

## Original Research Article

## Assessment of Lead and Cadmium Levels in Local and Imported Animal-Derived Foods in Iraq and Their Potential Health Risks

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**Abstract:** In this study, an evaluation was undertaken to assess the amounts of lead (Pb) and cadmium (Cd) in certain animal-origin food items, both locally and imported in Iraq. Samples of beef, chicken, and fish were acquired and determined employing Flame Atomic Absorption Spectrophotometry (FAAS). It was observed that the Pb contents were always found to be higher than those of Cd in all tested food materials. The maximum level of Pb was observed in the local fish belly (0.0955 mg/kg) and then in the local chicken skin (0.0860 mg/kg). The minimum Pb level was observed in the case of sardines (0.0022 mg/kg). Conversely, Cd content was detected to be lower, where the highest value was recorded in the local chicken breast (0.0053 mg/kg); several items contained non-detectable values. All the contents were found below the upper limit set by FAO/WHO. In terms of health risks, the estimated daily intake (EDI) was determined to be  $6.82 \times 10^{-5}$  mg/kg/day for Pb and  $3.78 \times 10^{-6}$  mg/kg/day for Cd. The THQ values were 0.0195 for Pb and 0.00378 for Cd; HI was calculated to be 0.0233. As HI was below one, there is no considerable health risk posed through non-cancer effects. The presence of relatively higher amounts in local samples than in imported samples indicates that there may be some effect of environmental pollution.

**Keywords:** Lead (Pb), Cadmium (Cd), Heavy metals, Animal-origin food, Beef, chicken, fish, Iraq.

## INTRODUCTION

Today, contamination of food by heavy metals is a phenomenon that develops rapidly worldwide manner. Heavy metals, which have toxicity, persistence, and a bioaccumulative nature, bring multifaceted risks for ecosystems and human life. Such non-essential trace elements in human biology, like lead (Pb) and cadmium (Cd), pose significant health risks, as these heavy metals cause neurotoxicity, kidney failure, and cardiovascular pathologies (Rai *et al.*, 2019; Wang *et al.*, 2019; Briffa *et al.*, 2020; Wróblewski *et al.*, 2025). The following causes are related to heavy metal contamination in ecosystems: industrial development, agriculture, and waste release in the environment.

There are international recommendations concerning the acceptable concentration of heavy metals in foods. In case of animal-derived food products, the maximum permissible level equals to 0.1 mg/kg for Pb and 0.05 mg/kg for Cd (FAO/WHO, 2011). Nonetheless, chronic exposure to heavy metals leads to their bioaccumulation in the body, causing further health risks for sensitive individuals (Dwanga *et al.*, 2024). In the modern world, animal-origin foods are key contributors to human consumption of heavy metals. Hazardous substances penetrate into the body through various environmental media and bioaccumulate in plant tissues, fish, and then reach animal-derived foods consumed by humans (Khan *et al.*, 2013; Oros, 2025). Metabolism promotes the heavy metals accumulation in different body tissues, including muscles, fat, and the liver (Munir *et al.*, 2021; Mititelu *et al.*, 2025).

Fish species appear to be especially prone to heavy metal accumulation due to the permanent presence in the environment. Many researchers note that increased concentrations of Pb and Cd occur in the organs of species of fish as a

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sign of environmental contamination (Abalaka *et al.*, 2022; Reda *et al.*, 2025). Thus, fish species are good pollution indicators and represent a considerable factor in heavy metal exposure among people (Burger & Gochfeld, 2005). Environmental characteristics of each region are associated with heavy metal accumulation in animal species inhabiting this territory. For example, effluents, pesticides from agriculture, and sewage are responsible for the detection of Pb and Cd in organisms living in Iraqi rivers such as the Tigris and Euphrates (Al-Obaidy *et al.*, 2020; Hassan *et al.*, 2022). Recently, Pb and Cd were quantified in samples of fish and poultry in different Iraqi cities: Baghdad, Basra, and the southern marshes (Al-Azawi *et al.*, 2024; Al-Khafaji *et al.*, 2023; Jawad *et al.*, 2024; Jalal *et al.*, 2025).

Apart from locally produced animal foods, imported products also form the structure of the market of animal-derived foods. In addition, the level of Pb and Cd depends on the environment where animal products are produced and health standards used by other countries. Information about the amount of heavy metal content in local and imported animal foods available on the Iraqi market is rather limited (Al-Azzawi & Al-Ani, 2022). Due to the growing demand for animal foods, it is crucial to estimate the level of heavy metals in animal products. The present research aimed to identify the level of lead and cadmium in selected imported and locally produced animal foods in Iraq, as well as to establish whether these concentrations correspond to permissible limits according to the FAO and WHO.

## MATERIALS AND METHODS

### Design and Sampling

The current study adopted a cross-sectional study design to assess Pb and Cd contents in selected animal food products sold in Iraqi markets. Foods included beef, chicken and fish samples purchased from retail outlets and supermarkets. Samples were classified as either locally produced or imported, with fifteen samples collected for each group through food quality evaluation (Hossain *et al.*, 2024; Al-Azawi *et al.*, 2024). Food samples were stored under sterile conditions in bags of polyethylene at 4°C and -20°C before being analyzed.

### Food Sample Preparation

The selected food samples were prepared as recommended by international standard procedures for trace metal analysis (FAO/WHO, 2011). The food specimens were first washed using distilled water and then homogenized. 1–2 g of the sample were weighed and then dissolved in acid for further analysis. Acid digestion was done using acid-cleaned glassware that were washed with distilled water.

### Wet Digestion

Food samples were dissolved employing a modified USEPA Method 3050B (Mohammed *et al.*, 2017). First, the samples were digested using concentrated nitric acid (HNO<sub>3</sub>) until there was visible complete dissolution followed by adding hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) to continue dissolving organic matter till clear solution was achieved. The resulting digestate was filtered and subsequently diluted to a final volume of 50 mL with distilled water.

### Instrumental Analysis

The flame atomic absorption spectrometry (FAAS) device was adopted to assess the Pb and Cd concentration levels. The measurement wavelengths were set at 217.0 nm and 228.8 nm using an air/acetylene flame. Standard calibration curves were created using stock solutions prepared from reference materials.

### Health Risk Assessment

A health risk assessment was undertaken to identify health risks due to dietary intake of samples containing Pb and Cd. To achieve this, the estimated daily intake (EDI), target hazard quotient (THQ), and hazard index (HI) amounts were determined using United States Environmental Protection Agency (USEPA) guidelines (2000; 2011).

#### Estimated daily intake (EDI):

$$EDI = (C \times IR) / BW$$

Where; EDI = estimated daily intake; C= metal content (mg/kg); IR = ingestion rate (kg/day); BW = body weight (kg)

#### Target hazard quotient (THQ):

$$THQ = EDI / RfD$$

Where; THQ = target hazard quotient; EDI = estimated daily intake; RfD = reference dose (mg/kg/day).

#### Hazard Index (HI):

$$HI = THQ(Pb) + THQ(Cd)$$

In which; HI < 1 indicates non-significant non-carcinogenic risk while HI > 1 is suggestive of health risk.

For this study, an ingestion rate (IR) of 0.05 kg/day and average body weight (BW) of 70 kg were used. Reference dose (RfD) values for Pb and Cd used were: 0.0035 mg/kg/day and 0.001 mg/kg/day, correspondingly (FAO/WHO, 2011; USEPA, 2011).

### Data Analyses

Values are expressed as mean  $\pm$  SD. The data obtained in this research were statistically analyzed employing SPSS V 26.0. Differences between locally produced and imported foods were determined using independent t-test. Variance among groups were evaluated using ANOVA while LSD post hoc test was used when necessary. Level of significance used was  $p < 0.05$ .

## RESULTS

### Concentrations of Lead (Pb) in the Studied Samples

Table 1 shows the Pb levels and their corresponding statistical groupings. There is a large difference in Pb levels between the samples ( $p < 0.05$ ). Samples with high Pb levels include the local fish belly ( $0.0955 \pm 0.0722$  mg/kg) and local chicken skin ( $0.0860 \pm 0.0263$  mg/kg), which are labeled as category "a". A relatively lower Pb concentration was recorded in Turkish chicken skin ( $0.0784 \pm 0.0615$  mg/kg). It belongs to category "ab", which partially overlaps with nearby categories. Samples with medium Pb concentrations include local chicken breast ( $0.0612 \pm 0.0097$  mg/kg), Turkish chicken thigh ( $0.0498 \pm 0.0149$  mg/kg), and fish muscles ( $0.0498 \pm 0.0119$  mg/kg), belonging to categories "b" and "bc," respectively. The samples with the lowest Pb concentrations include meat products and fish from abroad, namely tuna ( $0.0089 \pm 0.0053$  mg/kg) and sardines ( $0.0022 \pm 0.0019$  mg/kg), and belong to category "d."

According to statistical grouping, samples with the same letter do not show a significant difference between each other, while samples with different letters have remarkable differences in Pb concentration levels.

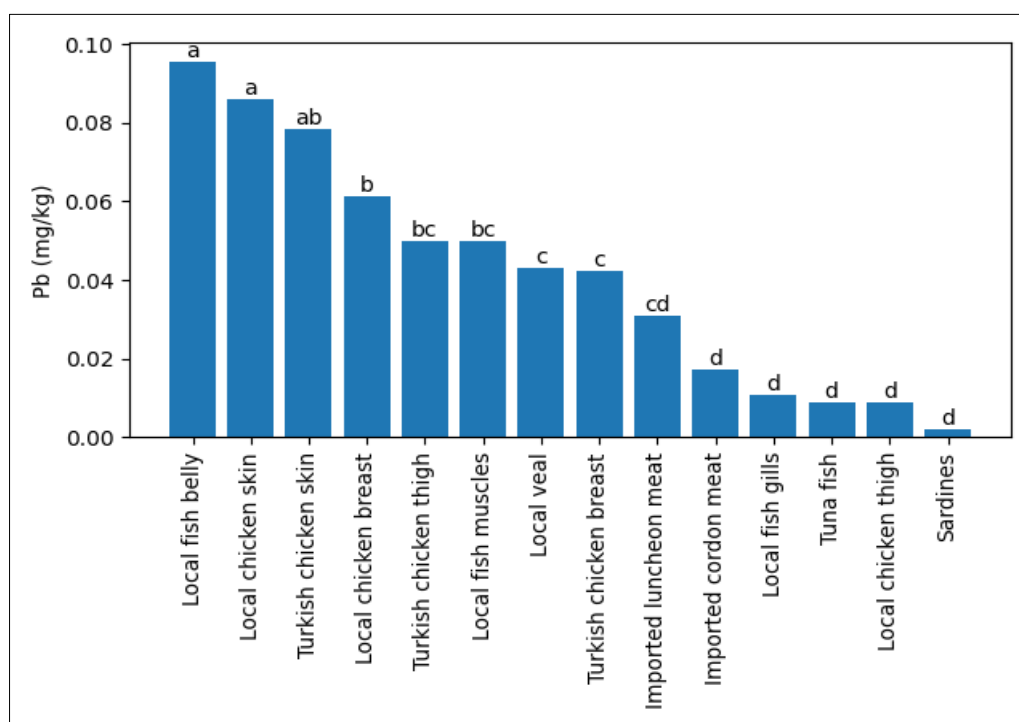


Figure 1: Lead (Pb) levels (mg/kg) of analyzed samples. Different letters denote statistically significant differences ( $p < 0.05$ )

Table 1: Pb concentrations (mg/kg) in studied samples

Sample	Pb (Mean $\pm$ SD)	letters
Local fish belly	0.0955 $\pm$ 0.0722	a
Local chicken skin	0.0860 $\pm$ 0.0263	a
Turkish chicken skin	0.0784 $\pm$ 0.0615	ab
Local chicken breast	0.0612 $\pm$ 0.0097	b
Turkish chicken thigh	0.0498 $\pm$ 0.0149	bc
Local fish muscles	0.0498 $\pm$ 0.0119	bc
Local veal	0.0430 $\pm$ 0.0333	c
Turkish chicken breast	0.0422 $\pm$ 0.0292	c

Sample	Pb (Mean ± SD)	letters
Imported luncheon meat	0.0308 ± 0.0146	cd
Imported cordon meat	0.0174 ± 0.0120	d
Local fish gills	0.0107 ± 0.0150	d
Tuna fish	0.0089 ± 0.0053	d
Local chicken thigh	0.0089 ± 0.0061	d
Sardines	0.0022 ± 0.0019	d

Different letters show statistically different values ( $p < 0.05$ ), LSD= 0.028.

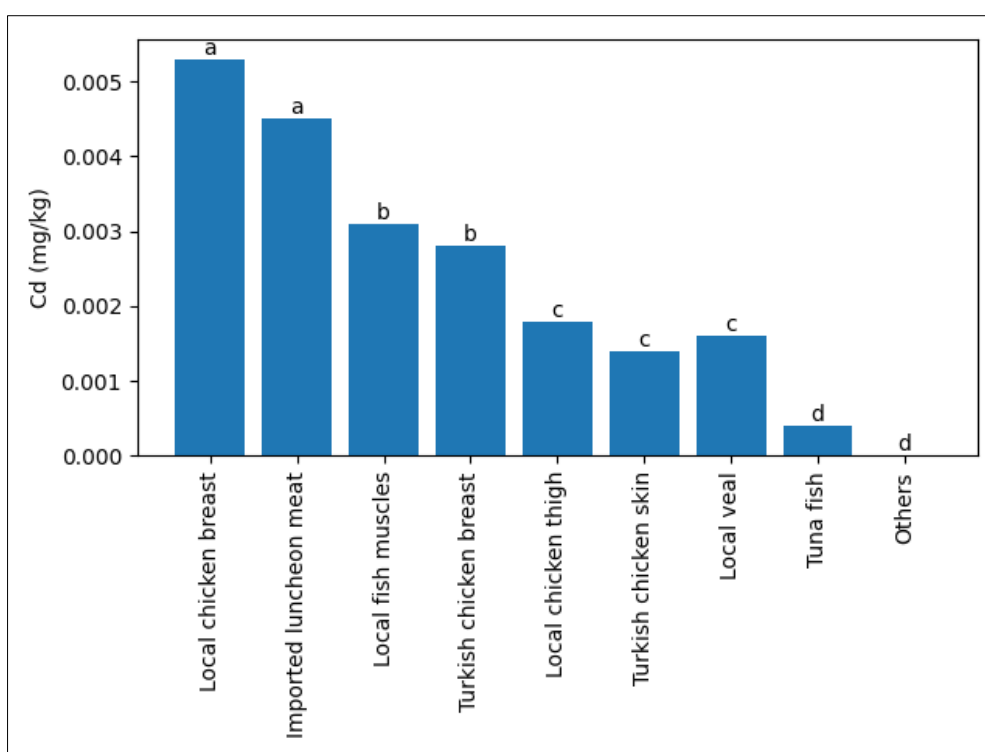
### Concentrations of Cadmium (Cd) in the Studied Samples

The data about cadmium (Cd) concentration along with its statistical distribution is presented in Table 2 and illustrated in Fig. 2. Cadmium concentration levels were lower compared to those of Pb and showed relatively little variations. High Cd concentration was noted in local chicken breast ( $0.0053 \pm 0.0031$  mg/kg) and luncheon meat ( $0.0045 \pm 0.0021$  mg/kg) which belong to group “a” but do not differ statistically from each other. Medium Cd concentration was noted in fish muscles ( $0.0031 \pm 0.0013$  mg/kg) and turkey chicken breast ( $0.0028 \pm 0.0017$  mg/kg), which form group “b”. Low Cd concentration was noted in local chicken thigh ( $0.0018 \pm 0.0012$  mg/kg), turkey chicken skin ( $0.0014 \pm 0.0010$  mg/kg) and local veal ( $0.0016 \pm 0.0010$  mg/kg). These products constitute group “c”. Very low concentration levels of Cd were shown by tuna ( $0.0004 \pm 0.0002$ ).

**Table 2: Cadmium (Cd) concentrations (mg/kg) in studied samples**

Sample	Cd (Mean ± SD)	letters
Local chicken breast	0.0053 ± 0.0031	a
Imported luncheon meat	0.0045 ± 0.0021	a
Local fish muscles	0.0031 ± 0.0013	b
Turkish chicken breast	0.0028 ± 0.0017	b
Local chicken thigh	0.0018 ± 0.0012	c
Turkish chicken skin	0.0014 ± 0.0010	c
Local veal	0.0016 ± 0.0010	c
Tuna fish	0.0004 ± 0.0002	d
Others (ND)	ND	d

Different letters show statistically different values ( $p < 0.05$ ), LSD= 0.0021.



**Figure 2: Cd contents (mg/kg) in the examined samples. Different letters denote statistically significant differences ( $p < 0.05$ )**

### Comparison of Heavy Metal Concentration with Permissible Limits

This part of the paper highlights a comparison between the concentration values obtained and the permissible limits by FAO/WHO. The findings are presented in Table 3. It is clear that all Cd concentrations were below permissible limits in meat and fish samples. Likewise, Pb concentrations were well below the permissible limit in all samples investigated. However, some samples showed concentrations nearing permissible limits. Local fish belly had 0.0955 mg/kg and chicken skin 0.0860 mg/kg.

**Table 3: Assessment of heavy metal concentrations against FAO/WHO permissible limits**

Metal	Food Category	Permissible Limit (mg/kg)	Maximum Observed (mg/kg)	Status
Pb	Poultry/Meat	0.1	0.0860	Within limit
Pb	Fish	0.3	0.0955	Within limit
Cd	Meat	0.05	0.0053	Within limit
Cd	Fish	0.05–0.1	0.0031	Within limit

### Health Risk Assessment

The findings of health risk assessment are presented in Table 4. The maximum EDI levels for Pb and Cd were observed for the local fish belly and chicken breast samples, with  $6.82 \times 10^{-5}$  mg/kg/day for Pb and  $3.78 \times 10^{-6}$  mg/kg/day for Cd, respectively. The THQ levels for Pb and Cd were detected to be 0.0195 and 0.00378, respectively, which were both below the threshold value of 1. The HI value was also less than 1 (0.0233), which implies no risk of adverse health effects due to non-carcinogenic impacts. From the above findings, it can be deduced that eating these foods does not present any risk to health; however, the presence of relatively high levels in locally-produced food items may indicate environmental influence on them.

**Table 4: Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), and Hazard Index (HI) of heavy metals in selected food samples**

Metal	Sample (Highest Concentration)	Concentration (mg/kg)	EDI (mg/kg/day)	THQ
Pb	Local fish belly	0.0955	$6.82 \times 10^{-5}$	0.0195
Cd	Local chicken breast	0.0053	$3.78 \times 10^{-6}$	0.00378

$$\text{Hazard Index (HI)} = 0.0233$$

Calculation outcomes of THQ and HI were all under the defined safety limit ( $\text{THQ} < 1$ ), signifying that there was no discernible non-carcinogenic hazard.

## DISCUSSION

The findings showed that Pb concentrations in all analyzed samples surpass the corresponding value of cadmium (Cd). Similar observations have been made in literature and are attributed to the wide distribution and long lifespan of lead in the environment (Tchounwou *et al.*, 2012; Jaishankar *et al.*, 2014). However, in some of the investigated samples, the concentration of Cd levels were lower due to its reduced environmental mobility compared to lead. As demonstrated in research by Copat *et al.*, (2015), Cd was found in animal tissues only in the cases of intentional exposure to industrial contamination. Yet, the identified presence of Cd in certain samples, for instance, in chicken skin and fish muscle tissue, can be accounted for due to contamination in the feed and drinking water for fish (Khan *et al.*, 2013).

An interesting finding from this study pertains to the higher Pb content in lipid-containing tissues, such as the skin of chickens and fish muscle tissue in the belly. These results are consistent with the available evidence regarding accumulation of heavy metals in fat tissues (Burger *et al.*, 2005; Copat *et al.*, 2015). The routine exposure of aquatic organisms to pollutants in the environment, especially water, allows for the bioaccumulation of contaminants, thus making fish an efficient bioindicator of pollution (Burger & Gochfeld, 2005). One more noteworthy outcome of this study involves differences in contamination levels among local and imported fish. Studies have found a higher contamination level in the local fish sample owing to the increased heavy-metal concentration in polluted aquatic systems due to wastewater discharge, industrial activities, and agricultural runoff (Authman *et al.*, 2015). It must be stressed that this result is highly significant in areas characterized by poor environmental regulation.

Similar outcomes have been obtained when comparing local and imported chicken. The source of contamination in poultry products includes feed and water sources used during farming. Hossain *et al.*, (2024) note contaminated feed as the leading cause of Pb and Cd pollution in chicken products. This conclusion aligns with the findings that local poultry has a higher contamination level compared to imported samples.

It should be noted that none of the recorded levels of Pb exceeds the safe thresholds set by FAO and WHO. At the same time, several samples are approaching the allowable limit values. The concern arises because low Pb exposure

has been shown to cause health problems. The World Health Organization (2011) states that any Pb exposure represents health hazards and that chronic low Pb exposure can lead to severe neurological and cardiovascular complications. Uneven concentrations of Pb in different samples are indicated by high standard deviations in some of them. The uneven contamination level based on spatial distribution of contaminants and their sources is often mentioned in environmental monitoring (Alloway, 2013).

Overall, from a public health perspective, continuous monitoring of heavy-metal contamination is needed especially for fish. The relatively low rate of contaminations among imported foods can be explained by the existence of more stringent regulatory regimes in their exporting countries (FAO/WHO, 2018). Improving local environmental and food safety measures might be instrumental in reducing contamination. According to the conducted analyses, the health risk resulting from Pb and Cd exposure is negligible since all THQ and HI values are smaller than unity. Recent studies on Pb and Cd exposure via foods found similar results (Belew *et al.*, 2024; Akinkpelumi *et al.*, 2025).

Given the higher biological persistence of Pb and bioaccumulation in aquatic organisms, a higher contribution of this metal into total health risk is expected (Rabeey *et al.*, 2025; Gazzawi *et al.*, 2025). Nevertheless, a cumulative influence of low Pb and Cd dietary exposure could eventually have an adverse health effect, which requires monitoring exposure as discussed recently (Bedoya-Perales *et al.*, 2025; Elbagory *et al.*, 2025). The slight increase in health risks in case of local samples is probably due to the influence of environmental factors, a phenomenon confirmed by previous research (Rabeey *et al.*, 2025; Akinkpelumi *et al.*, 2025).

## CONCLUSION

The results of this study suggest the presence of Pb and Cd in both locally produced and imported animal-based food products in Iraq. However, Pb was present at higher levels compared to Cd in most samples. All the recorded concentrations fell below the highest acceptable levels set by the FAO/WHO. Some samples approached the highest acceptable limits, especially those that included locally-produced fish and chicken skins, indicating the possibility of localized contamination. There was no risk of health effects on people consuming the contaminated foods since all THQ and HI amounts were less than 1. Despite the lower risk of health effects, the elevated levels of Pb and Cd quantified in local products compared to imported products highlight the role of pollution in the production of food products.

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