Tikrit Journal of Engineering Sciences (2024); 31(3): 258-265
DOI: http://doi.org/10.25130/tjes.31.3.24

IRAQI Academic Scientific Journals

ISSN: 1813-162X (Print); 2312-7589 (Online)
Tikrit Journal of Engineering Sciences
available online at: http://www.tj-es.com

TJES Tikrit Journal of Engineering Sciences

# Environmental Impact of Heavy Metals on Health in Soils Polluted with Medical Waste in Baiji City

**Khalid Ahmed Salih** *

*Environmental Department, Engineering College, Tikrit University, Tikrit, Iraq.*

***Keywords:***
*Incinerator; Management of medical waste; Poisonous metals; Waste pollution.*

***Highlights:***

- *This study was characterized by being one of the few or almost the first study of soils contaminated with medical waste in the city of Baiji in Iraq.*
- *The methods of determining toxic metals concentrations and the population survey showed an assessment of the presence of a high risk of soils to the environment.*
- *Both methods mentioned in determining the environmental risks of soils contaminated with medical waste gave credibility, accurate results, and high reliability.*

**ARTICLE INFO**

***Article history:***

| | | |
|---|---|---|
| Received | 24 July | 2023 |
| Received in revised form | 28 May | 2024 |
| Accepted | 19 July | 2024 |
| Final Proofreading | 19 Aug. | 2024 |
| Available online | 10 Sep. | 2024 |



**Citation:** Salih KA. **Environmental Impact of Heavy Metals on Health in Soils Polluted with Medical Waste in Baiji City**. *Tikrit Journal of Engineering Sciences* 2024; **31**(3): 258-265.
http://doi.org/10.25130/tjes.31.3.24

*Corresponding author:

**Khalid Ahmed Salih**
Environmental Department, Engineering College, Tikrit University, Tikrit, Iraq.

**Abstract**: Due to the environmental concerns of improper medical waste management inside and outside hospitals and health institutions, this issue is one of the most important environmental studies topics. Four places in Baiji City in Iraq were selected as study areas: Al-Hajjaj Health Center, Al-Boutama Health Center, Al-Zuwai Health Center, and Baiji General Hospital. This study investigates the environmental health risks of incineration treating hospital waste and health centers. According to the data obtained from practical and laboratory studies, Baiji General Hospital had the highest concentrations of the five toxic heavy metals tested, i.e., lead, cadmium, chromium, zinc, and nickel. These values peaked at 98.36, 59.54, 58.74, 79.52, and 13.32 mg/l for $Pb^{+2}$, $Cd^{+2}$, $Cr^{+3}$, $Ni^{+2}$, and $Zn^{+2}$, respectively. Exceeding the measured values of toxic metal elements within internationally permissible limits increases the concentration of these toxic metals, posing greater health risks to the population. This process appears clearly and significantly if medical waste is burned in random locations, producing toxic fumes and gases that can cause diseases dangerous to health when inhaled; therefore, there must be mechanisms and scientific management to control the combustion process in private health incinerators. The survey results showed that the indiscriminate burning of medical waste in surveyed areas leads to diseases and can pose a tangible and immediate threat to human life, such as high blood pressure, eye irritations, suffocation of patients with difficulty and shortness of breath, and asthma, especially the elderly and newborns. Original overshooting of the measured values of toxic metal elements within the internationally permissible limits can increase the concentration of these toxic metals, posing more significant health risks to the population.

# الأثر البيئي للمعادن الثقيلة على الصحة في الترب الملوثة بالنفايات الطبية في مدينة بيجي

**خالد احمد صالح**
قسم هندسة البيئة / كلية الهندسة / جامعة تكريت / تكريت – العراق.

**الخلاصة**

نظرا للمخاوف البيئية من الإدارة غير السليمة للنفايات الطبية داخل وخارج المستشفيات والمؤسسات الصحية، يعد هذا الموضوع أحد أهم موضوعات الدراسات البيئية. تم اختيار أربعة مواقع في مدينة بيجي في العراق كمناطق للدراسة: الموقع الأول مركز الحجاج الصحي، والموقع الثاني مركز البوطمة الصحي، والموقع الثالث مركز الاوية الصحي، والموقع الرابع مستشفى بيجي العام. تبحث هذه الدراسة في المخاطر الصحية البيئية المرتبطة بالحرق في معالجة نفايات المستشفيات والمراكز الصحية. وفقا للبيانات المقدمة التي تم الحصول عليها من الدراسة العملية والمخبرية، كان لدى مستشفى بيجي العام أعلى تركيزات من المعادن الثقيلة السامة الخمسة التي تم اختبارها (الرصاص والكادميوم والكروم والزنك والنيكل). بلغت هذه القيم ذروتها عند (٩٨,٣٦، ٥٩,٥٤، ٥٨,٧٤، ٧٩,٥٢ و١٣,٣٢ ملغم / لتر) للعناصر $Pb^{+2}$ و$Cd^{+2}$ و$Cr^{+3}$ و$Ni^{+2}$ و $Zn^{+2}$ على التوالي. ان تجاوز القيم المقاسة لعناصر المعادن السامة ضمن الحدود المسموح بها دوليًا يمكن أن يزيد من تركيز هذه المعادن السامة، مما يشكل مخاطر صحية أكبر على السكان. تظهر هذه العملية بوضوح وبشكل كبير إن حرق النفايات الطبية في أماكن عشوائية، يؤدي إلى أبخرة وغازات سامة يمكن أن تسبب أمراضًا خطرة على الصحة عند استنشاقها، لذلك يجب أن تكون هناك آليات وإدارة علمية للسيطرة على عملية الاحتراق في المحارق الصحية الخاصة. وتبين نتائج المسح أن الحرق العشوائي للنفايات الطبية في المناطق المشمولة بالمسح يؤدي إلى الإصابة بالأمراض ويمكن أن يشكل تهديدا ملموسًا وفوريًا لحياة البشر، مثل ارتفاع ضغط الدم، وتهيج العين، وخنق المرضى الذين يعانون من صعوبة وضيق في التنفس، خاصة لكبار السن والأطفال حديثي الولادة، يمكن أن يؤدي تجاوز القيم المقاسة لعناصر المعادن السامة في الحدود المسموح بها دوليا إلى زيادة تركيز هذه المعادن السامة، مما يشكل مخاطر صحية أكبر على السكان.

**الكلمات الدالة:** المعادن السامة، تلوث النفايات، ادارة النفايات الطبية، المحرقة.

## 1.INTRODUCTION

One of the essential things that health workers in most healthcare centers in Iraq overlook, which treat waste by incineration, is the process of random and unstudied disposal of ash resulting from burning the medical waste resulting from multiple activities in health centers, where ash waste is transported and emptied into containers. Then, these containers are transported and emptied in open areas to irregular sanitary dumps. Studies worldwide have shown the great danger that ash from burning medical waste can contain a high percentage of toxic heavy metals [1], which are the main threat to groundwater with the risk of contamination if disposed of by burying waste in inappropriate locations. Medical waste causes the transmission of some severe diseases, including multiple skin infections, polio at all levels, blood poisoning, respiratory infections, and severe viral hepatitis [2]. Christaldi [3] noted that the appearance of smoke in a dense manner containing the compound dioxin, the leading cause of cancerous diseases, as well as the toxic element cadmium and other compounds and elements, all of which resulted from burning waste in special incinerators resulting from hospitals and health centers; the waste contained plastics, contaminated cotton residues, and medical gauze resulting from medical treatment operations. Abbas et al. [4] analyzed hospital trash in Beirut, Lebanon, and found that medical waste combustion contributes to mercury pollution. Mercury minerals can harm the brain. Thus, the central nervous system could be affected, damaging the lungs, brain, and kidneys. Zhuang [5] focused on harmful elements in India and China from burning discarded electrical and electronic products, including lead, cadmium, mercury, and beryllium. Compared to distant populations, those living near medical and plastic waste incinerators had high tissue dioxin levels. The researchers also detected high mercury levels in the hair of those living near incinerators. Due to frequent exposure to medical waste ashes, personnel in incinerators, whether new or old, had high levels of dioxin chemicals in their tissues. Al Nakkash et al. [6] discovered that waste incinerator ash from Basra City hospitals in Iraq included hazardous chemicals. According to the authors, these hazards endanger the ecosystem. The study recommended chemical degradation before combustion and disposal in a well-planned and regulated sanitary landfill to safely dispose of rubbish. Stallkamp et al. [7] reported that burning hospital waste in Egypt released gasoline, toxic metals like tin, chromium, and other small particles that can enter the respiratory system and damage the immune, nervous, liver, and genitals. Ali et al. [8] suggested in their study in Al-Hila Teaching Hospital-Babylon Province, Iraq, that isolating medical trash in an indicator container and not mixing it before burning. The researchers explained that ash and water from burning medical waste must be disposed of safely to avoid harming the environment and groundwater. Ibrahim and Salih [9] showed that producing electrical energy from solid waste in Tikrit City generates large quantities annually from municipal solid waste and can be mixed with hospital waste. There is no safe way to dispose of it. Bolan et al. [10] showed that medical waste is infectious, toxic, radioactive, and contains heavy metals. Arsenic, cadmium, lead, and mercury are associated with Hepatitis C syndrome. Padmanabhan and Barik [11] reported that hospitals, clinics, and diagnostic and treatment centers produced hazardous waste that can cause life-threatening infections.

Okoro et al. [12] suggested a systematic strategy for improving pharmaceutical waste management regulations and techniques. Protecting public health and the environment requires thorough research into the environmental evaluation and promotion of carcinogenic chemicals, including hazardous agents and minerals. Reducing potentially dangerous pollutants in terrestrial and aquatic ecosystems is essential to protect animals and consumers. Su et al. [13] noticed that hospitals, clinics, and other healthcare facilities generated a significant quantity of dangerous medical waste, which, if not managed properly, poses a significant risk to public health and environmental sustainability. Tufail and Sofia [14] conducted a study in the hospitals of Islamabad, Pakistan. They utilized a flame atomic absorption spectrometer (FAAS) to determine the concentrations of $CD^{+2}$, $Cr^{+3}$, $Cu^{+2}$, $Pb^{+2}$, and $Zn^{+2}$. The study concentrated on the potential health and environmental hazards that these substances can pose to the environment if they are not handled and disposed of correctly. Zaynab et al. [15] elucidated the effects of toxic heavy metals and the consequent health hazards they pose to human beings. Niyongabo et al. [16] found that the possible carcinogenic health hazards associated with toxic metals for adults were below an acceptable range. However, there was a likelihood of high cancer risk in children. In general, the importance and the main objective of the study is to determine the environmental risks that the medical waste generated in hospitals and health centers through the knowledge of the concentrations of the elements of toxic minerals in them, which, if they exceed the limits permitted globally, this can lead to health risks for workers, residents, and the environment in general. In addition, the toxic minerals are a medical waste issue and the productivity that produced it for the first time in these areas.

## 2.MATERIALS AND METHODS

### *2.1.Study Area*

The field study was in Bajji City, Saladin Governorate, Iraq. Baiji City is in the center of Iraq and north of Baghdad, approximately 210 km. The study area included selecting four different sites in Baiji City: the General Hospital, the Health Care Center in the Al-Hajjaj area, the Health Care Center in the Al-Boutama area, and the Health Care Center in the Al-Zuwai area. Figure 1 shows the locations of the studied sites.

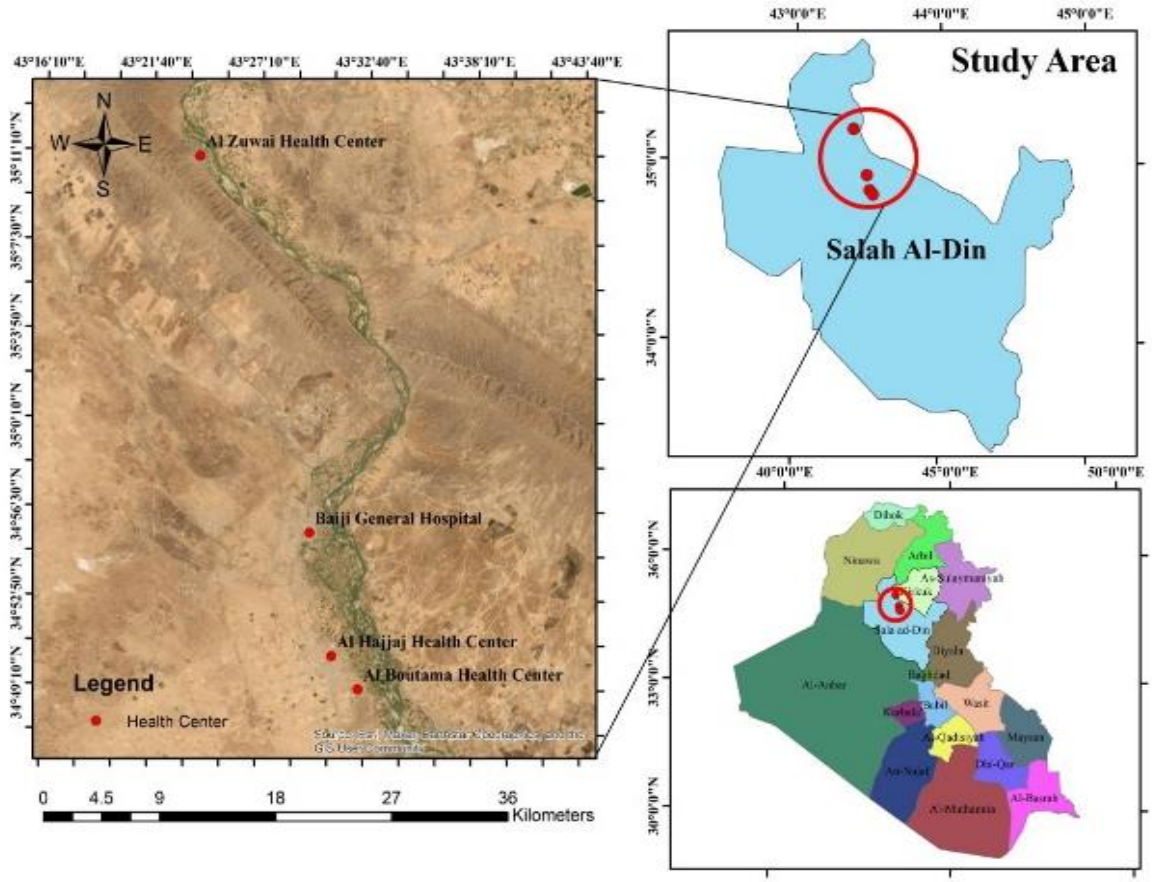



**Fig. 1** Iraqi Map Including Baiji City.

### *2.2.Fieldwork*

There are two primary stages to the process the work:

First Stage: At this stage, a critical questionnaire was conducted for the population who live in individual houses or form clusters in residential neighborhoods very close to the four study areas. The primary purpose of the questionnaire was to know the extent to which the population is affected by the continuous burning of medical waste to determine the area to which they are affected by the process of burning waste conducted at study sites, and undoubtedly toxic fumes and gases, and whether the population is affected by these pollutants and what results from that, especially if the burning is in a manner that does not comply with global health safety requirements. Health waste can be expressed as medical waste for all medical activities, including garbage from medical laboratories, debris from hospital health activities, medical pharmacies, and forensic activities [17, 18]. The questionnaire included fieldwork by conducting a field survey of the population in residential neighborhoods in studied areas, especially near health sites. The questionnaire forms were randomly distributed to the people. The questionnaire's primary purpose is to determine whether incinerators are for incineration of medical waste. Table 1 shows all sites details in which the survey was conducted in Baiji City. Table 2 contains a sample questionnaire form.

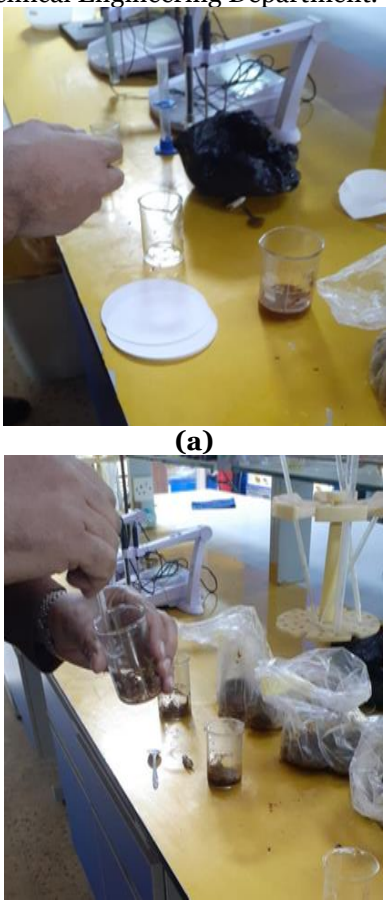
**Table 1** Details of Sites in which the Survey was Conducted in Baiji City.

| Site No. | Site name |
|---|---|
| The First site | Baiji General Hospital |
| The second site | Al-Hajjaj Health Center |
| Third site | Al-Boutama Health Center |
| Fourth site | Al-Zuwai Health Center |

**Table 2** Questionnaire Form.

| Questionnaire No. ( ) | |
|---|---|
| 1. Is burning medical waste densely accompanied by gases and fumes? | ( ) Yes, ( ) No |
| 2. Does burning medical waste significantly cause significant discomfort to the population? | ( ) Yes, ( ) No |
| 3. Are people worried about inhaling gases and fumes from burning medical waste? | ( ) Yes, ( ) No |
| 4. Has burning medical waste caused any diseases among the population? | ( ) Yes, ( ) No |

Analyzing and examining the samples obtained for the questionnaire process in the first stage, which included direct and sensitive questions for the population living in neighborhoods very close to the selected study sites, a standard deviation of 1.7 was obtained. This value is considered a reasonable degree of reliability of questionnaire models in statistical analysis through the presence of little dispersion, and it became clear after checking that the burning process occurs every three days and can be every four days in some study sites. A photo of a sample selected of ash taken before analysis is shown in Fig. 2 (a). On the other hand, Fig. 2 (b) depicts the procedure for digesting and analyzing research samples from ash in the analytical chemistry lab at Tikrit University in the Chemical Engineering Department.



**(a)**

**(b)**

**Fig. 2** (a) Photograph of the Digestion and Dissolution of Ash Samples. (b) Photograph of Ashes Being Broken Down and Dissolved in a Laboratory.

Minerals $Zn^{+2}$, $Pb^{+2}$, $Cd^{+2}$, $Cr^{+3}$, and $Ni^{+2}$ were measured by an atomic flame adsorbent (AAS). Five samples were identified for each study site, and the analysis was conducted for all these samples from all study sites. The results of the five minerals measured will be presented in the discussion section, and the results are detailed and obtained from the analysis of ash samples. Table 3 shows the global limits for permissible concentrations of lead, Cadmium, Chromium, Zink, and Nickel (mg/L).

**Table 3** Concentrations of Permissible Limits for Minerals Identified in the Study [19, 20].

| Metal | Permissible Limit (mg /l) |
|---|---|
| lead | 10 |
| Cadmium | 0.06 |
| Chromium | 5 |
| Nickel | 40 |
| Zinc | 50 |

### *2.3.Experimental Work*

Ash samples were collected from waste incinerators at Baiji General Hospital, Al-Hajjaj Healthcare Center, Al-Boutama Healthcare

Center, and Al-Zuwaia Health Care Center. The tests were conducted in the Analytical Chemistry Laboratory in the chemical engineering department of Tikrit University, based on the standard methods adopted in Standard Methods WPCF [21, 22] and as follows:

- Digestion and dissolution of ash samples: This test was conducted using nitric acid, a ceramic spoon, an electron microbalance of 0.002 mg, a burning furnace at a temperature of up to 40, filter paper No. 40, and distilled water.
- Examination of the mineral concentrations of Zink($Zn^{+2}$), lead ($Pp^{+2}$), Chromium ($Cr^{+3}$), Cadmium ($Cd^{+2}$), and Nickel ($Ni^{+2}$), tested using a flame atomic absorber, AA-6200.

## 3.RESULTS AND DISCUSSION

### *3.1.The Results of the First Stage*

Analyzing and examining the samples obtained for the questionnaire process in the first stage included direct and sensitive questions for the population living in neighborhoods very close to the selected study sites. A standard deviation of 1.7 was obtained, considered a reasonable reliability of questionnaire models in statistical analysis due to little dispersion. It became clear after checking that the burning occurred in some studied sites every three or four days. Figure 3 shows that most of the population that participated in the survey process answered very much in the affirmative of the questionnaire questions and with the word yes, i.e., 98.7% in the health center in Al-Hajjaj, 99.2% in the health center in Al-Boutama, 98.6% in the center Health in Al-Zuwai, and 96.1% in Baiji General Hospital. The very high values of yes indicate the population's dissatisfaction with burning medical waste. Also, the evaluation of the population living near the areas of burning medical waste clearly indicates the severe health damage that asthma can cause to elderly people and young infants. In addition, the uncontrolled random burning operations cause toxic gases and fumes emissions that can lead to death. Their amount was high. The diseases caused by toxic gases and vapors are pressure disease, eye ash, asthma, and shortness of breath. The real risks resulting from poisonous gases and vapors from burning medical waste are being burned randomly in open ground and uncontrolled. Furthermore, medical waste was not isolated from food waste and other types of debris, so the waste was untreated by any process before burning, leading to more significant and dangerous risks than the risks of inhaling medical waste containing a quantity of plastic that can result in inhalation of dioxin gas, which is the leading and most important cause of direct cancer diseases, and here lies the greatest danger in this issue. The incinerator in Baiji General Hospital is significantly damaged and abandoned and has not been used for a long time, as its filter has been substantially damaged and has not been replaced or repaired. As for the health centers in Al-Hajjaj, Al-Boutama, and Al-Zuwai, burning waste was irregular, random, and in open land. No incinerator is dedicated to burning medical waste indicating the population's dissatisfaction with the process of burning medical waste.

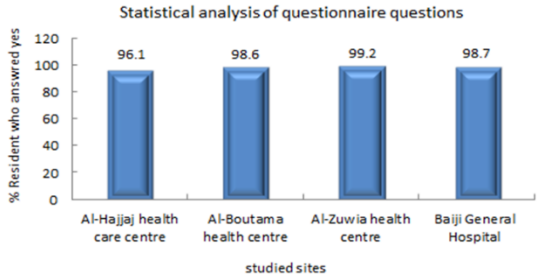



**Fig. 3** Statistical Analysis of Questionnaire Questions by the Population in Neighborhoods in the Studied Sites.

### *3.2.The Results of the Second Stage*

The AA-6200 atomic absorption flame emission spectrophotometer device was used to analyze (25) ash samples and (5) ash samples at four study sites. Tables 4- 7 show the results of all studied sites. To increase the clarity and importance of results, all values listed in the tables represent the average of every three values. Table 4 shows the laboratory analysis results of ash samples from Baiji General Hospital. The $Pb^{+2}$ concentrations were between 48.38 mg/l and 79.52 mg/l for the five studied ash samples. For cadmium $Cd^{+2}$, the concentrations were between (9.15 mg/l and 13.82 mg/l. The $Cr^{+3}$ concentrations were between 44.28 mg/l and 58.47 mg/l. The zinc $Zn^{+2}$ concentrations were between 42.45 mg/l and 59.54 mg/l. The nickel $Ni^{+2}$ concentrations were between 89.4 mg/l and 98.0 mg/l. By comparing these values with the globally permissible values, it is clear that the measured values of the five heavy metal elements $Pb^{+2}$, $Cd^{+2}$, $Cr^{+3}$, $Zn^{+2}$, and $Ni^{+2}$ obtained for Baiji General Hospital exceeded the globally defined values of 10 mg/l for lead $Pb^{+2}$, 0.06 mg/l cadmium cd+2, 5 mg/l chromium Cr+3, 50 mg/l zinc $Zn^{+2}$, and 40 mg/l nickel $Ni^{+2}$. Table 5 tabulates the laboratory analysis of the ash samples from the health center in Al-Hajjaj. The results for the five studied ash samples were as follows: the $Pb^{+2}$ concentrations ranged between (23.17 mg/l and 41.52 mg/l), the Cd concentrations ranged between (1.14 mg/l and 5.62 mg/l), the $Cr^{+3}$ concentrations ranged between (24.11 mg/l and 37.65 mg/l, the zinc $Zn^{+2}$ concentrations ranged between ( 22.20 mg/l and 31.86 mg/l), and the nickel $Ni^{+2}$ concentrations ranged between (72.83 mg/l and 81.61 mg/l). The measured data for the

health facility in Al-Hajjaj showed that all five heavy metal elements, $Pb^{+2}$, $Cd^{+2}$, $Cr^{+3}$, $Zn^{+2}$, and $Ni^{+2}$, were over internationally recognized levels. Table 6 tabulates the results of the lab tests on the samples of ash from the health center in Al-Boutama. For the five ash samples studied, it was found that the $Pb^{+2}$ concentrations were between (30.25 mg/l and 74.81 mg/l), the Cd concentrations were between (4.11 mg/l and 7.87 mg/l), the $Cr^{+3}$ concentrations were between ( 19.26 mg/l and 27.92 mg/l), the $Zn^{+2}$ zinc concentrations were between (19.54 mg/l and 30.81 mg/l), and the nickel $Ni^{+2}$ concentrations were between (77.76mg/l and 81.42 mg/l). The measured values of the five heavy metal elements $Pb^{+2}$, $Cd^{+2}$, $Cr^{+3}$, $Zn^{+2}$, and $Ni^{+2}$ obtained from the health center in Al-Boutama exceeded the internationally defined values. Table 7 tabulates the laboratory analysis results of the five ash samples for the health center in Al-Zuwai. The $Pb^{+2}$concentrations were between (42.71 mg/l and 63.72 mg/l), the Cadmium $Cd^{+2}$ concentrations were between (10.69 mg/l and 713.32 mg/l, the chromium $Cr^{+3}$ concentrations were between (22.78 mg/l and 35.32 mg/l), the zinc $Zn^{+2}$ concentrations were between (24.35 mg/l and 30.81 mg/l), and the nickel $Ni^{+2}$ concentrations were between 67.49 mg/l and 84.35 mg/l). The measured values of the five toxic metals elements Cadmium, Chromium, lead, Zinc, and Nickel in the Al-Zuwai health center exceeded the universally defined standards.

**Table 4** Results of Laboratory Analysis of Ash Samples for Baiji General Hospital.

| The Element Concentration (mg/l) | The First Sample | The Second Sample | The Third Sample | The Fourth Sample | The Fifth Sample |
|---|---|---|---|---|---|
| lead | 79.52 | 61.90 | 48.38 | 60.35 | 70.21 |
| Cadmium | 9.15 | 10.28 | 11.64 | 12.73 | 13.82 |
| Chromium | 56.37 | 47.30 | 58.74 | 48.83 | 44.28 |
| Nickel | 42.45 | 45.73 | 59.54 | 50.13 | 47.50 |
| Zinc | 98.36 | 96.48 | 89.4 | 92.49 | 89.54 |

**Table 5** Results of Laboratory Analysis of Al-Hajjaj Health Care Center Ash Samples.

| The Element Concentration (mg/ l) | The First Sample | The Second Sample | The Third Sample | The Fourth Sample | The Fifth Sample |
|---|---|---|---|---|---|
| lead | 39.61 | 28.23 | 35.51 | 41.52 | 23.17 |
| Cadmium | 3.31 | 4.81 | 2.77 | 1.14 | 5.62 |
| Chromium | 33.43 | 28.34 | 24.11 | 37.65 | 26.21 |
| Zinc | 28.27 | 23.83 | 30.20 | 31.86 | 22.20 |
| Nickel | 72.83 | 77.76 | 80.61 | 81.61 | 78.36 |

**Table 6** The Laboratory Analysis Results of Ash Samples for Al-Boutama Health Care Center.

| The Element Concentration (mg/ l) | The First Sample | The Second Sample | The Third Sample | The Fourth Sample | The Fifth Sample |
|---|---|---|---|---|---|
| lead | 35.31 | 30.25 | 55.72 | 74.81 | 48.43 |
| Cadmium | 7.21 | 6.53 | 4.11 | 4.69 | 7.87 |
| Chromium | 25.54 | 27.92 | 19.26 | 27.14 | 23.61 |
| Zinc | 23.53 | 21.11 | 30.81 | 19.54 | 26.27 |
| Nickel | 77.76 | 80.34 | 79.55 | 80.49 | 81.42 |

**Table 7** The Laboratory Analysis Results of Ash Samples for Al-Zuwai Health Care Center.

| The Element Concentration ( mg / l) | The First Sample | The Second Sample | The Third Sample | The Fourth Sample | The Fifth Sample |
|---|---|---|---|---|---|
| Lead | 42.71 | 44.13 | 63.72 | 58.11 | 53.13 |
| Cadmium | 13.32 | 11.53 | 11.11 | 10.69 | 12.87 |
| Chromium | 31.54 | 23.71 | 35.32 | 22.78 | 18.35 |
| Zinc | 25.14 | 27.42 | 29.76 | 24.35 | 30.81 |
| Nickel | 83.65 | 71.50 | 67.49 | 84.35 | 69.76 |

Figures 4 - 7 show the highest values obtained for study sites at Al-Hajjaj, Al-Boutama, and Al-Zuwai Health Care Centers and Baiji General Hospital. Upon reviewing the above forms, it can be inferred that Baiji General Hospital exhibited the most significant concentrations of the five hazardous heavy metals analyzed, lead, cadmium, chromium, zinc, and nickel, across all four research locations. Figure 7 shows the highest concentrations, i.e., (98.36, 59. 54, 58.74, 13.32, and 79.52 mg/l) for elements lead, cadmium, chromium, zinc, and nickel, respectively. The highest values were concentrated in Baiji General Hospital due to the medical waste in abundance and diversity in addition to its large quantities compared to the rest of the study sites. The concentrations in Baiji General Hospital exceeded the globally allowable limits. As a result, the population encounters more significant health risks, especially if the medical waste is burned in the wild and random places, generating toxic fumes and gases. When people inhale these fumes and gases, they face severe diseases, including pressure, eye redness, shortness of breath, and asthma. The most dangerous issue is the inhalation of gases and vapors of plastic medical waste, which is the main reason for cancer. Also, some toxic gases can lead to death [23-25].

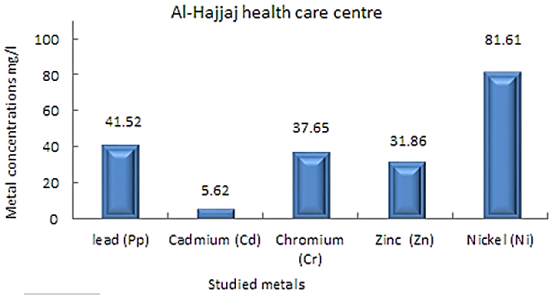



**Fig. 4** Metal Concentrations Studied in Al-Hajjaj Health Care Center.

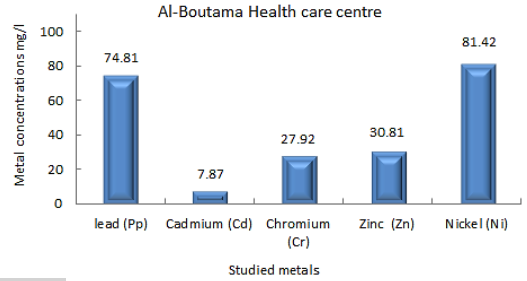



**Fig. 5** Metal Concentrations Studied in the Al-Boutama Health Care Center.

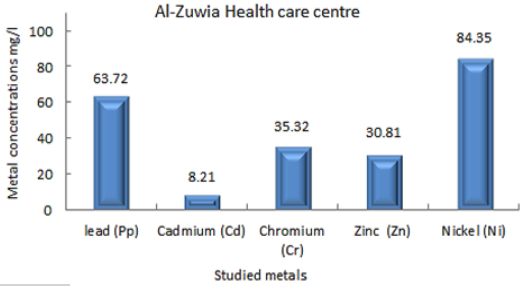



**Fig. 6** Metal Concentrations Studied in the Al-Zuwai Health Care Center.

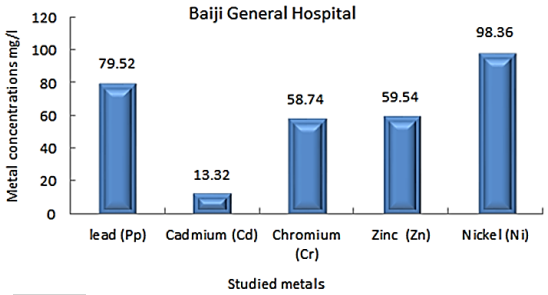



**Fig. 7** Metal Concentrations Studied in Baiji General Hospital.

## 4.CONCLUSIONS

The following are the key drawn conclusions:

- In all studied sites, the ash from burning medical waste contained heavy and toxic metals, namely $Pb^{+2}$, $Cd^{+2}$, $Cr^{+3}$, $Zn^{+2}$, and $Ni^{+2}$. The highest values of the five measured harmful heavy metal elements $Pb^{+2}$, $Cd^{+2}$, $Cr^{+3}$, $Zn^{+2}$ and $Ni^{+2}$ for the four study sites were at Baiji General Hospital, i.e., (98.36, 59. 54, 58.74, 13.32, and 79.52 mg/l ) for $Pb^{+2}$, $Cd^{+2}$, $Cr^{+3}$, $Zn^{+2}$, and $Ni^{+2}$, respectively. These high values were concentrated in Baiji General Hospital due to the abundance, diversity, and large quantities of medical waste compared to the rest of the study sites. These values exceeded the globally allowable limits.
- The questionnaire results in this study demonstrated that the haphazard burning of medical waste in the study areas caused disease and may pose an immediate risk of death, including cases of patients suffering from asthma and shortness of breath, particularly among the elderly and newborns. As a result, there must be scientific controls to regulate the combustion process in private health incinerators.
- According to the questionnaire survey, the standard deviation value was (1.7 out of 10), which is a minimum value that indicates the reliability of the questionnaire process conducted and the success of the process with very little dispersion.
- It can be concluded that the conditions and procedures for sound management following universal health conditions were unavailable when dealing with medical waste in studied sites.
- It is important to expand the field of research by selecting other new elements of pollutants for study in the same areas.

## ACKNOWLEDGEMENTS

The author would like to thank the Department of Environmental Engineering and the Department of Chemical Engineering, Faculty of Engineering, Tikrit University.

## NOMENCLATURE

| | |
|---|---|
| $Zn^{+2}$ | Zinc |
| $Pp^{+2}$ | lead |
| $Cr^{+3}$ | Chromium |
| $Cd^{+2}$ | Cadmium |
| Ni | Nickel |
| mg/l | milligram/liter |
| WPCF | Water Pollution Control Federation |

## REFERENCES

**[1]** Khan HA, Alshukri AS. **Evaluation of Environmental and Health Risks Related with the Management of Medical Waste in AlNajaf City.** *Journal of Engineering Science and Technology* 2020 ;**15**(6): 4383-4391.

**[2]** Matin HH,Purwono P, Alfajrin AC, Inaku, AH. **Solid Medical Waste Management of Hazardous and Toxic at UNS Hospital Surakarta**. *Jurnal Presipitasi: Media Komunikasi Dan Pengembangan Teknik Lingkungan* 2022; **19**(2): 398-407.

**[3]** Christaldi RA. **Dying from Dioxin: A Citizen's Guide to Reclaiming Our Health and Rebuilding Democracy**: **Book Reivew**. *JSTOR* 1996; **11**(2):467-472.

**[4]** Abbas II, Chaaban JK, Al-Rabaa AR, Shaar AA. **Solid Waste Management in Lebanon: Challenges and recommendations**. *Journal of Environment and Waste Management* 2017; **4**(2): 53-63.

**[5]** Zhuang X. **Chemical Hazards Associated with Treatment of Waste Electrical and Electronic Equipment**. In: Prasad MNV, Vithanage M. (Eds), Electronic Waste Management and Treatment Technology. Oxford, United Kingdom: Butterworth-Heinemann; 2019.

**[6]** Al-nakkash IA, Al-hiyaly SA, Faraj BH, Kasim SA. **Assessment of Health Care Waste Management (HCWM) in Iraq, Effects and Control.** *International Journal of Innovative Science and Research Technology* 2019; **4**(5):861-864.

**[7]** Stallkamp C, Hennig M, Volk R, Richter F, Bergfeldt B, Tavakkol S, Stapf D. **Economic and Environmental Assessment of Automotive Plastic Waste End-of-Life Options: Energy Recovery Versus Chemical Recycling**. *Journal of Industrial Ecology* 2023; **27**(5): 1319-1334.

**[8]** Ali ZH, Al-Hiyaly SA, Rashid GY. **Environmental Impact Assessment of Medical Wastes Shredding Machine in Al-Hila Teaching Hospital-Babylon Province, IRAQ**. *Indian Journal of Public Health Research & Development* 2019; **10**(6):88-92.

**[9]** Ibrahem MM, Salih KA. **Using Solid Wastes of Tikrit City to Produce Electric Energy**. *Modern Environmental Science and Engineering* 2015; **1**: 39-48.

**[10]** Bolan S, Padhye LP, Kumar M, Antoniadis V, Sridharan S, Tang Y, Bolan N. **Review on Distribution, Fate, and Management of Potentially Toxic Elements in Incinerated Medical Wastes.** *Environmental Pollution* 2023; **321**: 121080.

**[11]** Padmanabhan KK, Barik D. **Health Hazards of Medical Waste and its Disposal.** In: Barik D. Energy from Toxic Organic Waste for Heat and Power Generation. Sawston, United Kingdom: Woodhead Publishing; 2019.

**[12]** Okoro HK, Orosun MM, Oriade FA, Momoh-Salami TM, Ogunkunle CO, Adeniyi AG, Ngila JC. **Potentially Toxic Elements in Pharmaceutical Industrial Effluents**: **A Review on Risk Assessment, Treatment, and Management for Human Health**. *Sustainability* 2023; **15**(8): 6974.

**[13]** Su G, Ong HC, Ibrahim S, Fattah IR, Mofijur M, Chong CT. **Valorisation of Medical Waste Through Pyrolysis for a Cleaner Environment**. *Environmental Pollution* 2021; **279**(2): 116934.

**[14]** Tufail M, Sofia K. **Heavy Metal Pollution from Medical Waste Incineration at Islamabad and Rawalpindi, Pakistan**. *Microchemical Journal* 2008; **90**(1): 77-81.

**[15]** Zaynab M, Al-Yahyai R, Ameen A, Sharif Y, Ali L, Fatima M, Khan K, Li S. **Health and Environmental Effects of Heavy Metals**. *Journal of King Saud University-Science* 2022; **34**(1): 101653.

**[16]** Niyongabo E, Jang YC, Kang D, Sung K. **Generation, Management Practices and Rapid Risk Assessment of Solid Medical Wastes**. A case study in Burundi. *Journal of Material Cycles and Waste Management* 2019; **21**: 950-961.

**[17]** Soltani G, Somayeh MG, Morteza G, Gheysouri M. **Pollution, Human Health Risk Assessment and Spatial Distribution of Toxic Metals in Urban Soil of Yazd City, Iran.** *Environmental Geochemistry and Health* 2021; **43**(9): 3469-3484.

**[18]** Wisner B, John A. **Environmental Health in Emergencies and Disasters**. WHO: Geneva; 2002: p.1-272.

**[19]** Sadiq M. **Arsenic Chemistry in Soils: An Overview of Thermodynamic Predictions and Field Observations**. *Water, Air, and Soil Pollution* 1997; **93**: 117-136.

**[20]** Mwewa B, Stopic S, Ndlovu S, Simate GS, Xakalashe B, Friedrich B. **Synthesis of Poly-Alumino-Ferric Sulphate Coagulant from Acid Mine Drainage by Precipitation**. *Metals* 2019; **9**(11): 1166.

**[21]** Abbawi SA, Hassan MS. **Environmental Practical Engineering Water testing**. Mosul University, In Arabic; 1990.

**[22]** Ali SK, Jasim DT. **Assessment of Medical Solid Waste Generation Rates for Teaching Hospitals in Baghdad City**. *Association of Arab Universities Journal of Engineering Sciences* 2018; **25**(1): 160-169.

**[23]** Salih KA. **Environmental Risks Study of Toxic Metals Contamination for Medical Wastes.** *3rd International Conference for Civil Engineering Science (ICCES 2023);* AdDiwaniyah, Iraq: 2023.

**[24]** Tsakona M, Anagnostopoulou E, Gidarakos E. **Hospital Waste Management and Toxicity Evaluation: A Case Study**. *Waste Management* 2007; **27**(7): 912-920.

**[25]** Shen W, Zhu N, Xi Y, Huang J, Li F, Wu P, Dang Z. **Effects of Medical Waste Incineration Fly Ash on the Promotion of Heavy Metal Chlorination Volatilization from Incineration Residues**. *Journal of Hazardous Materials* 2022; **425**: 128037.