International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(10): 569-573
www.biochemjournal.com
Received: 10-08-2025
Accepted: 11-09-2025

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The effect of higher levels of heavy metals on the increasing incidence of gastrointestinal cancer

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i10h.6123

Abstract
Water is vital for life; nevertheless, industrial operations and the overuse of pesticides and fertilizers have resulted in considerable pollution, which contributes to various health problems, including cancer. This study investigated the impact of heavy metal pollution of the Kufa River on gastrointestinal cancer during the period from 2019 to 2021. The concentrations of heavy metals (lead and cadmium) were obtained from published research, where water samples from the Kufa River were digested with nitric acid and hydrogen peroxide and analyzed using an Atomic Absorption Spectrometer (AAS) at two stations: near the Kufa Bridge and the second station in the Al-Barakiya area, Al-Issa Bridge. The number of people with gastrointestinal cancer was obtained from the Najaf Health Department.
Preliminary epidemiological findings revealed an increase in GI cancer incidence, particularly peaking in 2021, which coincided with elevated levels of Pb and Cd in the river water. Statistical analysis demonstrated a strong positive correlation between the concentrations of these heavy metals and cancer incidence, highlighting the urgent need for environmental monitoring and effective pollution-control strategies to mitigate public health risks.

Keywords: Water pollution, heavy metals, lead, cadmium, gastrointestinal cancer, Kufa River

1. Introduction
Gastrointestinal (GI) malignancies, mainly including tumors of the esophagus, stomach, and colon/rectum, are among the highly prevalent cancers in humans [1, 2]. There is a global trend of a steadily growing occurrence of gastrointestinal (GI) cancers with diverse epidemiological factors and genomic and epigenomic alterations, making them one of the most frequent cancers globally with typically poor survival rates. Despite various standard treatments, such as chemotherapy, radiotherapy, and surgical approaches, patients with advanced-stage disease present a dismal prognosis [3, 4]. The outcomes of GICs are still disappointing since they often develop asymptomatically and are frequently detected at late [5, 6]. Esophageal cancer is responsible for approximately 509,000 deaths annually, making it the sixth leading cause of cancer-related mortality. It is also the seventh most common cancer, with an estimated 572,000 new cases reported each year [7, 10]. Similarly, stomach cancer remains a major global health concern, with over 1 million new cases diagnosed in 2018. This type of cancer ranks as the fifth most frequently diagnosed and accounts for around 783,000 deaths worldwide. Most of these diseases are linked to a combination of nutritional, environmental, physiological, and genetic factors [9, 10]. Heavy metals, such as lead, cadmium, and mercury, are chemical elements characterized by high atomic weight and density. These metals are hazardous environmental pollutants found in water, air, soil, and food, which makes monitoring their levels in the food chain crucial [11, 12]. While elements like copper, nickel, and zinc are essential micronutrients in small amounts, they can become toxic when present in excess [13]. Cadmium, lead, arsenic, and mercury, in particular, are toxic to both plants and animals. These metals accumulate in plant tissues and enter the food chain, eventually reaching humans and posing serious health risks [14, 15]. Additionally, specific interactions between certain elements and biochemical imbalances contribute to their development. Research suggests that up to 80% of cancer cases are influenced by environmental factors. In this regard, trace elements and heavy metals are considered significant contributors to the environmental risks associated with cancer [16]. Lead (Pb) is a heavy metal known for its distinctive chemical properties, including exceptional resistance to

corrosion, a low melting point, softness, high density, and relatively low electrical conductivity. These characteristics have made lead a versatile material, utilized extensively across various industries throughout history [17]. Today, lead remains in widespread use in different chemical forms, such as lead dioxide and alloys, finding applications in the production of storage batteries, radiators, cable sheathing for communication and power systems, as well as in dyes and ammunition manufacturing [18].

2. Materials and Methods

This study was conducted to evaluate the effect of concentrations of some heavy metals (lead Pb, cadmium Cd, and zinc Zn) in the water of the Kufa River and their relationship to the increased incidence of gastrointestinal cancers in Najaf Governorate during the period from 2019 to 2021. The study relied on data published in two previous scientific studies, Focusing exclusively on two locations on the river, namely the Kufa Bridge and the Al-Barakiya area (Al-Isa Bridge), as they represent populated areas close to agricultural and industrial activities.

In the first study (Tweij, 2019) [19], water samples were collected from five sites on the Kufa River, but the current study was limited to data from the two sites mentioned. The samples were collected in sterile 1-liter plastic containers and subjected to chemical digestion using concentrated nitric acid (HNO3) and hydrogen peroxide (H2O2 30%). Hydrogen (H2O2 30%). The samples were then evaporated in a water bath until the digestion process was complete. After cooling, they were treated with deionized water, filtered to remove precipitates, and made up to 100 ml. The concentration of heavy metals (Pb, Cd, Zn) was measured using an Atomic Absorption Spectrophotometer (AAS).

As for the second study (Kamel *et al.*, 2022) [20], it included collecting samples from six sites on the Euphrates River during the period from July 2020 to January 2021 using sterile 1-liter plastic bottles, to which 1 ml of diluted nitric acid (1:1) was added for preservation purposes. Similarly, this study was limited to data from the Kufa Bridge and Al-Barakiya/Al-Isa sites. Analysis was conducted using an atomic absorption spectrometer (AAS, SHIMADZU, Japan) to estimate the concentrations of lead, cadmium, and zinc. This data provided a more up-to-date picture of pollution levels in the river, enabling comparison with the results of the initial study to assess the continuity of pollution over time.

Epidemiological data were obtained from the Najaf Health Department, where statistics on gastrointestinal cancer cases were collected for the years (2019-2021), including the number of cases recorded annually, in addition to some demographic characteristics (age and gender), for the purpose of comparison with the levels of heavy metals measured in river water at the two study sites.

The data were statistically analyzed using Excel, where correlation coefficients were calculated between lead, cadmium, and zinc concentrations and incidence rates of gastrointestinal cancers, with a statistical significance level of ($p \leq 0.05$).

This study adhered to approved ethical standards by ensuring the confidentiality of patient data and obtaining approval from relevant local authorities. This methodology provides an important scientific basis for understanding the environmental impacts of heavy metal pollution on public health in the region and supports the development of effective strategies to mitigate risks.

3. Results

The original values of heavy metal concentrations (Pb, Cd, and Zn) were collected at the two study sites during the years (2019-2021), in addition to the number of digestive cancer cases recorded in Najaf Governorate for each year. These data were used as the basis for conducting statistical analyses, as shown in Table (1).

Table 1: Raw data

Year	Sit1 Pb	Sit2 Pb	Sit1 Cd	Sit2 Cd	Sit1 Zn	Sit2 Zn	Cancer
2019	0.093	0.00355	0.00355	0.0036	0.292	0.29275	80
2020	0.142967	0.242	0.012033	0.008967	0.741	0.968333	119
2021	0.108967	0.199833	0.011133	0.005733	0.920567	1.081067	109

Statistical analysis showed a clear variation in metal concentrations between the two studied sites. Table (2) shows the descriptive statistics (mean, standard deviation, median, variance, and coefficient of variation) for lead, cadmium, and zinc in both sites. The results showed that the average concentration of lead (Pb) in the second site (0.148 mg/L) was higher than the first site (0.115 mg/L), while cadmium (Cd) was relatively higher in the first site (0.0089 mg/L) compared to the second site (0.0061 mg/L). Zinc (Zn) recorded the highest concentrations among the metals in both sites, with an average of (0.651 mg/L) in the first site and (0.781 mg/L) in the second site.

Table 2: Descriptive statistics of minerals.Note: The statistical power of this analysis is limited by the small sample size (n = 3 years). The results show strong correlational trends that warrant further investigation with longer-term data

Variable	Mean mg/l	SD	Median	Variance	CV %	Correlation (r)	p-value
Sit1 Pb	0.114978	0.020837	0.108967	0.000434	18.12	0.887173	0.305332
Sit2 Pb	0.148461	0.103904	0.199833	0.010796	69.99	0.99656	0.052816
Sit1 Cd	0.008905	0.003805	0.011133	0.000014	42.72	0.988366	0.097202
Sit2 Cd	0.0061	0.002206	0.005733	0.000005	36.17	0.924117	0.249605
Sit1 Zn	0.651189	0.264353	0.741	0.069882	40.6	0.862603	0.337666
Sit2 Zn	0.780717	0.3481	0.968333	0.121174	44.59	0.927917	0.243196

From a health perspective, data from the Najaf Health Department showed a gradual increase in digestive cancer cases during the study period, as the number of cases reached (80 cases) in 2019, rose to (119 cases) in 2020, and then decreased slightly to (109 cases) in 2021. The descriptive statistics for this data are shown in Table (3).

Table 3: Descriptive statistics for cancer.

Variable	Mean	SD	Median	Variance	CV %
Cancer	102.6667	20.25669	109	410.3333	18.58

The results of the correlation and linear regression showed a strong positive relationship between the concentrations of some heavy metals and the increase in gastrointestinal cancer cases. It was found that lead (Pb) in the second site had the highest positive correlation with infections (R^2 = 0.9931), as shown in Figure (1), while cadmium (Cd) in the first site also showed a strong positive correlation (R^2 = 0.9769), as shown in Figure (2).

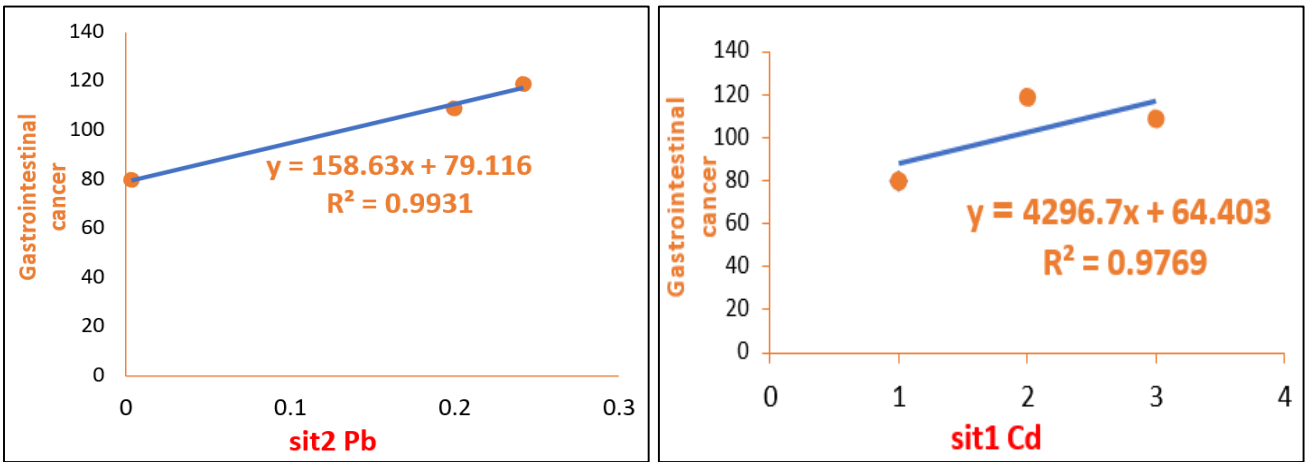

Fig 1-2: Regression results (Pb and Cd).

These results clearly indicate that elevated levels of lead and cadmium in the Kufa River water may be a contributing factor to the increased incidence of gastrointestinal cancer in Najaf province during the study period.

4. Discussion

The results of this study showed a strong correlation between the concentrations of some heavy metals in the Kufa River water (particularly lead and cadmium) and the incidence rates of gastrointestinal cancers during the period (2019-2021). The data showed that lead concentrations at the second site were higher than at the first site (0.148 vs. 0.115 mg/L), while cadmium concentrations were slightly higher at the first site (0.009 mg/L) than at the second site mg/L). Zinc was the most abundant, with an average concentration of 0.651-0.781 mg/L, but it remained within the internationally permissible limits (0.5-1 mg/L), making it less dangerous than lead and cadmium.

From a health perspective, the number of gastrointestinal cancer cases increased from 80 in 2019 to 119 in 2020, then decreased slightly to 109 in 2021. This temporal pattern is consistent with fluctuating heavy metal concentrations and supports the hypothesis that environmental pollution may be a contributing factor to the increased incidence rates. Correlation coefficient results also showed a particularly strong positive relationship between lead (at site 2) and cadmium (at site 1) and infection rates ($r \approx 0.99$ and $r \approx 0.98$, respectively).

These results are consistent with numerous previous studies that have confirmed the carcinogenic role of lead and cadmium through mechanisms including free radical generation, increased oxidative stress, and inhibition of DNA repair enzymes. The potential for these elements to bioaccumulate increases their risk to human health with chronic exposure. In contrast, zinc concentrations did not show a strong association with cancer rates, which is expected given its role as an essential trace element that the body needs in small amounts, unless its levels become excessively high.

Despite the strength of the correlation coefficients, the limited sample size (only three years) is one of the most prominent weaknesses of this study, as this was reflected in the statistical significance values most correlations did not reach statistical significance ($p>0.05$) in most variables. Therefore, the current results should be treated as preliminary indicators that need to be confirmed by larger studies spanning longer periods and including a larger number of samples. Furthermore, it is essential to standardize the statistical methodology (using the population formula for all calculations) to ensure the accuracy and comparability of the results.

Additionally, the study did not address other potential factors that may contribute to increased cancer rates, such as dietary patterns, smoking, or genetic predispositions. Including such variables in future research will be essential for a more comprehensive understanding of the relationship between the environment and human health.

Overall, the results indicate that lead and cadmium contamination of the Kufa River may represent an important environmental risk factor for gastrointestinal cancers in Najaf Governorate. This underscores the need to strengthen environmental monitoring efforts and develop effective strategies to limit the discharge of industrial and agricultural pollutants into the river, thus contributing to protecting public health and reducing the burden of disease.

5. Conclusions

The results of this study indicate that the concentrations of some heavy metals, particularly lead (Pb) and cadmium (Cd), in the Kufa River water during the period (2019-2021) were positively associated with the incidence of gastrointestinal cancers, reflecting the seriousness of these elements as environmental pollutants and their impact on public health. Lead concentrations ranged between 0.115 and 0.148 mg/L, and cadmium between 0.006 and 0.009 mg/L. These concentrations are close to or exceed the internationally permitted limits, which increases the likelihood of their harmful effects on human health. Zinc (Zn), despite being the most abundant metal, has average concentrations ranging between 0.651 and 0.781 mg/L, However, it remained within the permissible limits and did not show a strong association with cancer rates, making it less dangerous compared to lead and cadmium. The significant increase in the number of cancer cases, from 80 cases in 2019 to 119 cases in 2020 and then a decline to 109 cases in 2021, was consistent with changes in heavy metal concentrations, This reinforces the hypothesis of a potential relationship between environmental pollution and human health. However, the limited sample size (only three years) requires treating these results as preliminary indicators that should be verified by more comprehensive future studies encompassing longer time periods and a larger number of samples to ensure the strength and accuracy of the conclusions.

6. Recommendations

Based on the results obtained, this study recommends the need to strengthen environmental monitoring programs for the Kufa River water to monitor the concentrations of heavy metals, especially lead and cadmium, on a regular and periodic basis, due to their potential serious health effects. Health and environmental authorities should also work to develop effective strategies to reduce the discharge of industrial and agricultural pollutants into the river, by tightening controls on pollution sources and enforcing relevant environmental legislation. From a research perspective, the study recommends expanding the scope of future studies to include longer time periods and a larger number of samples, while also including additional variables such as dietary patterns, smoking, and genetic factors, in order to build a more comprehensive picture of the relationship between environmental pollution and human health. It is also advisable to conduct parallel clinical and biological studies to measure the accumulation of these metals in the human body and link them to health and disease indicators, thus contributing to supporting preventive health policies and reducing the disease burden in society.

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