection	Centrifuge
Adsorption isotherm	Freundlich, Langmuir
pH	5-6

Study Result

The study was carried out using live bacterial masses of *S. maltophilia* and *Bacillus subtilis* as effective absorbents, where the maximum absorption capacity, respectively, for Pb (II), Zn (II) and Ni (II)) for calculated biosorption of langmuir by B.subtilis and S. maltophilia was 133.33, 54.3, 47.8 mg/g and 166.7, 49.7, 57.8 mg/g.

Analytical Study No. (3)

Kipigroch Katarzyna (2020) [28]studied the comparison between the evaluation of the effectiveness of removing zinc and lead ions from the solution with the participation of two groups of algae cultured under laboratory conditions and a mixed group of Chlorophyta coming from a natural water reservoir. The experiment assumed that the conduct of a model study included starting the process of bio-sorption of metal ions with the participation of both groups through doses of lead and zinc ions. The most important points are summarized in the following Table 7.

Table 7. Showing the removal of zinc and lead from industrial water by algae.

Minerals studied in this article	Pb(II) , Zn(II)
Removal of heavy metals from	Industrial water
Removal method	Bio sorption
Removal material	Algae
Removal ratio	Pb= 48-57% Zn= 69-75%
Technologies used for Detection	SAA
pH	5-6

Study Result

Two algae cultures were used: a mixed group of *R.*

subcapitata and Chlorophyta with a high eutrophication in water reservoir. The different algae had better efficiency in removing zinc ions from wastewater. As for lead ions, the opposite was the case. The diversity of functional groups in the mixed algae is the main reason for the best efficiency removal.

Analytical Study No. (4)

Boulaiche Wassila & Amar Slatina (2016) [29]- studied e-exploiting the fungal biomass resulting from industrial fermentable residues of an antibiotic to get rid of heavy metals through adsorption. For this reason, the adsorption phenomenon was studied while varying some physical and chemical parameters (pH, contact time, biomass concentration, and initial concentration). Metal ions in adsorption kinetics using classical mathematical models (the most important points are summarized in the following Table 8.

Table 8. Shows the adsorption of heavy metal ions by fungal biomass for industrial water treatment.

Minerals studied in this article	Ni, Cd
Removal of heavy metals from	Industrial water
Removal method	Bio sorption
Removal material	La biomasse pleurtusmultilus
Removal ratio	Cd= 98.5% Ni = 91%
pH	4-10

Study Result

High efficiency in removing both nickel and cadmium ions. It is concluded that this biomass (LBPM) with a biosorbent concentration of L\gm3 and a stirring speed of 250 tr\ min has sufficient remo*val efficiency.*

Analysis of the articles studied above

Previous work was done in the industrial environment to remove some metals (zinc, lead, copper, nickel, cadmium) from polluted water. The most two common metals in their study were zinc and lead, and they mentioned the danger of lead in the first study of wastewater. Now, we will discuss the danger of zinc in industrial waters into the sea or the river water, it may affect marine organisms present in these waters, which in turn affects the human body, As result, it can lead to colds or digestive disorders. It can also lead to the possibility of developing prostate cancer if consumed in excess. Human inputs of zinc comes from the environment like mining sources, agricultural applications, and cultural activities.

The effectiveness of adsorbents with heavy metals in industrial water is affected by several factors, including temperature, pH, concentration, and size of the granular phase. As a result, high selectivity for certain electrolytes appears due to ion exchange, which they were conducted on electrolytes.

The removal methods used in these studies were: adsorption, ion exchange, and bio sorption, which is one of the most used removal methods in some regions of the world in which the study was conducted like: Tunisia, Poland, and Syria.... etc.

The absorbent materials used for removing metals was natural zeolite. It is a type of aluminum silicate stone, which has a highly porous solid body and the property of ion exchange, which gives it a great importance in the water desalination process. Silicate is a chemical compound that contains oxygen and silicon ions with the chemical formula 4SiO. Moreover, living biomass are organic materials composed of the remains of plants, animals, and microorganisms that are used as biofuel.

Finally, algae are one of the available sources for producing biomass that can be converted into an energy source. Some of the elements were used in previous study, showed pH values ranged from [4-10], that is, varied into 3 mediums: acidic, neutral, and basic, in addition to the methods of the detection process like, the SAA atomic absorption device and the XRD device. The device was used in the removal process was the centrifuge. As a result of these factors that affect the removal rate, the largest percentages that were achieved were for the following metals: Cu = 77%, Zn = 85%, Ni =91% Cd = 98%, Pb = 100%.

IV. CONCLUSIONS

This work aims to present a survey of the removal of some heavy metals from aquatic media, and through a series of studied scientific research, the following are the most important points were concluded: Water has been defined as a good solvent for many organic and inorganic compounds, and is divided into types, including surface water, groundwater, and stored water. This water may be exposed to pollutants (physical, chemical, and biological) depending on the medium in which it is found. This study addresses the treatment of these pollutants. Some of the most commonly used heavy metals were chosen for study because of their toxicity and danger to the environment (plants, animals, humans), although their presence is beneficial to human health to a small extent, unlike their danger if they exceed the permissible limit and may cause humans to suffer from serious diseases that lead to death. Therefore, researchers resorted to studying the proper methods for removing them from the environment. The methods were used to remove heavy metals were biological processes, chemical precipitation, adsorption, and electrocoagulation. The most common methods are adsorption and biological processes. The adsorbent materials used in studies are a lot and varied including natural and prepared materials. To clarify the nature of the adsorption force, models were chosen. The most famous models were Freundlich and Langmuir, which are used in most studies Previously, the adsorption of metals was subject to isotherm Langmuir.

To study the surface of the adsorbent material by applying morphological studies, the most important of which are SEM, FTIR, and XRD. The first work was done to prove adsorption on the surface in the absence and presence of the metal. The second work was done to identify the functional groups presenting in the adsorbent material. The third work gives information about the crystalline structure, chemical composition, physical properties of materials and thin layers of crystalline materials.

Finally, we can direct researchers to value these studies undertaken to detect and eliminate heavy metals from water, finding solutions to this danger and finding better, faster and less expensive removal methods.

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CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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