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UTILIZATION OF UNI-POLAR AND BI-POLAR ELECTROCOAGULATION (EC) TO OVERCOME HEAVY METAL POLLUTION IN SLAUGHTERHOUSE WASTE WATER

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ABSTRACT

Electrocoagulation is a perspective well known modern alternative technology used to remove or mitigate the concentration of organic pollutants including heavy metal residues which accumulate and pollute raw and wastewater. Recent researches have been concentrating on finding new solutions through using new technologies, in order to improve and update the depollution process performance. The paper presents a new technical method for wastewater treatment using electrocoagulation. The results cleared that all wastewater samples contained heavy metals within the permissible limits except for Fe. Both Uni and Bi-polar methods have eliminated Zn & Cu completely by 100% from polluted cattle slaughterhouse waste water. Bi-polar electrocoagulation method was best than Uni-polar one as it was able to remove all types of heavy metal residues under test successfully (100%), although, the Uni-polar mitigate the level (mg/L) of Pb by 25% reduction level (0.009), Mn by 33.3 (0.05), while Fe level transformed from non-acceptable to acceptable level by 93% reduction percentage (0.3 to 0.02 mg/L).

KEYWORDS: Wastewater treatment, electric cell, anode, cathode, CD power supply, Uni and Bi-polar Electrocoagulation methods.

INTRODUCTION

In the global context of sustainable management of natural water resources aimed at conserving wastewater, electrocoagulation treatment methods have attracted considerable attention from a variety of researchers. This technology employs an electric field within an electrolysis cell filled with wastewater, promoting the treatment and flocculation of contaminants, such as heavy metal residues, without relying on chemical coagulants. (**Butler *et al.*, 2011 and Vepsäläinen, 2012**).

The electrocoagulation process occurs within an electric cell that contains two metal electrodes: one serving as the anode and the other as the cathode. Upon the establishment of an electric field, electrochemical principles are activated, leading to the oxidation of the cathode, which loses electrons, while the anode facilitates the reduction of water by accepting electrons. This interaction is crucial for effective water treatment. As a result, hydroxide ions (OH-) are generated, which neutralize particles and promote the formation of flocs. (**Butler *et al.*, 2011; Pisoi *et al.*, 2011 and Vepsäläinen 2012).** The formation of these agglutinated masses begins at the bottom of the cell and can be subsequently removed through filtration. When regarded as part of an electrocoagulation-flotation process, the organic particles, along with heavy metals, will float to the surface as a result of hydrogen generation at the anode; these particles can then be scraped away. (**Mollah *et al.*, 2004 and Vepsäläinen, 2012)**.

Water is considered lifeline for animals and humans and any country economically success depends mainly on the clean water resources. The multiplicity of new industrial fields, frontier technology, and civilizational progress and world expansion will result in accumulation of unusable organic compounds in industrial and agricultural wastewater. These water pollutants are dangerous and may constitute health risk for both of human, animals as well as environment. Among these most common pollutants, heavy metals such as Chromium (Cr), Lead (Pb), Cadmium (Cd), Zinc (Zn), Nickel (Ni), and Arsenic (As) that are considered the most poisonous pollutants. As a result, heavy metal removal or mitigation from wastewater is an urgent demand. Currently, several technologies are utilized to remove high percentage of toxic metals density. Heavy metals like lead, cadmium, mercury, and cobalt are detected previously in industrial wastewater **(Järup, 2003 and Alaji *et al.*, 2012).**

Heavy metals even at lowest levels or quantities constitute a high risk to aquaculture and human environment as well as human health. Unsanitary metal processing, storage as well as using of agricultural chemicals at high temperatures, faulty programs used for cleaning wastewater, and cows and sheep manure utilization are all sources of heavy metal. Heavy metals can be inhaled or swallowed through food, drink, fumes, or dust, all of which can harm the health of mankind **(Walsh, 2001; Attia, 2013 and An *et al.*, 2017).**

In the majority of populations, cadmium (Cd) exposure predominantly arises from the consumption of specific foods grown in contaminated soil containing Cd. For smokers, tobacco use represents one of the most significant sources of cadmium exposure. Additionally, individuals employed in industries involving cadmium may experience inhalation exposure in environments with poor industrial hygiene. (**Pamela and Tucker, 2011).** Cadmium poses significant toxic risks to the kidneys, along with adverse impacts on the skeletal and respiratory systems. It is classified as a carcinogen for humans **(WHO, 2019 and Hawaas *et al.*, 2023).** Moreover, Lead (Pb) originated from mining waste, incinerating of ash, water from lead welding pipes, and automobile exhaust, with symptoms including paint, nervous manifestations, and kidney damage and learning delays. On the contrary, at low concentrations, Zinc (Zn) and Copper (Cu) ions are largely harmless to human and animal health, as they are necessary for several biological activities in living organisms. However, when present in high concentrations, these elements can pose considerable health risks to both humans and animals. (**Abu-El-Halawa, 2017** and **Hawaas *et al.*, 2023).** The removal of different heavy metals from polluted water through application of several technologies including adsorption, electrocoagulation, ion exchange, chemical precipitation, membrane filtration and electrochemical methods. Such technologies are selected according to the efficacy of application, costs, influence on the environment and operational facilities among others **(Zamora-Ledezma *et al.*, 2021).** Monomeric types such as $Al(OH)^{2+}$, $Al(OH)_2{}^{+}$, $Al_2(OH)_2{}^{4+}$, $Al(OH)^{4-}$ and polymeric types such as $Al_6(OH)_{15}{}^{3+}$, $Al_7(OH)_{17}{}^{4+}$, $Al_8(OH)_{20}{}^{4+}$, $Al_{13}O_4(OH)_{24}{}^{7+}$, $Al_{13}(OH)_{34}{}^{5+}$ are formed during the electrocoagulation process (**Can *et al.*, 2003 & 2006** and **Canizares *et al.*, 2005**). The aluminum hydroxide flocks serve as adsorbents and/or traps for various pollutants, facilitating their removal from the solution **(Cenkin & Belevstev, 1985 and Ogutveren *et al.*, 1994).**

Heavy metals are elements that are found in nature, distinguished by their high atomic weight and a density that exceeds five times that of water. The increased presence of these elements in the environment can be attributed to various human activities, including industrial operations, household usage, agricultural endeavors, and technological innovations. This situation has led to growing apprehension regarding their potential harmful effects on human health and the associated environmental degradation. The toxicity of heavy metals is determined by multiple factors, including the amount of exposure, the route of exposure, and the concentration of the metals. Additionally, factors such as the age, gender, and nutritional condition of the exposed individuals are crucial in assessing the risk. Arsenic, cadmium, lead, and mercury are particularly concerning due to their high toxicity levels and are classified as priority metals that warrant significant public health attention. These metals have the potential to cause organ failure even at minimal exposure levels and are classified as human carcinogens by both the U.S. Environmental Protection Agency and the International Agency for Research on Cancer **(Tchounwou *et al.*, 2012).**

Environmental contamination is a critical issue of worldwide significance that affects all components of ecosystems. Contaminants from human waste and industrial sources are consistently reintroduced into the environment, impacting agricultural lands, vegetation, livestock, and ultimately humans through the food chain. The contamination of drinking water with toxic metals has emerged as a major global concern, causing disruptions in bodily systems and, in some cases, resulting in fatalities among both animals and humans. Many environmental organizations have sought to regulate activities that increase the risk associated with heavy metals. The presence of these hazardous metals, which pose significant health risks even at low concentrations, generally diminishes the quality and safety of water. **(Noor *et al.*, 2024).**

Therefore, treatment, control, and/or mitigation of heavy metals residues in slaughterhouse wastewater considered the main purpose of the current research study to comply with the permissible residual limits mentioned by environmental legislation authorities at national or international levels in order to prevent environmental pollution as well as consumer health hazards.

2 MATERIAL AND METHODS

2.1. Characteristics of slaughterhouse wastewater

Physico-chemical characteristics of slaughterhouse wastewater are tested in Reference laboratory for food safety analysis of food of animal origin - Animal Health Research Institute-Agriculture Research Center (AHRI-ARC).

2.2. Experimental design (Atiyah and Abdul-Majeed, 2019)

In the electrocoagulation process, aluminum foil is utilized as the anode electrode, that creates the difference in the field of traditional electrocoagulation mode, making the aluminum electrode an innovative solution that promotes efficiency and ensures stable flow by employing non-scaling, sacrificial electrode technology. Electrocoagulation cell used in this research is shown in **Photos (1, 2 & 3)**, where the anode electrode represented by Al foil and the cathode represented by Fe in Bi-polar while Uni-polar electrocoagulation system consisted of Fe/Fe for both Anode & Cathode.

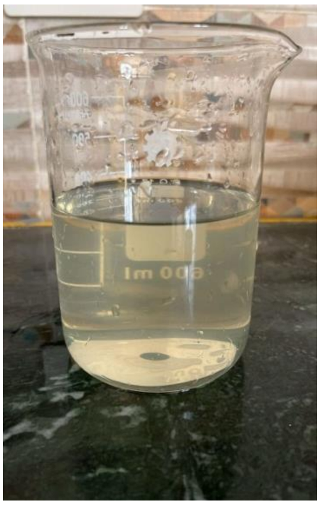

Photo (1)

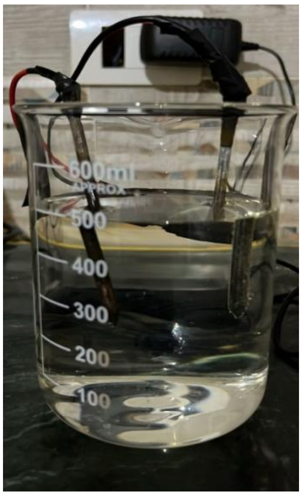

Photo (2)

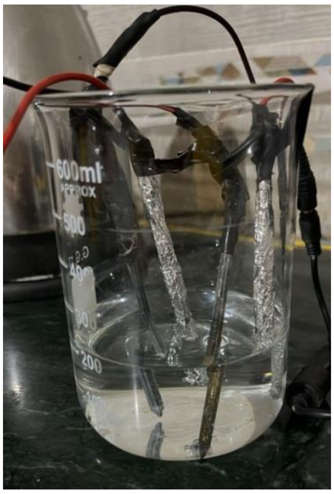

Photo (3)

Photo (1) Slaughterhouse wastewater before treatment
Photo (2) Slaughterhouse wastewater after Uni-polar Electrocoagulation treatment
Photo (3) Slaughterhouse wastewater after Bi-polar Electrocoagulation treatment

2.3 Experimental procedure according to Atiyah and Abdul-Majeed (2019) and Hedes *et al.* (2019)

2.3.1. The experiment was conducted with 1000 ml of wastewater obtained from a slaughterhouse for each run.
2.3.2. Each tape of aluminum foil was folded to be 7 cm height and 3 cm width.
2.3.3. One pole of the Al foil electrode (anode) and one pole of Fe (Cathode) were connected to the power supply. The other Al. & Fe poles were kept freely in the solution and not connected to the DC power supply.
2.3.4. Each run of the experiment was timed for 30 min.
2.3.5. After every experimental run, the treated wastewater from the slaughterhouse was set aside to settle for 30 minutes.
2.3.6. For the analysis of heavy metal residues, thirty milliliters of treated water were drawn from the midpoint of the beaker using a syringe.
2.3.7. Each run of the experiment was triplicated, and the average result was taken to avoid mistakes as well as to calculate statistically the mean SD.

2.4. **Chemical reactions of electrocoagulation process (Bazrafshan *et al.*, 2015 and Huang *et al.*, 2020) as follows**

2.4.1. At the cathode, hydroxyl ions are produced as water and oxygen are reduced, as shown by the following chemical equations.

$2\ H_2O + 2e^- \rightarrow 2OH^- + H_2$ (Cathode)
$2\ H_2O + O_2 + 4e^- \rightarrow 4OH^-$ (Cathode)

2.4.2. Al^{3+} ions are produced as a result of oxidation, and aluminum hydroxide precipitates.

$Al \rightarrow Al^{3+} + 3e^-$
$Al^{3+} + 3OH^- \rightarrow Al\ (OH)_3$

2.4.3. For electrodes made of iron (Fe), as in the reaction occur in the following equations

$Fe\ (s) \leftrightarrow Fe^{+3} + 3e^-$ (anode)
$3H_2O + 3e^- \leftrightarrow 3/2\ H_{2g} + 3OH^-_{aq}$ (cathode)

In addition, Fe^{3+} and OH^- ions generated at electrode surfaces react in the bulk wastewater to form ferric hydroxide:

$Fe^{+3}_{aq} + 3OH^-_{aq} \leftrightarrow Fe\ (OH)_3$.

2.5. Detection and quantification of heavy metals (AOAC, 2005)

Atomic Absorption Spectrophotometry (AA), (SensAA DUAL GBS scientific Equipment, Melbourne, Australia) was used to determine the metals concentration, SensAA DUAL likely refers to the dual-beam design, which enhances measurement stability and accuracy, and/or the capability of using both flame and graphite furnace techniques within the same instrument. This makes the SensAA DUAL a versatile tool for comprehensive metal analysis following the procedures outlined in **AOAC Official method (974.27)** for detection of Cadmium, Chromium, Copper, Iron, Lead, Manganese, Magnesium, Silver, and Zinc in water. Initially, water samples were filtered and preserved with the addition of nitric acid to facilitate the separation of dissolved metals. The analysis of suspended metals involved a comprehensive series of heating, digestion, and dilution steps. Metals at low concentrations, such as lead (Pb) and cadmium (Cd), were concentrated and chelated prior to extraction and measurement. The prepared samples subsequently underwent Atomic Absorption (AA) analysis, where the concentrations of metals were determined by comparing the absorption readings to standard calibration curves established with Standard Metal Solutions, enabling the calculation of Mean ±SD.

The reduction efficiency was calculated using the following equation:

Reduction percentage (R %) = $\frac{Co - Ce}{Co} \times 100$

Where **Co** and **Ce** are the initial and final concentrations, respectively, of the heavy metal in mg/L.

RESULTS

All the conditions are shown in Table (1). Hydrogen ion concentration (pH) was adjusted to 7 with 60 min contact time, electrode metal of Al/Fe and 24/12 current (A/V)

Table 1: Electrocoagulation operational conditions.

Pollutant Heavy metal	pH	Contact time (min)	Electrode metal	Current V/A
Zinc (Zn)	7	60	Al/Fe	24/12
Cupper (Cu)				
Lead (Pb)				
Cadmium (Cd)				
Iron (Fe)				
Manganese (Mn)				

Table (2) & Fig. (1) revealed that all control and treated samples were free from pollution with Cd. Zinc and Cu which was recorded 0.022±0.003 and 0.01±0.003 mg/L in control samples respectively, which were completely, eliminated using both Uni and Bi-polar methods. Also, all metals were successfully eliminated in wastewater by using Bi-polar method as compared with control and Uni-polar for Pb (0.036±0.004 & 0.27±0.002); Fe (0.3±0.03 & 0.020±0.002) and Mn (0.15±0.02 & 0.1±0.02 mg/L), respectively. However, these results showed significant decrease in heavy metal levels including Pb, Fe and Mn in treated samples using uni-polar electrocoagulation method as compared with control. All samples within the permissible accepted limits except for Fe which exceeded the permissible limits according to the standards of international institutions listed in **Table (3)**

Table 2: Heavy metal concentrations (mean±SD) in control and both of Uni and Bi-polar electrocoagulation treated samples.

Heavy metal / Method	Zn	Cu	Pb	Cd	Fe	Mn
Control	0.022±0.003	0.01±0.003	0.036^{a}±0.004	0.0	0.3^{b}±0.03	0.15^{d}±0.02
Unipolar	0.0	0.0	0.027^{a}±0.002	0.0	0.02^{b}±0.002	0.1^{d}±0.02
Bi-polar	0.0	0.0	0.0	0.0	0.0	0.0

There are a significance difference (P<0.05) between metal values within the same column with the same superscribed letter

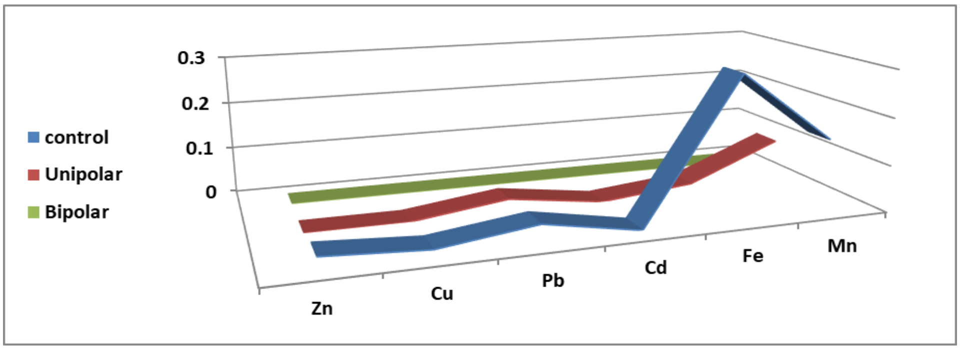

Fig. (1): Heavy metal residues before and after electrocoagulation treatment

Table 3: Acceptability % of different types of heavy metals residues as compared with WHO standard values.

Heavy metal in SH water	WHO Standard Maximum allowable (mg/L)	Acceptability %
Iron (Fe)	0.2	UA
Cadmium (Cd)	0.003	100
Lead (bp)	0.01	100
Zinc (Zn)	3.0	100
Copper (CU)	2	100
Manganese Mn	0.4	100

UA= Unaccepted **SH=Slaughterhouse**

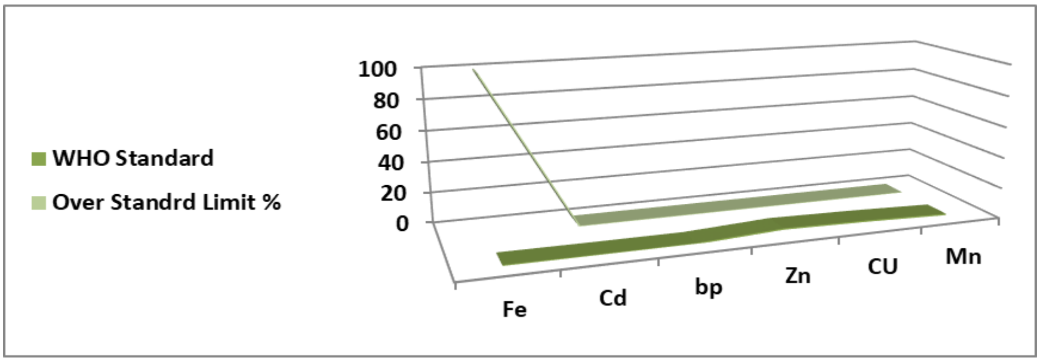

Fig. (2): Over standard limit of Fe according to WHO standards for Heavy.

Metals

Table (3) illustrated that all metals are within the acceptable limits except for Fe, the mean concentration of examined samples were recorded 0.3 mg/l which exceeded by 100% the permissible limits (0.2 mg/L) recommended by **WHO (2007), Ministry of Health Regulation Number 492 (2010),** and **Jamshaid *et al.* (2018)** as shown in **Fig. (2),** such control samples which were high in Fe became within the permissible limit (**0.02±0.002**) after application of Uni-polar electrocoagulation method, while the samples were completely free from Fe after treatment with Bi-polar electrocoagulation method.

As shown in **Table (4) & Fig. (3),** reduction % induced by Uni-polar method recorded 100% reduction for both Zn & Cu, followed by 93% for Fe, 25% for Pb, and finally 33.3 for Mn, while Bi-polar electrocoagulation method could eliminate all residues of heavy metals (100%) from of all samples under test. This complete reduction may be attributed to the presence of aluminum foil electrode (anode) in Bi-polar electrocoagulation system as described by **Asselin *et al.* (2008).**

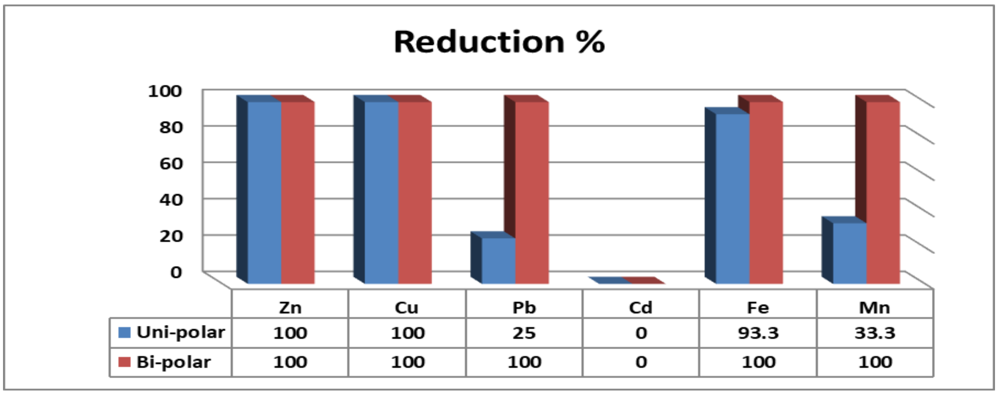

Fig 3: Reduction Percentage of different heavy metals using Uni and Bi-polar electrocoagulation.

Table 4: Mean reduction level and % of Unipolar and Bi-polar electrocoagulation compared with control samples.

Heavy metal	Control	Unipolar reduction		Bi-polar reduction	
		level	%	level	%
Zn	0.022	0.022	100	0.022	100
CU	0.01	0.01	100	0.01	100
Pb	0.036	0.009	25%	0.036	100
Cd	-----	-----	-----	-----	-----
Fe	0.3	0.28	93.3	0.3	100
Mn	0.15	0.05	33.3	0.5	100

DISCUSSION

Electrocoagulation criteria and its implication in controlling of heavy metal residues

The provision of clean water is a critical concern due to its direct relationship with public health, energy production, economic development, and growth. Additionally, the increasing population will inevitably influence water demand, highlighting the urgent need for advanced water treatment technologies and materials to efficiently remove heavy metals **(Senanu *et al.*, 2023).** Presence of some dangerous heavy metals even at low concentrations or exposure of human to low level of such metals will result in some organs malfunction or even failure **(Tchounwou *et al.*, 2014).**

The work which has adopted in Abattoirs may be additional source of heavy metal pollution these metals are negatively affect the soil, water, air and overall environment (**Adesemoye, 2006).** Slaughterhouse wastewater has been concluded to be very risky to the environmental and humn health. The consumption of polluted plants and water containing heavy metals by animals leads to the release of these metals into the soil at the time of slaughter, which subsequently causes soil pollution (**Ojekunle and Lateef, 2017).**

Hydrogen ion concentration (pH) considered one of the factors that affecting EC performance **(Malakootian *et al.* (2010).** While **Chen *et al.* (1997)** stated that pH did not interfere with the removal of heavy metals from wastewater. In contrary, **Kobya *et al*. (2006)** stated that pH plays an important role in EC process. In this regard, **Adhoum *et al*. (2004)** mentioned that pH more than 4 considered efficient for removal of Zn and Cu from polluted wastewater. This agreed with the pH level (7) which used in the current study **(Table 1)** as it is found to be sufficient to remove Zn and Cu from cattle slaughterhouse wastewater. Moreover, **Zailani and Zin (2017)** concluded that pH factor is considered as an important item reflected positively on EC performance beside the electrode type. In this regard, **Bakry *et al*. (2024)** mentioned that the pH value made the EC process easier and also reduced the cost of adding chemicals to adjust the pH in the solution. The author adjusted the pH to 6, 7, 6.9, 7, and 6 for Pb, Cd, Zn, Mn and Cu, respectively. The author added that most published researches used pH range from 4 – 8 and that also comply with the pH used in our study (pH, 7) as well as the adjusted pH is in compliant with several investigators (**Xu *et al.*, 2017; Thakur *et al.*, 2023 and Huang *et al.*, 2020**). In this respect, **Ganesan *et al.* (2013)** found that at a neutral pH of 7, there was a significant reduction in magnesium, attributed to the formation and precipitation of polymeric aluminum species as $Al(OH)_3$, which prevents the existence of soluble species. This process promotes the adsorption of manganese onto aluminum hydroxide flocs. In contrast, higher pH levels are more conducive to hydroxide precipitation rather than coagulation or flocculation, with specific pH ranges for metal hydroxide precipitation being 8–8.5 for lead, 9.0–9.5 for zinc, 8.5–9.5 for copper, 9–9.5 for manganese, and 11 for cadmium. **(Zainuddin *et al.*, 2019 & Ahmed *et al.*, 2022).** Regarding the Aluminum electrode foil electrode which used in the anode side of the current study, **Israa and Basma (2019)** concluded that it has many benefits: inexpensive to operate, low capital costs, low power requirements, no chemicals required, treatment of various contaminants, and fewer and thinner layer reduce weight. **Huang *et al.* (2020)** concluded that aluminum hydroxide $Al(OH)_3$ is recognized as an amphoteric hydroxide, which means it can react with both acidic and alkaline substances to form salt and water. As a result, the pH level of most $Al(OH)_3$ products generally ranges from 5 to 8. Furthermore, aluminum hydroxide functions as a coagulant to eliminate heavy metal ions. With the passage of time during the coagulation process, the pH of the solution increases beyond 8, causing $Al(OH)_3$ to slowly dissolve in the alkaline solution.

Heavy metal levels and impact of Uni and Bi-polar electrocoagulation

In Khartoum slaughterhouse drinking water, **Ahmed *et al.* (2020)** concluded that heavy metal concentrations were recorded 12.1 mg/l for Iron, 0.01 for Zn and 0.07 for Cu, while Nickel, Cd and Pb were not detected. While, inlet slaughterhouse wastewater contained Iron (0.92), Cu (0.03) while Cd, Pb & Zn are not detected (ND). In this respect the same authors recorded Iron by 0.92, Cu (0.03) while Cd, Pb, Zn were not detected in process water outlet**.** Iron is the only metal that exceeds the permissible limit (0.2 mg/L) which comply with our results as iron was the sole element exceeded the permissible limit (Table 2 and Fig. 1). Moreover, the authors added that fresh water used for animals drinking and slaughtered animals cleaning and sanitization shall be treated in a manner permit the removal of heavy metals prior and after use. They recommended using a proper mechanical screen, chemical coagulation flocculation process, or any approved method to remove the secondary sludge that containing heavy metals. Further studies should be carried out in order to propose a cost-effective treatment methods of slaughterhouse wastewater. This is incompliant with the vision of the work in the current study through using of electrocoagulation (Uni and Bi-polar) method for removing of heavy metals or reduces their levels to be compatible with the locally and internationally acceptable levels**.**

Abdel-Rahman (2022) found that high concentration level of Pb, Cd, Cu, Mn, Zn (36.6, 14.7, 65.7, 59.0, and 90.6) respectively, in irrigation water samples collected from the drain of Bahr El-Baqar in Egypt. This considered higher than the collected data in the present study. The elevated levels of contamination may be ascribed to the characteristics of the water, the nature of the industrial or agricultural operations, and the size of the sample utilized. In this regard, **Rozana *et al.* (2020)** could detect Cd with average concentration of 0.003 mg/L, Zn (0.026), Cu (0.024), Fe (0.006), and Mg (0.103 mg/L) in control samples. These results are nearly similar to the results of the current study for zinc, but higher for copper and cadmium and lower for iron and manganese. In this regard, **Ramchander *et al.* (2015)** stated that concentration of heavy metals is variable from one state to another, in general the average of heavy metals in wastewater collected from the four states between 0.03 – 0.05 ppm for pb, 0.003 – 0.004 for Cd, 1.8-2.01 for Cu, 0.4 – 0.5 for Fe and 2.9 – 3.8 for ZN. Such results indicated that mean heavy metal level is over the permissible limit of **WHO (2007).**

Heavy metals reduction levels

Bakry *et al.* (2024) revealed that the reduction percentages of lead were 100% for lead after 20 min, 98% for cadmium after 40 min, 100% for zinc after 40 min, 98% for manganese after 60 min, and 93% when using 5 mA/cm^2 at 20 min and Cu reduction reached to 100% at exposure time 40 and 60 min at CD = 15 mA/cm^2 and 25 mA/cm^2. The author concluded that as the voltage increase, the removal amount of heavy metal increase. This substantiates the CD used in the present study (CD= 27A/12A) as well as compliant with, **Kashi, 2023** (pH, 7 for 30 min) and **Akbal and Camci, 2010** [electrocoagulation for 30 min., pH (5-7)]. Also, the results for Zn and Cu are compliant with our results, while it is more or less assent with lead and Mn reduction rate as well as agreed with the results recorded by **Adhoum *et al.* (2004),** The contact time in the present study was 60 min. The findings suggested that the majority of heavy metal elimination occurred within the initial 25 minutes of the reaction. This is consistent with the results of **Adhoum *et al.* (2004); Bakry *et al.* (2024) and Merzouk *et al.* (2009).** Also, the present research data proved that the results for the degree of pH, removal time of heavy metal and the reduction rate are close to results of **Merzouk *et al.* (2009)** as he could remove heavy metal ions such including iron (Fe), nickel (Ni), copper (Cu), zinc (Zn), lead (Pb) and cadmium (Cd) with different initial concentrations in the range of 50–600 mg/L and pH between range (7.5 - 7.8). This in less than 15 min electrocoagulation–electroflotation process with removal rate reaches 95%.

CONCLUSION

The rapid development worldwide regarding the agriculture and industrial institution or factories including meat processing in slaughterhouse in addition to, the growth of population causes an emerging of many of environmental hazards as pollution of wastewater with heavy metals. The current study considered as a trial for using electrocoagulation technologies to mitigate such harmful heavy metals pollution in slaughterhouse wastewater to the acceptable limits that were determined by several bodies and organizations concerned with food safety which have a significant adverse impact on the aquatic surroundings as well as the human health and safety in addition to the economic aspects related to it. The electrocoagulation technologies are characterized by their sensible nature and also environmentally friendly, fast results and clear straight forward.

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