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## Effect of pH and Temperature on Copper ions Adsorption from Aqueous solutions into Iron Slag

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### Keywords:

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### ABSTRACT

Heavy metal pollution has become one of the most important environmental problems. Heavy metal pollution has properties that accumulate in nature and cannot be degraded. The aim of this work is to study the effect of pH and temperature on the effectiveness of iron slag in removing copper ions from aqueous solutions. The results indicated that the best removal of copper ions was at temperature (25 °C), weight of the adsorbent (3.5 g), and pH (5). The best removal percentage was (99.55 %) at the initial concentration of the solution. From these results iron slag can be used as reliable remover of copper ions from wastewater and industrial wastewater

تأثير الرقم الهيدروجيني ودرجة الحرارة على امتصاص أيونات النحاس من المحاليل المائية باستخدام خبث الحديد

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### الكلمات المفتاحية:

أيونات النحاس  
خبث الحديد  
الرقم الهيدروجيني  
درجة الحرارة  
المحاليل المائية

### الملخص:

لقد أصبح تلوث المعادن الثقيلة من أهم المشاكل البيئية، حيث أن تلوث المعادن الثقيلة له خصائص تتراكم في الطبيعة ولا يمكن تحليلها. يهدف هذا العمل إلى دراسة تأثير الرقم الهيدروجيني ودرجة الحرارة على فعالية خبث الحديد في إزالة أيونات النحاس من المحاليل المائية. أشارت النتائج إلى أن أفضل إزالة لأيونات النحاس كانت عند درجة الحرارة (25 درجة مئوية) ووزن المادة الماصة (3.5 جرام) ودرجة الحموضة (5) وكانت أفضل نسبة إزالة تقدر (99.55%) عند التركيز الأولي للمحلول. من هذه النتائج يمكن استخدام خبث الحديد كمزيل موثوق لأيونات النحاس من مياه الصرف الصحي ومياه الصرف الصناعي

### Introduction:

Heavy metals are among the major pollutants of water sources [1]. Despite this, heavy metals are considered sensitive indicators for monitoring changes in the aquatic environment. Due to human industrial activities, the levels of heavy metals in the aquatic environment are seriously increasing and have aroused great global concern [2,3]. Some of these minerals are essential for the growth, development and health of living organisms, while others are not essential as they are indestructible and most of them are classified as types that are toxic to living organisms [4]. However, the toxicity of metals depends on their concentration levels in the environment. As concentrations in the environment increase and the soil's ability to retain heavy metals decreases, they leach into groundwater and soil solution. These toxic metals can therefore accumulate in living tissues and be concentrated throughout the food chain. Cadmium is considered one of the most dangerous pollutants in the modern era [5,6]. Copper is classified as a priority pollutant due to its adverse health effects [7].

**1.1. Copper's effects on the environment and human health**  
persistent inhalation of copper-containing spray has been associated

with a rise in lung cancer cases among workers who have been exposed. The acceptable upper bound of in water, Cu (II) is 2.5 mg/L [8]. The byproducts of industries like metallurgy are the main sources of copper ions, preservation, plating, electronics plating, tanning, corrosion inhibition, wire drawing, and printing operations [9]. Skin and respiratory tract corrosion, lung cancer, inflammation, and other health problems are brought on by exposure to copper dust and mist. Workers who are exposed to copper spray have an increased chance of developing lung cancer if they inhale it [10]. The elimination of copper ions is becoming increasingly important from an economic and environmental standpoint because of its grave risks to people, animals, and plants. Cu (II) contamination in the environment typically causes major health consequences because it accumulates in living tissues throughout the food chain as a non-biodegradable contaminant [9-11]. Adsorption works on the principle of adhesion. In the case of water treatment, organic contaminants are attracted to the adsorbent. They adhere to its surface through a combination of complex physical forces and chemical action. For adsorption to be effective, the adsorbent must provide a very large surface area to which contaminating chemicals can adhere [12, 13,14 ,15].

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**1. MATERIALS &METHODS**

**1.1 Iron Slag**

Slag is a by-product obtained from the smelting of recycled metals and ores (pyrometallurgical) [16]. The major ingredients of slag are silicon dioxide and metal oxides. It can be broadly categorized as nonferrous/base metals (by-products of recovering non-ferrous resources like copper, nickel, zinc, and phosphorus), ferrous (by-products of processing iron and steel), or ferroalloy (by-product of ferroalloy manufacture). Slags can be further divided into subcategories based on its precursor and processing circumstances, such as blast furnace slags, air-cooled blast furnace slag, basic oxygen furnace slag, and electric arc furnace slag, under these broad categories [17].

Components are identified using X-ray diffraction (XRD).

**Table [1] :** Chemical composition of iron slag

Constituent	wt. (%)
AL2O3	6.4860
CaO	49.0679
Cl	0.0060
Fe2O	14.7312
K2O	0.0085
MgO	9.2741
Na2O	0.0807
SiO2	21.7082

**2.2 Spectrophotometer**

The spectrometer that was utilised to measure the amounts of copper in a variety of samples both before and after treatment Maker of the spectrophotometer is made by (Labmod,inc ,U.S.A)



**Figure (1):** Spectrophotometer

**2.3 Laboratory Water Bath**

It is used to heat samples at certain temperatures



**Figure (2):** Laboratory water bath

**3. Experimental Studies**

**3.1. Preparation of adsorbent**

Iron slag, a by-product of the steel making process, was acquired from the Libyan Iron and Steel Company in Misurata and employed as an adsorbent material in the adsorption experiment. After cleaning, it was placed in an air furnace and allowed to dry at 100°C for at least 24 hours. Following that, a disc machine was used to grind it, and a laboratory test sieve was used to sort the particles into the desired size.



**Figure (3):** Iron Slag

**3.2 Preparation of Adsorbed Solution**

By dissolving a precisely balanced amount of water copper sulphate (CuSO<sub>4</sub>.5H<sub>2</sub>O) in (1000 ml ) of distilled water, a copper stock solution was created. After that, deionized water was used to dilute the stock solutions to the necessary concentrations (1000,1500,2000,2500, and 3000 ppm)

**3.3 Adsorption experiments**

Experiment is to identify and verify the parameters that influence the removal of copper (II) from standard solution. Additionally, it involves assessing the ideal conditions for the adsorption process, study the impact of PH and temperature. The mass balance equation (1) was utilized to compute the quantity of copper adsorbed onto iron slag:

$$q = \frac{V(C_0 - C_e)}{W} \dots\dots\dots (1)$$

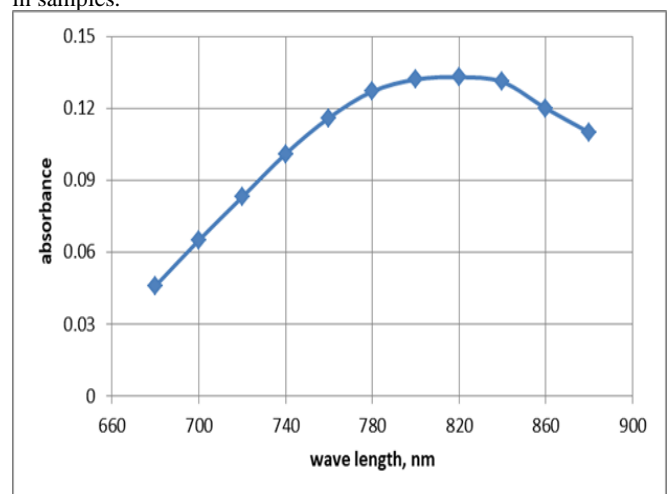
where: (V) is the volume of solution in litres, (W) is the mass of the adsorbent in grammes, (C<sub>0</sub>) is the initial metal ion concentration in solution, and (q<sub>e</sub>) is the amount of copper

adsorbed on the adsorbent. The percentage removal metal ions are also calculated reported using Eq (2) [18,19]:

$$R = \frac{(C_0 - C_e)}{C_0} * 100 \dots\dots\dots (2)$$

**3.3.1 Selection Wave Length**

Before starting the experiments to measure copper concentration, the optimal wavelength was studied. The relationship between wavelength and absorptivity is shown in Figure (4), absorption increases with wavelength until maximum absorption is reached at 820 nm. Then the absorption starts to decrease as the wavelength increases. Therefore, this wavelength is used for quantitative analysis of copper in samples.



**Figure (4):** Maximum absorbent of copper (II) solution

**3.3.2. Calibration Curve**

Calibration standard solutions are analyzed to obtain a calibration curve that correctly fits the sample to be analyzed. To test copper(II) uptake, a series of standards from 1000 ppm to 3000 ppm (1000, 1500, 2000, 2500, 3000 ppm) were prepared. The absorbance of each

solution was then recorded and a standard calibration curve was created as shown in Figure (5).

Condition:(adsorbent dosage =3.5 g/100 ml, pH=5, contact time=90 min, particle size=(d=0.200 mm),and temperature 25 °C)

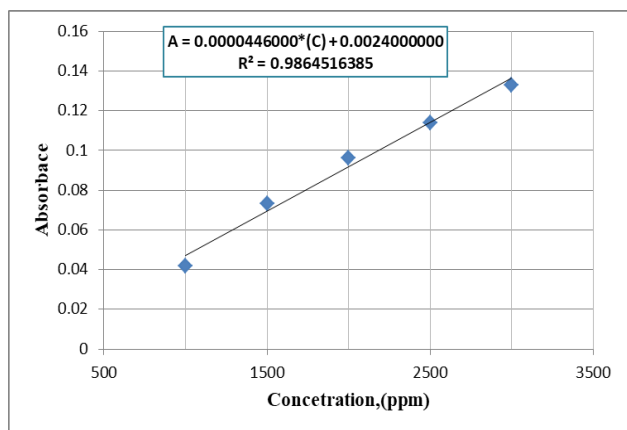


Figure (5): Calibration curve of cu(ii) solution

4. RESULTS AND DISCUSSIONS

4.1 Effect of PH

The effect of changing the initial pH 5 at 25 °C with an adsorbent dose of 3.5 g/L was studied for a contact time of 90 min. The copper concentration remained constant at 3000 ppm. The results and figure (6) showed that the highest copper removal percentage was 99.55 % at pH 5. This trend was expected. Adsorption increases as the pH rises to a certain value and decreases with that the increase. When the pH value increases above 8, the removal rate decreases; because it leads to Copper precipitation as Cu(OH)<sub>2</sub>.

4.3 Effect of Initial Copper Concentration

The effect of initial copper concentrations on copper (II) removal by iron slag is clear in Figure (8). Other variables are fixed such as adsorption, contact time, stretching temperature holding temperature at 3.5 g, 90 min, diameter 200 μm, temperature 25 °C, and pH = 5. It has been observed that as the initial concentration increases, the removal percentage increases and this is due to covering a larger area. More heavy metal ions are available to occupy the available adsorption sites on the surface of the adsorbent [21].

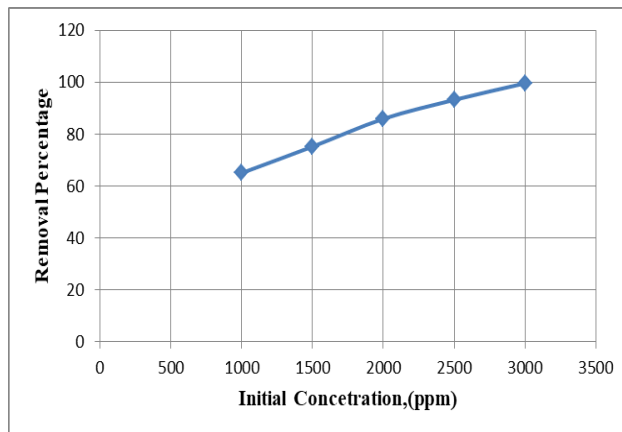


Figure (8) : Effect of Initial Concentration on removal percentage of Cu (II)

Condition:(adsorbent dosage =3.5 g/100 ml, pH=5, contact time=90 min, particle size= (d=0.200 mm), and temperature 25 °C)

4.4 Adsorption Isotherm

The effect of initial copper concentration on equilibrium was investigated by performing adsorption experiments with the following: Conditions (dose = 3.5 g, V = 100 ml, T = 25 °C, pH = 5, t = 90 min). The distribution of adsorbed species between the liquid and the sorbent is described by mathematical models. There are many iso-thermal models to study and determine system equilibrium Adsorbent capacity. Typically, Langmuir, Freundlich and Temkin model.

4.4.1 Langmuir adsorption Isotherm

The model assumes homogeneous monolayer surface adsorption where there is no displacement or molecular interaction and all binding sites have the same energy and affinity. Hence, saturation can be obtained.[22]. Plotting Ce/qe versus Ce results in a straight line with intercept 1/KL and slope aL/KL, from equation (3) Figure (9). Table (2) lists the appropriate correlation coefficient and Langmuir constants aL, KL, and Q<sub>0</sub> for the Cu(II)/iron slag system. When comparing this model with experimental data, the average overall error (2.52 %) is, and the saturation capacity of the monolayer (Q<sub>0</sub>) is 23.52 mg/g.

$$\frac{C_e}{q_e} = \frac{1}{qm*kl} + \frac{C_e}{qm} \dots\dots\dots 3$$

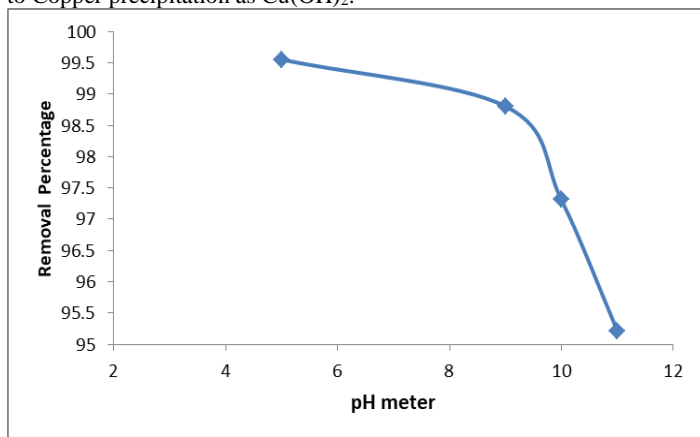


Figure (6): Effect of pH on copper adsorption

Condition:(adsorbent dosage =3.5 g/100 ml,pH=5,contact time=90 min,particle size=(d=0.200 mm),and temperature 25 °C)

4.2 Effect of Temperature

They were studied at (25, 35, and 60 °C) with a pH = 5, and an adsorbent dose of 3.5 g/L and Call duration is 90 minutes. It was found that with increasing temperature, the efficiency removal was increased and maximum removal was 99.98 % at 60 °C. Efficiency removal increase with temperature may be due to surface coverage expansion and due to the reactive and active sites [20].

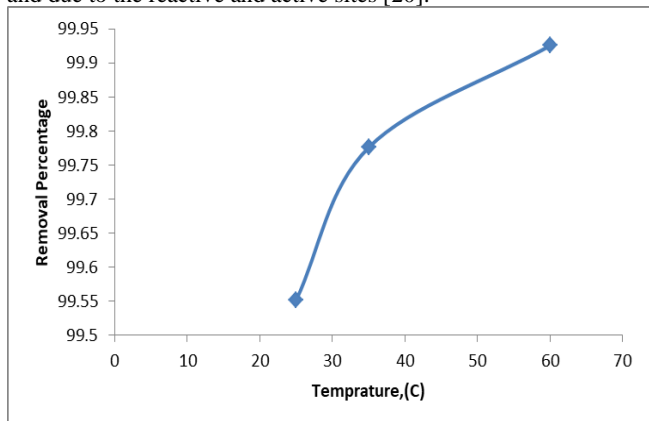


Figure (7): Effect of temperature on copper adsorption

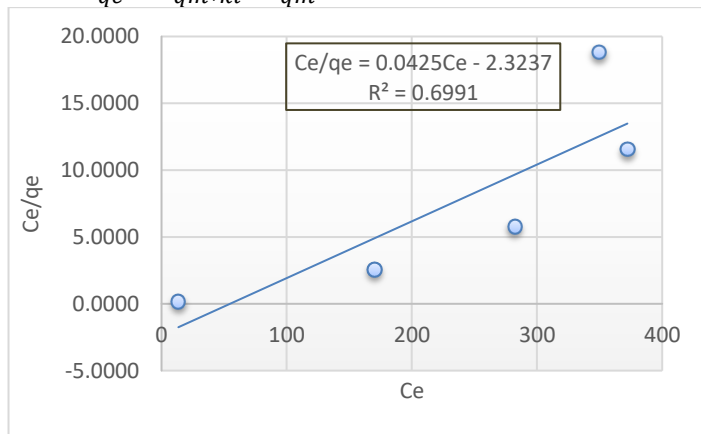
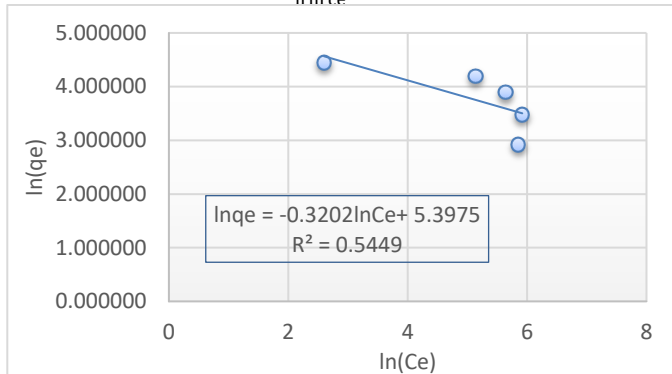


Figure (9): Langmuir adsorption isotherm for Cu(II) adsorption  
Condition:(adsorbent dosage =3.5 g/100 ml, pH=5,contact time=90 min, particle size=(d=0.200 mm),and temperature 25 °C)

4.4.2. Freundlich adsorption Isotherm

According to the Freundlich model, multilayer adsorption occurs on heterogeneous surfaces, and as concentration rises, the amount of deposited adsorbate grows endlessly [23]. From equation (4) the data that the correlation coefficient is far away from 1 ( $R^2=0.54$ ), and the total error (1.59 %) is less than the Langmuir model.

$$\ln(q_e) = \ln kF + \frac{1}{n} \ln C_e \dots\dots\dots 4$$



**Figure (10):** Freundlich adsorption isotherm for Cu (II) adsorption Condition:(adsorbent dosage =3.5 g/100ml, pH=5, contact time=90 min, particle size=(d=0.200 mm),and temperature 25 °C)

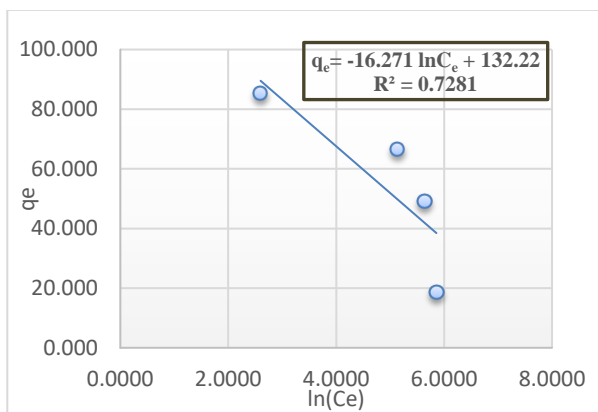
**4.4.3. Temkin adsorption Isotherm**

If sorption data is analyzed in reference to the linear equation (5) . a plot of  $q_e$  versus  $\ln C_e$  figure (11) enables one determine the constants A and B. Temkin constants A and B are listed in table (2) and the theoretical plot of this isotherm is shown in figure (11). The correspond correlation coefficient table (2) equals ( $R^2=0.72$ ) where the total mean error equals to (1.48%) of a lower value than the Langmuir's and Freundlich's. Among the three models it is clear that the Temkin model has a better fit with the experimental data than the Langmuir and Freundlich model.

$$q_e = \frac{RT}{b} \ln(A) + \frac{RT}{b} \ln(C_e) \dots\dots\dots 5$$

Where:  $\frac{RT}{b} = B$

where  $q_e$  is the adsorbed ions at equilibrium, A is the equilibrium constant interrelated to the maximal binding energy ( $L g^{-1}$ ), R is the universal gas constant (8.314 J/mol.K), and T is the temperature in kelvin. By plot of  $q_e$  versus  $\ln C_e$ , enables one to determine the constant A and B .



**Figure (11):** linear from Temkin isotherm Condition:(adsorbent dosage =3.5g/100 ml, pH=5 ,contact time=90 min, particle size=(d=0.200 mm),and temperature 25 °C)

**Tables (2):** Langmuir, Freundlich Isotherm contact

Langmuir isotherm				
$K_L(l/g)$	$a_L(l/mg)$	$Q_o(mg/g)$	$R^2$	$\epsilon \%$
-0.43	-0.079	23.52	0.69	2.62
Freundlich isotherm				
$K_F(l/g)$	n	$R^2$	$\epsilon\%$	
220.8	-2.73	0.54	1.59	
Temkin isotherm				
B(mg/g)	A(l/g)	$R^2$	$\epsilon\%$	
-16.271	0.000392	0.72	1.48	

**5.CONCLUSIONS:**

Adsorption of Cu (II) by iron slag is investigated in batch experiments and kinetics and equilibrium experiments are conducted for synthetic feedstock solution simulated of industry effluents. The following conclusions are drawn from the data:

- The optimal parameters for removing Cu (II) are: AC dosage = 3.5 g/100 ml, particle size (d = 200 mm), starting pH = 5, temperature = 25 °C, and 90 minutes of contact time.
- Compared to Freundlich and Temkin isotherms, Temkin isotherm more accurately depicts the adsorption process of iron slag/Cu (II).
- Therefore, the current study demonstrates the viability of using iron slag as a readily available, low-cost adsorbent for the efficient removal of Cu (II) from aqueous solution under ideal circumstances.

**6. RECOMMENDATION: -**

1. It might also be possible to do additional research to examine the possibility of using iron slag again (recycling it and using it again for adsorption).
2. Examine how the agitation rate affects the adsorption process.
3. Modifying the iron slag characteristics with chemicals as this might increase the adsorption capacity.
4. Study of the ability of iron slag to absorb other heavy metals uch as lead, cadmium, and chromium.
5. Investigating the safe disposal of the wasted adsorbent is necessary.
6. Use other devices to determine absorption such as an atomic absorption spectrophotometer (A.A.S)

**REFERENCES:**

- [1]- Journal of Environmental Health Science & Engineering, 6(2), 73-80.
- [2]- Marcovecchio, J. E., & Botté, S. E. (2007). Heavy metals, major metals, trace elements. In Handbook of water analysis (pp. 289-326). CRC Press.
- [3]- Khodabakhshi, A., Amin, M., & Mozaffari, M. (2011). Synthesis of magnetite nanoparticles and evaluation of its efficiency for arsenic removal from simulated industrial wastewater. Journal of Environmental Health Science & Engineering, 8(3), 189-200.
- [4]- Ghasemi, M., Keshkar, A., Dabbagh, R., & Safdari, S. J. (2011). Biosorption of uranium in a continuous flow packed bed column using Cystoseira indica biomass. Journal of Environmental Health Science & Engineering, 8(1), 65-74.
- [5]- Underwood EJ: Trace elements in humans and animals nutrition. 3rd edition. New York: Academic Press; 1956.
- [6]- Maha B. Al-Janabi1, Manal Adnan Mohammed, Asrar A. Alobaidy, Mustafa H. Al-Furaiji3. 2023, Use of Low-Cost Adsorbent for Copper and Lead Removal from Aqueous Solutions. Journal of Ecological Engineering 2023, 24(9), 19–26
- [7]- <https://doi.org/10.12911/22998993/167950>
- [8]- Wang LK, Chen JP, Hung YT, Shammas NK: Heavy metals in the environment. London: Taylor and Francis; 2009.
- [9]- Yu, B., Zhang, Y., Shukla, A., Shukla, S. S., & Dorris, K. L. (2000). The removal of heavy metal from aqueous solutions by sawdust adsorption—removal of copper. Journal of hazardous materials, 80(1-3), 33-42.
- [10]- Gaikwad, R. W., Misal, S. A., & Gupta, D. V. (2009). REMOVAL OF COPPER IONS FROM ACID MINE DRAINAGE (AMD) BY ION EXCHANGE RESINS: INDION 820 AND INDION 850. Journal of Applied Sciences in Environmental Sanitation, 4(2).
- [11]- Aydın, H., Bulut, Y., & Yerlikaya, Ç. (2008). Removal of copper (II) from aqueous solution by adsorption onto low-cost adsorbents. Journal of environmental management, 87(1), 37-45.
- [12]- Ho, Y. S. (2003). Removal of copper ions from aqueous solution by tree fern. Water research, 37(10), 2323-2330..
- [13]- Cheremisinoff, P. N. (2019). Handbook of water and wastewater treatment technology. Routledge.
- [14]- Awwa, W. S. (2010). Principles And Practices Of Water Supply Operations Series..
- [15]- <https://www.cheresources.com/wminzz.shtml>
- [16]- Júlia Pedó Gutkoski, ... Camila Michels . (2024). How effective is biological activated carbon in removing micropollutants? A comprehensive review. <https://www.sciencedirect.com/journal/journal-of-environmental-management>

- [17]- Piatak, N. M., Parsons, M. B., & Seal II, R. R. (2015). Characteristics and environmental aspects of slag: A review. *Applied Geochemistry*, 57, 236-266.
- [18]- National Academies of Sciences, Engineering, and Medicine. (2013). *Recycled Materials and Byproducts in Highway Applications—Summary Report, Volume 1.45*
- [19]- L. Li, S. Wang, Z. Zhu, *Journal of Colloid and Interface Science*, 300, 52-59 (2006)
- [20]- Horsfall MJ, Abia AA and Spiff AI. Kinetic studies on the adsorption of Cd<sup>2+</sup>, Cu<sup>2+</sup> and Zn<sup>2+</sup> ions from aqueous solutions by gassava (*manihot esculenta*) tuber bark waste. *J. of Biores Technol.* 97; 2006: 283-291.
- [21]- Kumar, P. S., Ramalingam, S., Sathyaselvabala, V., Kirupha, S. D., Murugesan, 46A., & Sivanesan, S. (2012). Removal of cadmium (II) from aqueous solution by agricultural waste cashew nut shell. *Korean Journal of Chemical Engineering*, 29, 756-768.
- [22]- Kopac, T., Sulu, E., & Toprak, A. (2016). Effect of KOH treatment on bituminous coal for the effective removal of basic blue 41 dye from aqueous solutions. *Desalination and Water Treatment*, 57(59), 29007-29018.
- [23]- Al-Ghouti, M. A., Li, J., Salamh, Y., Al-Laqtah, N., Walker, G., & Ahmad, M. N. (2010). Adsorption mechanisms of removing heavy metals and dyes from aqueous solution using date pits solid adsorbent. *Journal of hazardous materials*, 176(1-3), 510-520. and cadmium ions through adsorption on water-quenched blast furnace slag. *Desalination and Water Treatment*, 57(47), 22493-22506.
- [24]- Lujanienė, G., Šemčuk, S., Lečinskytė, A., Kulakauskaitė, I., Mažeika, K. S., Valiulis, D., ... & Tumėnas, S. (2017). Magnetic graphene oxide based nanocomposites for removal of radionuclides and metals from contaminated solutions. *Journal of environmental radioactivity*, 166, 166-174.