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Assessment of Heavy Metal Concentrations in Poultry Feed Samples from Erbil Governorate

Mohammed S. Jalal **Zakariya A. Hussein** **Jaafar M. Smail**

Department of Physics/ Faculty of Science and Health/ Koya University/ Koya KOY45/ Kurdistan Region - F.R. Iraq

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corresponding author:
Mohammed S. Jalal
Mohammed.safin@koyauniversity.org
Zakariya A. Hussein
zakariya.hussein@koyauniversity.org
Jaafar M. Smail
jahfer.majeed@koyauniversity.org

ABSTRACT

This study evaluates the concentrations of five toxic heavy metals (Ni, Co, Cd, Cr, and Br) in thirty poultry feed samples collected from different locations in Erbil Governorate, Iraq, utilizing X-ray fluorescence spectroscopy, a non-destructive analytical technique used to determine the elemental composition of samples quickly and accurately, making it valuable for detecting heavy metals in food products. The average concentrations significantly exceeded international safety thresholds, set by nutrient requirements of poultry. These findings highlight a major contamination concern and underscore the urgent need for stricter regulatory standards and monitoring in poultry feed production. Toxic heavy metals (Ni, Co, Cd, Cr, and Br) were found. The average concentrations of Ni, Co, Cd, Cr, and Br in poultry feeds are 334.1±199.65, 163.8±94.88, 33.81±12.8, 44.67±11.55, and 25.78±10.067 ppm, while the maximum tolerable limit is 250, 25, 10, 500, and ≥1 ppm, respectively. The findings additionally present a comparison of heavy metal concentrations in local chicken feed vs. those detected in 30 industrial chicken feed samples within the research area. This research emphasizes significant pollution in chicken feed this raising concerns over, for both human consumers and poultry. This study recommends implementing stricter quality control measures and regular monitoring of poultry feed in Erbil to reduce heavy metal contamination, along with encouraging the use of safer alternative feed sources, such as food leftovers, to minimize health risks.

Keywords: XRF-technique, heavy metals concentration, poultry feed, Erbil governorate.

INTRODUCTION

Poultry farming is a crucial component of global agriculture, providing a significant source of protein through meat and eggs. As more people want chicken products, it's become seriously important to make sure the feed we give our chickens is safe and nutritious (Banerjee *et al*., 2022). What we feed the chickens impacts their health, how well they grow, and the quality of the food we get from them. However, contamination of poultry feed with harmful substances, including heavy metals, is a growing concern (Wang *et al*., 2013). Micro-minerals are essential nutrients required by the human body in amounts below 100 mg/day. Many of these are classified as heavy metals due to their high density and can accumulate in the body and environment over time (Iqbal *et al*., 2023). These can be dangerous for the chickens and for us. This harmful stuff can end up in the feed due to dirty environment, bad raw materials, or incorrect making processes. Thus, monitoring the composition of poultry feed is essential. This helps ensure the food we get is safe and that we're sticking to the rules (Wang *et al*., 2013).

The distribution of these pollutants is closely linked to human activities like vehicle emissions, industrial waste, poor disposal practices, and agrochemical use. As Erbil grows, assessing and managing heavy metal contamination is crucial to protect the environment and public health. (Ismael and Goran, 2024; Salih *et al*., 2024). It's very important to do a complete study of these using methods we can trust and that give us detailed results. Due to the potential health risks, XRF spectroscopy is an excellent tool for analyzing feed contamination. It's a powerful technique that doesn't damage the samples and it's renowned for its high level of sensitivity and correctness. However, it hasn't been used much yet to check the quality of chicken feed in the Erbil region of Iraq (Rajib *et al*., 2021). A thorough investigation is essential to protect public health in Iraq, especially given the lack of local studies in Erbil. Implementing strict feed regulations, promoting diagnostics, and researching local pollution sources are critical. Animals can absorb environmental metals, leading to contamination of the food chain (Qu *et al*., 2020). The focus on local farms and manufacturers in Erbil, Iraq, was driven by their widespread use of locally sourced or self-mixed feed, which may not be subject to the same regulatory oversight as imported commercial feeds. This raises concerns about the potential for contamination with heavy metals. Anthropogenic activity, particularly the mining, smelting, foundry, and other metal-based sectors, has resulted in heavy metal pollution. Metals can leach from a variety of sources, including landfills, waste dumps, excrement, animal and poultry manure, runoff, cars, and road construction (Adei and Forson-Adaboh, 2008).

(Ukpe and Chokor, 2018) published a study on the correlation between the concentrations of Some heavy metals in poultry feed and waste in Nigeria, emphasizing the transfer of these metals through the food chain from soil to plants, then into poultry feed, and eventually accumulating in animals and humans. Their analysis revealed that the poultry feeds contained notable levels of heavy metals, which subsequently enriched the poultry waste with similar contaminants. Specifically, the concentrations of heavy metal ions measured in the analyzed poultry waste were nickel (Ni) at 1.89 g/kg, cobalt (Co) at 0.43 g/kg, lead (Pb) at 1.17 g/kg, chromium (Cr) at 0.846 g/kg, and cadmium (Cd) at 0.53 g/kg. This research highlights the environmental and health implications of heavy metal contamination in poultry production systems.

(Okoye *et al*., 2011), conducted an assessment of heavy metal concentrations in poultry feed marketed in South-Eastern Nigeria, using atomic absorption spectrophotometry. The investigation revealed variable concentrations of multiple elements: Zinc (Zn) (34.038-49.950 ppm), Iron (Fe) (50.575-170.075 ppm), cupper (Cu) (6.52-14.20 ppm), Pb (1.10-7.85 ppm), Cd (0.038-0.463 ppm), Ni (2.250-4.875 ppm) and Co (0.613-3.200 ppm), notably, essential micronutrients (Zn, Fe) were detected at suboptimal levels, while Pb exceeded regulatory thresholds-a phenomenon attributed to environmental contamination from combustion processes and inadequate waste disposal systems. The findings reveal notable Pb contamination in local poultry feed, posing health risks to livestock and consumers. This underscores the need for stricter regulation and systematic monitoring to reduce heavy metal exposure and protect public health.

(Imran *et al*., 2014), conducted a comprehensive analysis of heavy metal contamination in poultry feeds sourced from various manufacturers and farms in Kasur, a region significantly impacted by tannery industry pollution. Employing inductively coupled plasma mass spectrometry (ICP-MS) methodology, the researchers quantified substantial concentrations of multiple heavy metals, including Cd (0.004-0.249 ppm), Cu (0.45-3.26 ppm), Cr (0.14-1.82 ppm), Fe (3.78-5.18 ppm), Pb (0.10-3.21 ppm), manganese (Mn) (0.43-10.20 ppm), Ni (9.77-42.93 ppm), and Zn (0.51-55.38 ppm). Lead levels exceeded the UK threshold of 1 ppm but remained below the global 10 ppm limit, while mercury levels were above safety standards in all samples. These results highlight industrial contamination and underscore the need for stricter feed quality control and stronger environmental regulations to reduce heavy metal bioaccumulation in the food chain.

Heavy metal contamination in animal feed is a significant public health and agricultural concern, as toxic metals can accumulate in poultry and subsequently enter the human food chain. In Erbil Governorate, Iraq, poultry farming is a major part of local agriculture, yet there is limited data on the presence and concentration of hazardous heavy metals in poultry feeds. This gap in knowledge raises serious concerns about food safety, animal health, and environmental contamination. Without regular monitoring and strict quality controls, contaminated feed may pose health risks to both poultry and consumers (Hussein, 2015). Despite increasing awareness, no comprehensive study has been conducted to systematically evaluate heavy metal levels in poultry feed across Erbil (Zhang *et al*., 2016; Hussein, 2023). This research aims to fill that gap by assessing the concentrations of key heavy metals, providing essential data to inform public health policies and improve feed safety standards in the region.

Material and Methodology

Study area

The location of the study was Erbil, Iraq. The study area covers approximately 15.074 km². located between the coordinates 37.322212N-35.424460S and 43.327328W-45.064541E. Collected samples of poultry feed in farms from thirty locations for Erbil governorate, as shown in Fig. (1). We selected Erbil for our study to strategically consider it as a regional market and having well-developed agricultural infrastructure (Hussein *et al*., 2021).

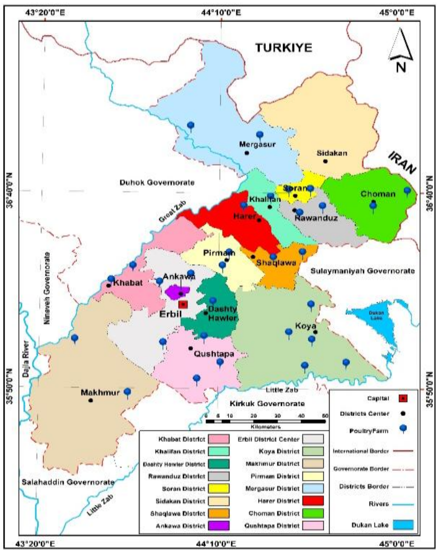

Fig. 1: Thirty different poultry farms of the Erbil in Iraq, that we collected data on them.

Sample collection and preparation

We got from each poultry farm nearly 2 kg of poultry feed. Sample were collected in late September to early November, coinciding with cooler seasonal conditions optimal for feed stability, which will prevent poultry feed disorders because of the temperature. Nearly for each district, we have two samples as shown in the table. We cover a large area in Erbil; we choose the poultry farms that are famous and largest in each place, we choose this way because of that we want to take that sample have more exposure or most eaten in region. Many poultry farm owners did not help to obtain data from them because they were afraid that their name would be spread badly and that their poultry feed would contain many harmful substances or that they might have broken the law somewhere and did not want to be disclosed. We used XRF analysis, a powerful non-destructive technique used to determine the elemental composition of various materials, including animal feed (Enzweiler and Vendemiatto, 2024).

Ni, Co, Cd, Cr, and bromine (Br) were selected because each is a known contaminant or bioactive element of concern in poultry. Ni, Cd and Cr are toxic heavy metals that readily accumulate in soils and can enter feed ingredients; they are frequently found at elevated levels in agricultural environments and have hazardous effects when ingested (Aljohani, 2023). For example, recent surveys in Iraq report very high Cr and Ni in sediments (hundreds of ppm) due to industrial/agricultural pollution (Mijbas *et al*., 2024). Cobalt was included because, unlike ruminants, poultry do not require dietary Co (they obtain B_{12} through gut synthesis) and any excess Co in feed usually indicates contamination; indeed, poultry nutrition studies explicitly note Co is "not considered an essential mineral for chickens" (Kato *et al*., 2003). Bromine was targeted because inorganic bromide (from brominated pesticides, fertilizers or water) can concentrate in feed and eggs; studies have documented rising Br levels in poultry feed and eggs in contaminated regions (Orobchenko *et al*., 2022). Monitoring Ni, Co, Cd, Cr and Br covers both known heavy metals and an unusual trace element.

To achieve accurate and representative XRF results, the poultry feed samples were prepared as follows: A representative portion of each feed sample (∼100 g) was weighed and placed in a clean wide bowl that can withstand oven temperature. The samples were then dried in a laboratory by oven lab tech universal drying oven LDO-060E, at 70°C for 24 hours or until a constant weight was achieved (Rajib *et al*., 2021; Saleh *et al*., 2024). This step removes moisture, which can interfere with XRF analysis and affect the accuracy of elemental concentration measurements. Rationale for choosing 70°C to minimize the risk of losing volatile metals while still ensuring sufficient moisture removal. The dried feed samples were grinding into a fine powder using a laboratory-Newal COF-3823-Nuts and spices Grinder-Silver. The goal was to achieve a particle size of less than 75 µm, ensuring sample homogeneity and optimal interaction with the X-ray beam during XRF analysis (Kalnicky and Singhvi, 2001). Approximately 5-7 g of the finely ground feed powder was transferred into a pellet die and subjected to pressure using a hydraulic press. The manual press machine (TP Herzog) has been utilized, possessing a maximum load capacity of 200 KN (pressure). The TP is a manually operated benchtop pelletizing press utilized for the production of pressed powder sample tablets for XRF analysis (Aladdin *et al*., 2022). A pressure of (1 to 2) tons was applied for 1-2 minutes to create a uniform, durable pellet with a smooth surface suitable for XRF analysis (Buhrke *et al*., 1998).

X-ray fluorescence spectrometry Calibration

X-ray fluorescence spectrometry (XRF) that shows in Fig. (2), is a fast reliable method used to qualitatively and quantitatively determine major, minor, and trace elements in various sample types without requiring extensive operator training. The XRF system includes an X-ray tube with a palladium (Pd) target, secondary targets (Mo, Cu, Al, RX9) for detecting different element groups, and the SDD (silicon drift detector) collects the electrons generated when X-rays strike the sample and converts them into electrical signals, enabling precise element identification. It collects and measures X-ray-induced electrons; the Rigaku RPF-SQX software processes this data to determine the chemical composition of the samples.

Daily MCA calibration, using the standard sample provided by Rigaku, ensures accurate peak positions of fluorescent X-rays and prevents analysis errors. Monthly calibration, done with Sn, Cu, and SiO_2 standards, adjusts peak profiles and corrects X-ray intensity drift. Without regular calibration, data accuracy declines due to shifting peaks and intensity variations. MCA calibration should be done regularly, followed by monthly library calibration to maintain reliable results.

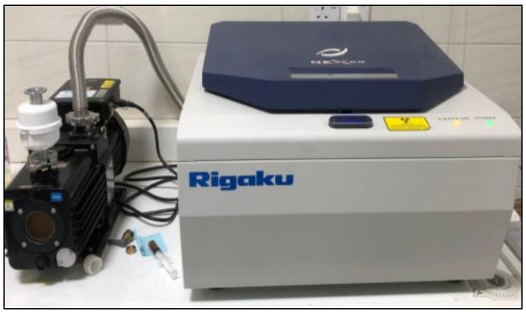

Fig. 2: X-ray fluorescence and, our samples on XRF.

RESULTS AND DISCUSSION

We conducted a detailed analysis of Ni, Co, Cd, Cr, and Br in chicken feed samples from local poultry farms in Erbil Governorate, Iraq. Using IBM SPSS 23, we compared the measured heavy metal concentrations to international maximum tolerable limits (MTLs) via descriptive statistics and one-sample t-tests to evaluate safety. The results are presented in (Table 1).

Table 1: The data of heavy metal in poultry feed (manufactured feed) in different location for Erbil Governorate (F= poultry feed).

Sample code	Location	Toxic Element (ppm)				
		Ni	Co	Cd	Cr	Br
F.1	Sktan	540	260	91	54.6	33.8
F.2	Koysinjaq	500	210	88.2	53.2	33.1
F.3	Degala	440	200	86.1	52.4	32.2
F.4	Taqtaq	300	105	78.2	44.4	26.2
F.5	Ashti	280	100	76.1	43.2	25.1
F.6	Shaqlawa	420	185	85.1	50.6	31.1
F.7	Balisan	390	165	83.1	48.2	30.1
F.8	Pirmam	188	90	70.1	38.6	20.8
F.9	Kore	168	88	69.1	37.2	19.6
F.10	Harir	335	122	80.1	46.4	28.4
F.11	Shamamik	90	72	57.6	24.6	9.1
F.12	Central of Erbil	82	66	52.5	21.2	4.1
F.13	plain of Erbil	94	77	62.2	30.1	12.2
F.14	Murtka	135	85	68.1	35.1	17.8
F.15	Qushtappa	104	82	67.1	33.2	16.6
F.16	Bahrka	99	80	62.8	30.8	12.9
F.17	Ainkawa	98	80	64.1	31.1	13.4
F.18	Khalifan	210	92	72.2	40.1	22.2
F.19	Akoyan	658	322	105	65.4	42.2
F.20	Rawanduz	555	280	80	53.1	33.1
F.21	Soran	576	288	82	55.1	34.2
F.22	Shawrawa	590	290	92	55.8	34.8
F.23	Haji Omaran	515	305	100	60.2	40.1
F.24	Choman	650	320	99	62.8	41.4
F.25	Mergasur	600	298	90	57.6	37.2
F.26	Barzan	582	290	84	56.2	36.1
F.27	Khabat	250	94	74.1	41.6	23.8
F.28	Ifraz	210	91	73.1	40.2	22.2
F.29	Gwer	188	90	71.2	39.1	20.4
F.30	Makhmur	175	86	70.1	38.1	19.2
Mean		334.1	163.8	77.81	44.67	25.78
maximum		658	322	105	65.4	42.2
minimum		82	66	52.5	21.2	4.1
Std. Deviation		±199.65	±94.88	±12.8	±11.55	±10.067

Ni Silvery-white, hard, ductile, and malleable transition metal (group 10), (Jackson 2020). Our analysis revealed that (Ni) was present at an average concentration of 334.07 ppm, significantly exceeding the MTL of 250 ppm according to (Imran *et al*., 2014). The one-sample t-test confirmed that this difference was statistically significant (t=2.306, p=0.028). The highest concentration level of heavy metal Ni was found in Akoyan location 658 ppm and lowest in central of Erbil 82 ppm. The high level of nickel affected. Signs of damage include smaller livers. Ni doesn't just lead to weight issues and liver damage. It also makes it difficult for the chickens to use the nutrients in their food effectively. Too much nickel in the body is harmful (Bersényi *et al*., 2004). For finding Mean and standard deviation, we use these equations:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Where $\bar{x}$ is the mean, x_i is each value, and n is the total number of values (Miller and Miller, 1998).

$$SD = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Where SD is standard deviation, $\bar{x}$ is the mean, x_i is each value, and n is the total number of values (Miller and Miller, 1998).

Co Hard, lustrous, silver-gray, ferromagnetic transition metal (group 9), (Jackson, 2020). We also found that Cobalt (Co) levels were exceptionally high, with a mean concentration of 163.77 ppm, more than six times the established limit of 25 ppm according to (NRC, 2005). This deviation was statistically significant (t=8.011, p<0.001), The level concentration heavy metal of (Co) varies between 66 ppm to 322 ppm and average is 163.8 ppm The amount of cobalt in chicken food gets too high (over 25 ppm), it can cause big problems for the chicken. It can slow down how quickly they grow. It can mess up their blood and make them lack iron. They might even experience heart failure and fall sicker easily. If we look on our data, we see nine places have cobalt concentration more than 250 ppm (Diaz *et al*., 1994). As show in Fig. (3).

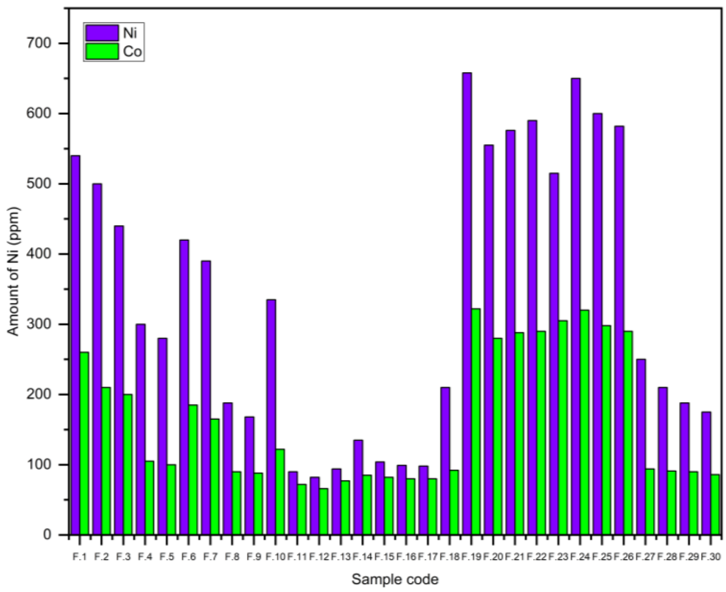

Fig. 3: Amount of heavy metal (Ni and Co) vs sample code for all feeds in poultry farms in Erbil.

Cd Soft, silvery-white, bluish-tinged transition metal (group 12), (Jackson, 2020). Cd levels in the feed were also alarmingly high, with a mean concentration of 77.81 ppm, far above the MTL of 10 ppm according to (NRC, 2005). The t-test result ($t = 29.012$, $p < 0.001$) confirmed this difference to be highly significant. Also, the table 1 show that the concentration of Cd varies between 52.5 ppm to 105 ppm and average is 77.81 ppm. note that exposure to high levels of cadmium triggers oxidative stress, which damages cells and can ultimately lead to programmed cell death (apoptosis) or uncontrolled cell destruction (necrosis) (Kar and Patra, 2021). Experian's those chickens exposed to dietary cadmium levels of 30 ppm or higher cause of liver tissue damage as observed under histopathological examination, worsening progressively with higher cadmium concentrations; As well as led to severe toxicity in poultry, significantly increasing mortality rates (Kar and Patra, 2021), as shown in Fig. (4).

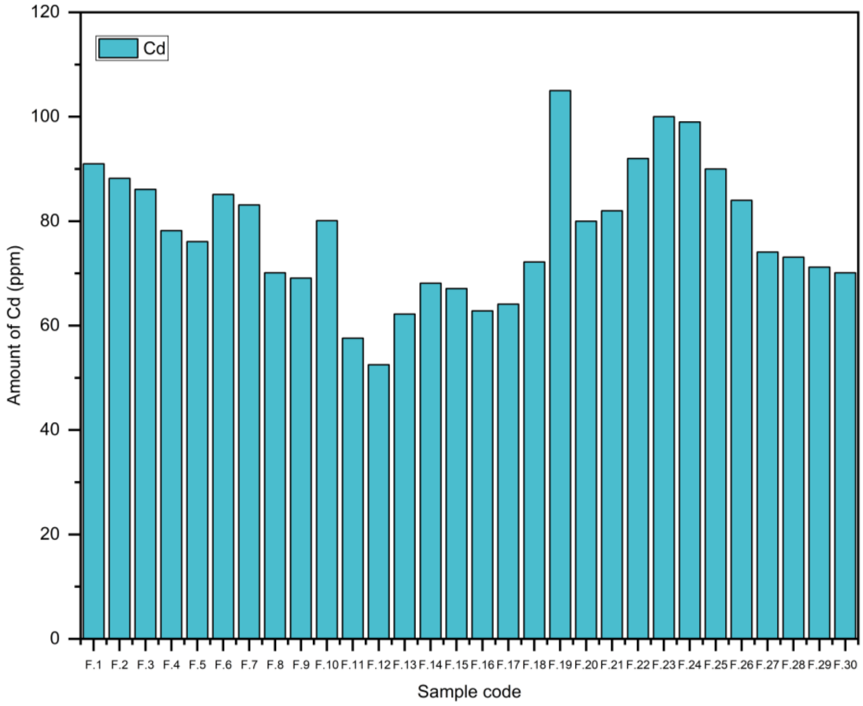

Fig. 4: Amount of heavy metal (Cd) vs sample code for all feeds in poultry farms in Erbil.

Cr steely-grey, lustrous, hard, and brittle transition metal (group 6), (Jackson, 2020). In contrast, Cr was the only metal we found to be within safe levels. The mean concentration was 44.67 ppm, significantly below the MTL of 500 ppm according to (Imran *et al.*, 2014). Although the t-test still showed statistical significance ($t=-215.88$, $p<0.001$), it indicated that chromium levels were well within a safe and potentially beneficial range. As chromium supports glucose metabolism in animals, the levels observed may be nutritionally advantageous (Bakhiet and Elbadwi, 2007). The maximum and minimum concentration of chromium element is 65.4 ppm and is 21.2 ppm respectively. as shown in Fig. (5).

Br reddish-brown, fuming liquid at room temperature with a pungent, irritating odor. Halogen (group 17), (Jackson, 2020). Our results also showed elevated Br levels, with a mean of 25.78 ppm, exceeding the recommended limit of 1 ppm according to (FAO and WHO, 2006). The t-test confirmed this as a significant difference ($t=13.481$, $p<0.001$). Br, the maximum and minimum are 4.1 ppm to 42.2 ppm respectively. The level concentration of bromine if (≥1 ppm) reduction in body weight gain, negatively impacting overall growth and performance (Koreneva *et al.*, 2023), as shown in Fig. (5).

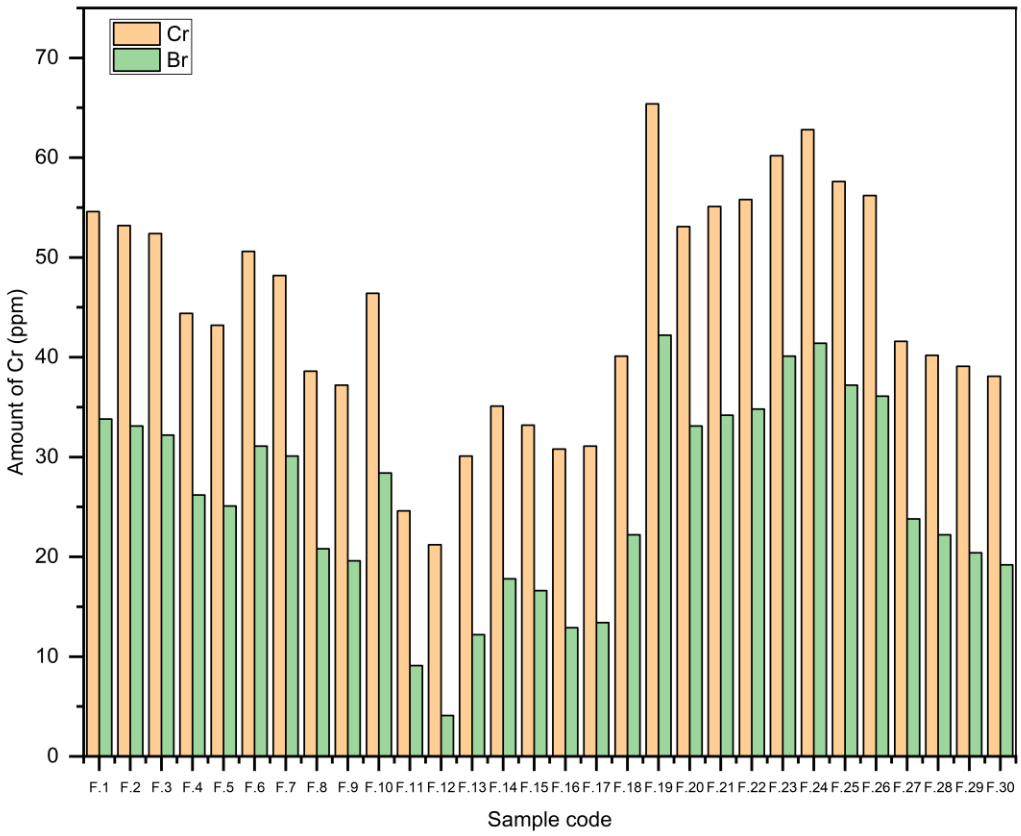

Fig. 5: Amount of Heavy metal (Cr and Br) vs sample code for all feeds in poultry farms in Erbil.

Taken together, our findings indicate that four of the five metals analyzed-Ni, Co, Cd, and Br-were present at levels well above their respective MTLs, and all differences were statistically significant. These elevated concentrations suggest contamination sources such as substandard raw materials, environmental pollutants, or lapses in manufacturing and storage practices. The presence of these metals raises serious concerns about bioaccumulation in poultry and the potential transmission of heavy metal to consumers through meat and eggs.

Table 2: Statistics analyses for all 30 data. A. Multiple modes exist. The smallest value is shown.

Statistics		Ni	Co	Cd	Cr	Br
N	Valid	30	30	30	30	30
Mean		334.0667	163.7667	77.8067	44.6733	25.7800
Std. Deviation		199.65193	94.88094	12.80121	11.55222	10.06799
Minimum		82.00	66.00	52.50	21.20	4.10
Maximum		658.00	322.00	105.00	65.40	42.20
Percentiles	25	159.7500	85.7500	68.8500	36.6750	18.8500
	50	290.0000	102.5000	77.1500	43.8000	25.6500
	75	543.7500	282.0000	86.6250	54.7250	33.9000

In our statistical analysis of heavy metals in chicken feed samples (N=30), we are finding varying concentrations across five elements. We observe that Ni shows the highest mean concentration (334.07±199.65) and the widest range (82.00-658.00), indicating substantial variability between our samples. We note that Co exhibits the second highest mean concentration (163.77±94.88) with a range of 66.00-322.00, while Cd shows a more consistent profile with a mean of 77.81±12.80 and range of 52.50-105.00. Our measurements of Cr present moderate levels (mean 44.67±11.55, range 21.20-65.40), and we find that Br has the lowest mean concentration (25.78±10.07) with values ranging from 4.10 to 42.20. We are particularly noting the substantial standard deviations, especially for Ni and Co, suggesting considerable heterogeneity in contamination levels across our sampled farms, which we attribute to variations in feed sources, environmental conditions, or manufacturing processes. We observe that the median values for Ni (290.00) and Co (102.50) being lower than their respective means suggests positively skewed distributions, potentially indicating some samples with exceptionally high contamination levels that we believe warrant further investigation regarding regulatory compliance and potential health impacts on poultry and consumers.

High levels of Ni, Co, Cd, and Br in poultry feed can be attributed to a combination of factors, starting with the contamination of raw materials, grains, and mineral additives due to environmental pollution (Mottalib *et al*., 2018). Industrial and environmental pollution from sources such as mining, smelting, industrial waste, and fossil fuel combustion (Okoye *et al*., 2011), alongside contaminated soil and water from industrial runoff, contributes to metal accumulation in feed crops (Muhammad *et al*., 2020). Furthermore, feed processing and equipment can introduce metals like Ni, Cr, and Co into the feed through leaching from metal equipment, pipes, and storage tanks (EFSA CONTAM Panel, 2018), and the use of contaminated water in feed preparation, particularly groundwater and surface water, can be a significant source of Ni, Cd, and Cr exposure. While cobalt is intentionally added as a micronutrient, it can reach unsafe levels if not properly regulated in supplements (Oladeji *et al*., 2023). Finally, the application of poultry manure, which contains heavy metals, on agricultural land can lead to these metals re-entering the food chain through crops and subsequently bioaccumulating in poultry products like meat, liver, and eggs, posing potential health risks to humans (Korish and Attia, 2020; Muhammad *et al*., 2020). To generalizing the findings of this study are particularly relevant to poultry farms in Erbil and potentially to other regions in Iraq and the Middle East where feed manufacturing, farming practices, and environmental exposure conditions are not similar. However, caution should be taken when generalizing the results to regions with different industrial activities, feed regulation standards, or environmental pollution levels. Further studies from various geographic areas and with a broader range of sampling sites are needed to validate and expand upon these results.

For chickens that consume food leftovers instead of commercial poultry feed, the levels of toxic metals are presented in (Table 2).

Table 3: Number of Heavy metal leftovers of food, and compeer to manufactured feed

Sample code	Heavy Metal				
	Ni	**Co**	**Cd**	**Cr**	**Br**
Local P. Feed 1	0	0	15.1	0.87	2.35
Local P. Feed 2	0	0	15.3	0.82	2.25
Local P. Feed 3	0	0	14.9	0.77	2.45
Average Local	0	0	15.1	0.82	2.35
Average Manufactured Feed	334.1	163.8	77.81	44.67	25.78
Std. Deviation Local	0	0	0.2	0.05	0.1

Based on our graphical analysis, we observed that the concentrations of heavy metals-including Ni, Co, Cd, Cr, and Br-were consistently higher in the original chicken feed compared to the leftover feed. This indicates that some of these metals may have been partially absorbed or filtered out during feeding. The leftover feed showed reduced levels across all measured elements, staying closer to or even below the recommended limits set by MTL these results suggest that the leftover feed may actually pose less risk in terms of heavy metal exposure, making it a potentially safer and more economical choice for farmers, provided it remains uncontaminated and properly stored.

So, we suggestion farmers to use food leftovers to make feed and stay away from manufactured feed that contains heavy metal that affect the growth of chickens as well as effect to human health. Fig. (6) shown the compare between feeds poultry and food leftovers for heavy metal.

To reduce the risk of heavy metal exposure in poultry feed, strict monitoring and regulation should be implemented at all stages of feed production. International guidelines, such as those from the FAO/WHO Codex Alimentarius and the European Commission, emphasize controlling contamination at the source, certifying raw materials, and regularly testing feed for metals like Cd, Pb, and Hg (Alimentarius, 2009). In the Middle East, environmental factors such as industrial waste, use of untreated water, and local soil conditions necessitate targeted monitoring and stricter enforcement of feed quality standards (Ali *et al*., 2020). In Iraq-particularly in regions like Erbil studies have found elevated levels of toxic metals in poultry products, underscoring the urgent need for validated testing protocols, regulation of feed materials, and educational outreach to farmers regarding safe feed practices and potential contamination sources.

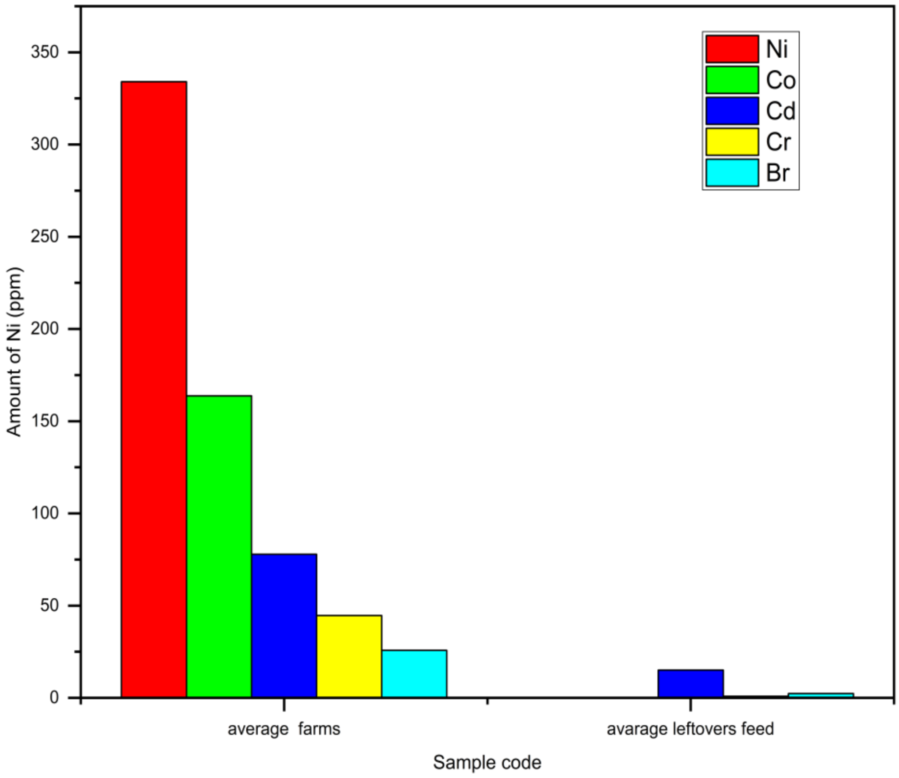

Fig. 6: Average amount of heavy metal for feeds in poultry farms and leftover feed.

Compeer to other results

Table 4: Compeer my result to other results (N.M.: not mention).

Location	**Ni**	**Co**	**Cd**	**Cr**	**Br**	**Pb**	**References**
Nigeria	1.89	0.43	0.53	0.846	N.M.	1.17	(Ukpe and Chokor, 2018)
Bulgaria	3.57	N.M.	0.34	2.26	N.M.	4.80	(Aleksiev *et al*., 2008)
Pakistan	4.14	N.M.	0.44	1.93	N.M.	3.78	(Imran *et al*., 2014)
Bangladesh	N.M.	N.M.	N.M.	0.0073	N.M.	0.2375	(Chandro, 2021)
Saudi Arabia	2.74	N.M.	0.136	N.M.	N.M.	5.05	(Korish and Attia, 2020)
Bangladesh	0.4263	N.M.	0.2114	3.8253	N.M.	0.6817	(Shahriar *et al*., 2025)
China	13.93	N.M.	1.34	58.93	N.M.	12.43	(Liu *et al*., 2020)
USA	1	N.M.	N.M.	4.02	N.M.	N.M.	(Dai *et al*., 2016)
Iraq	334.1	163.8	77.8	44.7	25.78	N.M.	My Work

In our study, we found that the concentrations of heavy metals in chicken feed samples collected from local farms in Iraq were significantly higher than those reported in other countries such as Nigeria, Saudi Arabia, Bulgaria, Pakistan, USA, China, and Bangladesh. Our feed sample contained

334.1 ppm of Ni, 163.8 ppm of Co, 77.8 ppm of Cd, 44.7 ppm of Cr, and 25.8 ppm of Br. These levels are dramatically elevated compared to international values, which typically range below a few ppm. The high concentration levels observed in this study may be attributed to several local environmental factors, such as industrial activity, waste disposal practices, or geological characteristics specific to the sampling area. Additionally, it is possible that certain farming practices contribute to the elevated levels. Many chicken farmers in the region either produce their own feed or purchase it from local manufacturers, and some may add materials intended to promote faster growth. In some cases, medicines may also be mixed with feed to accelerate treatment while the chickens are ill. These practices could potentially introduce additional heavy metals into the food chain. This stark difference suggests possible environmental contamination or poor-quality control in feed production. The unusually high levels of toxic metals in our sample raise serious concerns about poultry health and point to an urgent need for improved monitoring and regulation of feed ingredients in the region.

CONCLUSIONS

The goal of this study is to use the XRF technique to evaluate the amount of heavy metal contamination in chicken diets and the buildup of heavy metals in the Erbil Governorate, Iraq. According to the health risk assessment, eating chicken meat has some poultry carcinogenic risks for the public, as most metal intake estimates are at the upper limit. The levels of heavy metal in poultry feed exceed recommended safety limits, posing potential health risks. The average of Heavy metal for food leftovers is very low compared with the food of poultry. These high toxin levels can make the chickens sick; they don't produce as well, and they get diseases more easily. It really shows that we need better quality control for feed production.

Based on our results, we emphasize the urgent need for robust monitoring programs, quality assurance protocols, and stricter regulatory enforcement in the poultry feed industry. We also need to figure out where all this heavy metal contamination is coming from and find ways to make sure the feed is both nutritious and safe. So, we suggest farmers use food leftovers to make feed and stay away from manufactured feed. Additionally, we recommend further investigation into the origins of contamination and the extent of heavy metal transfer into poultry products in order to better protect animal health and public safety.

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REFERENCES

Adei, E.; Forson-Adaboh, K. (2008). Toxic (Pb, Cd, Hg) and essential (Fe, Cu, Zn, Mn) metal content of liver tissue of some domestic and bush animals in Ghana. *Food Add. Contam.: Part B,* **1**(2), 100-105. DOI:10.1080/02652030802566319

Aladdin, D.; Ismail, A.H.; Taha, A.H.; Hussein, Z.A. (2022). Evaluation of the trace element concentration in some livestock and poultry bone samples using X-ray fluorescence. *ZANCO J. Pure App. Sci.*, **34**(4), 67-73. DOI:10.21271/ZJPAS.34.4.7

Aleksiev, D.; Chobanova, S.; Ilchev, A. (2008). Study on the level of heavy metal contamination in feed materials and compound feed for pigs and poultry in Bulgaria. *Trakia J. Sci. (Bulgaria)*, **5**(2). 61-66.

Ali, H.S.; Almashhadany, D.A.; Khalid, H.S. (2020). Determination of heavy metals and selenium content in chicken liver at Erbil city/ Iraq. *Italian J. Food Saf.*, **9**(3), 8659. DOI:10.4081/ijfs.2020.8659

Alimentarius, C. (2009). Foods derived from modern biotechnology. Codex Alimentarius Commission, Joint FAO/WHO Food Standards Programme, Rome, Italy.

Aljohani, A.S. (2023). Heavy metal toxicity in poultry: A comprehensive review. *Front. Veter. Sci.*, **10**, 1161354. DOI:10.3389/fvets.2023.1161354

Bakhiet, A.O.; Elbadwi, S.M.A. (2007). Effects of dietary chromium supplementation on the performance and some serum parameters in bovans-type chicks. *J. Pharm. Toxi.*, **2**(4), 402-406. DOI:10.3923/jpt.2007.402.406

Banerjee, M.; Chakravarty, D.; Kalwani, P.; Ballal, A. (2022). Voyage of selenium from environment to life: Beneficial or toxic? *J. Biochem. Mole. Toxic.*, **36**(11), e23195. DOI:10.1002/jbt.23195

Bersényi, A.; Fekete, S.G.; Szilágyi, M.; Berta, E.; Zöldág, L.; Glávits, R. (2004). Effects of nickel supply on the fattening performance and several biochemical parameters of broiler chickens and rabbits. *Acta Veter. Hung.*, **52**(2), 185-197. DOI:10.1556/AVet.52.2004.2.7

Buhrke, V. E.; Jenkins, R.; Smith, D. K. (1998). "A Practical Guide for the Preparation of Specimens for X-Ray Fluorescence and X-Ray Diffraction Analysis. (No Title)". Wiley-VCH, New York.

Chandro, A. (2021). Evaluating the levels of heavy metals in poultry feed and poultry products (egg and meat) in Savar Upozilla of Bangladesh. A Thesis, Sher-E-Bangla Agricultural University, Dhaka-1207, Department of Poultry Science.

Dai, S.Y.; Jones, B.; Lee, K.M.; Li, W.; Post, L.; Herrman, T.J. (2016). Heavy metal contamination of animal feed in Texas. *J. Regu. Sci.*, **4**(1), 21-32. DOI:10.21423/JRS-V04N01P021

Diaz, G.J.; Julian, R.J.; Squires, E.J. (1994). Lesions in broiler chickens following experimental intoxication with cobalt. *Avi. Dis*., **38**(2), 308-1. DOI:10.2307/1591955

EFSA CONTAM Panel. (2018). On the risks to animal and public health and the environment related to the presence of nickel in feed. Environmental Science*, Agr Food Sci.* Semantic Scholar.

Enzweiler, J.; Vendemiatto, M.A. (2004). Analysis of sediments and soils by X-ray fluorescence spectrometry using matrix corrections based on fundamental parameters. *Geost. Geoan. Res.*, **28**(1), 103-112. DOI:10.1111/j.1751-908X.2004.tb01046.x

FAO; WHO. (2006). Code of practice for the prevention and reduction of dioxins, dioxin-like pcbs and non-dioxin-like pcbs in food and feed. In. CXC 62-2006.

Hussein, Z.A. (2015). Rn-222 concentration in greenhouses in Erbil governorate. *Inter. J. Enhanc. Res. Sci. Tech. Eng.*, **4**(1), 193-197.

Hussein, A.A.; Omer, S.S.; Ali, I.S.; Suleiman, B.F. (2021). Assessment of hepatic mineral composition in sheep, cattle, chicken, and fish in Erbil City, Kurdistan Region-Iraq. *Kurdistan J. App. Res.*, **6**(1), 46-55. DOI:10.24017/science.2021.1.6.

Hussein, Z.A. (2023). Assessment of heavy radionuclides in blood samples for workers of a cement factory by X-ray fluorescence. *J. Radi. Res. App. Sci.*, **16**(2), 100553. DOI:10.1016/j.jrras.2023.100553.

Imran, R.; Hamid, A.; Amjad, R.; Chaudhry, M.A.; Yaqub, G.; Sana, A. (2014). Evaluation of heavy metal concentration in the poultry feeds. *J. Biodiv. Envir. Sci.*, **5**(2), 394-404. DOI 10.5555/20153012675

Iqbal, H.; Shafique, M.A.; Khan, M.J. (2023). Evaluation of heavy metals concentration in poultry feed and poultry products. *J. Spo. Med. Ther.*, **8**(3), 030-035. DOI:10.29328/journal.jsmt.1001069

Ismael, D.S.; Goran, S.M.A. (2024). Health risk assessment of heavy metals in some vegetables-Erbil City-Kurdistan Region of Iraq. *Envir. Monit. Assess.*, **196**(5), 417. DOI:10.1007/s10661-024-12542-0

Jackson, T. (2020). "The Periodic Table: A Visual Guide to the Elements". White Lion Publishing.

Kalnicky, D.J.; Singhvi, R. (2001). Field portable XRF analysis of environmental samples. *J. hazar. Mat.*, **83**(1-2), 93-122. DOI:10.1016/S0304-3894(00)00330-7.

Kar, I.; Patra, A.K. (2021). Tissue bioaccumulation and toxicopathological effects of cadmium and its dietary amelioration in poultry-a review. *Bio. Trace Elem. Res.*, **199**(10), 3846-3868. DOI:10.1007/s12011-020-02503-2.

Kato, R.K.; Bertechini, A.G.; Fassani, E.J.; Santos, C.D.; Dionizio, M.A.; Fialho, E.T. (2003). Cobalt and vitamin B12 in diets for commercial laying hens on the second cycle of production. *Brazilian J. Poul. Sci.*, **5**, 45-50. DOI:10.1590/S1516-635X2003000100006

Koreneva, Y.M.; Orobchenko, O.L.; Romanko, M.Y.; Malova, N.G.; Sachuk, R.M.; Gutyj, B.V.; Radzykhovskyi, M.L. (2023). Influence of high-bromine poultry products on clinical-biochemical blood parameters of white rats. *Regu. Mech. Biosys.*, **14**(1), 125-130. DOI:10.15421/022319.

Korish, M.A.; Attia, Y.A. (2020). Evaluation of heavy metal content in feed, litter, meat, meat products, liver, and table eggs of chickens. *Anim.*, **10**(4), 727. DOI:10.3390/ani10040727

Liu, W.R.; Zeng, D.; She, L.; Su, W.X.; He, D.C.; Wu, G.Y.; Ma, X.R.; Jiang, S.; Jiang, C.H.; Ying, G.G. (2020). Comparisons of pollution characteristics, emission situations, and mass loads for heavy metals in the manures of different livestock and poultry in China. *Sci. Total Envir.* **734**, 139023. DOI:10.1016/j.scitotenv.2020.139023

Mijbas, Y.A.; Fayidh, M.A.; Nasif, R.M. (2024). Evaluation of heavy metals pollution in the sediments of diyala river lower reaches, Eastern Iraq. *Iraqi Geo. J.*, 32-45. DOI:10.46717/igj.57.1d.4ms-2024-4-14.

Miller, J.C.; Miller, N.J. (1998). “Statistics for Analytical Chemistry”. 4th ed., Ellis Howood Limited, Great Britain.

Mottalib, M.A.; Zilani, G.; Suman, T.I.; Ahmed, T.; Islam, S. (2018). Assessment of trace metals in consumer chickens in Bangladesh. *J. Health Pollution*, **8**(20), 181208. DOI:10.5696/2156-9614-8.20.181208

Muhammad, J.; Khan, S.; Lei, M.; Khan, M.A.; Nawab, J.; Rashid, A.; Ullah, S.; Khisro, S.B. (2020). Application of poultry manure in agriculture fields leads to food plant contamination with potentially toxic elements and causes health risk. *Envir. Tech. Innov.*, **19**, 100909. DOI:10.1016/j.eti.2020.100909

NRC. (2005). “Mineral Tolerance of Animals”. 2nd Revised Ed., Washington, D.C., National Academies Press. DOI:10.17226/11309

Okoye, C.O.B.; Ibeto, C.N.; Ihedioha, J.N. (2011). Assessment of heavy metals in chicken feeds sold in south eastern, Nigeria. *Adv. App. Sci. Res.*, **2**(3), 63-68.

Oladeji, F.O.; Adepoju, A.; Tawakalitu, T.A.; Awodele, O.; Ojedeji, K.A.; Adedayo, O.J. (2023). An evaluation of the presence of heavy metals in the poultry feeds marketed in Ijebu Jesa, Osun State. *Asian J. Chem. Sci.*, **13**(5), 71-77. DOI:10.9734/ajocs/2023/v13i5254

Orobchenko, O.; Koreneva, Y.; Paliy, A.; Rodionova, K.; Korenev, M.; Kravchenko, N.; Pavlichenko, O.; Tkachuk, S.; Nechyporenko, O.; Nazarenko, S. (2022). Bromine in chicken eggs, feed, and water from different regions of Ukraine. *Slovak J. Food Sci.*, **16**, 42-54. DOI:10.5219/1710

Qu, K.-C.; Li, H.Q.; Tang, K.K.; Wang, Z.Y.; Fan, R.F. (2020). Selenium mitigates cadmium-induced adverse effects on trace elements and amino acids profiles in chicken pectoral muscles. *Bio. Tra. Ele. Res*., **193**(1), 234-40. DOI:10.1007/s12011-019-01682-x

Rajib, A.; Rahman, M.T.; Ismail, A.B.M. (2021). Using X-ray fluorescence technique propagation of chromium (Cr) from poultry feeds to different parts of chicken including her eggs. *J. Phy.: Confer. Ser.*, **1718**(1), 012015. DOI:10.1088/1742-6596/1718/1/012015

Saleh, D.S.; Salh, H.; Smail, J.M.; Ahmad, S.T.; Kareem, S.R. (2024). Estimation of radiological health risks due to 226Ra, 232Th, and 40K in foods consumed in Iraqi Kurdistan Region. *Iso. Envir. Heal. Stud.*, **60**(6), 628-641. DOI:10.1080/10256016.2024.2411360

Salih, Z.R.; Othman, B.A.; Aweez, S.J. (2024). Assessment of heavy metals in rainfall as an indicator of air pollution from Erbil steel factory in Iraq. *Envir. Monit. Assess.*, **196**(3), 319. DOI:10.1007/s10661-024-12501-9

Shahriar, S.M.S.; Haque, N.; Hasan, T.; Sufal, M.T.A.; Hassan, M.T.; Hasan, M.; Salam, S.M. (2025). Heavy metal pollution in poultry feeds and broiler chickens in Bangladesh. *Toxic. Rep.*, **14**, 101932. DOI:10.1016/j.toxrep.2025.101932

Ukpe, A.R.; Chokor, A.A. (2018). Correlation between concentrations of some heavy metals in poultry feed and waste. *Open Access J. Toxic.*, **3**(2), 555609. DOI:10.19080/OAJT.2018.03.555609

Wang, H.; Dong, Y.; Yang, Y.; Toor, G.S.; Zhang, X. (2013). Changes in heavy metal contents in animal feeds and manures in an intensive animal production region of China. *J. Envir. Sci.*, **25**(12), 2435-2442. DOI:10.1016/S1001-0742(13)60473-8

Zhang, R.; Wang, L.; Zhao, J.; Wang, C.; Bao, J.; Li, J. (2016). Effects of selenium and cadmium on Ion profiles in the brains of chickens. *Bio. Tra. Ele. Res.*, **174**(1), 218-225. DOI:10.1007/s12011-016-0693-4

تقييم تركيزات المعادن الثقيلة في عينات أعلاف الدواجن من محافظة أربيل

محمد سفين جلال **زكريا عادل حسين** **جعفر مجيد إسماعيل.**

قسم الفيزياء/ كلية العلوم والصحة/ جامعة كويه/ كويه/ العراق

الملخص

تُقيّم هذه الدراسة تراكيز خمسة معادن ثقيلة سامة (النيكل، والكوبالت، والكادميوم، والكروم، والبروم) في ثلاثين عينة من أعلاف الدواجن جُمعت من مواقع مختلفة في محافظة أربيل بالعراق، باستخدام مطيافية الأشعة السينية الفلورية، وهي تقنية تحليلية غير مدمرة تُستخدم لتحديد التركيب العنصري للعينات بسرعة ودقة، مما يجعلها قيّمة للكشف عن المعادن الثقيلة في المنتجات الغذائية. تجاوزت متوسطات التركيزات بشكل ملحوظ عتبات السلامة الدولية، التي حددتها متطلبات المغذيات للدواجن. تُسلط هذه النتائج الضوء على مصدر قلق رئيسي بشأن التلوث، وتُؤكد الحاجة المُلحة إلى معايير تنظيمية ومراقبة أكثر صرامة في إنتاج أعلاف الدواجن. وقد عُثر على معادن ثقيلة سامة (النيكل، والكوبالت، والكادميوم، والكروم، والبروم). متوسط تركيزات النيكل والكوبالت والكادميوم والكروم والبروم في أعلاف الدواجن هي 199.65±334.1 و94.88±163.8 و12.8±33.81 و11.55±44.67 و10.067±25.78 جزء في المليون، في حين أن الحد الأقصى المسموح به هو 250 و25 و10 و500 و≤1 جزء في المليون على التوالي. تقدم النتائج أيضًا مقارنة بين تركيزات المعادن الثقيلة في أعلاف الدجاج المحلية وتلك التي تم اكتشافها في 30 عينة من أعلاف الدجاج الصناعية في منطقة البحث. يؤكد هذا البحث على التلوث الكبير في أعلاف الدجاج مما يثير المخاوف بشأن كل من المستهلكين من البشر والدواجن. توصي هذه الدراسة بتنفيذ تدابير أكثر صرامة لمراقبة الجودة والمراقبة المنتظمة لأعلاف الدواجن في أربيل للحد من تلوث المعادن الثقيلة، إلى جانب تشجيع استخدام مصادر الأعلاف البديلة الأكثر أمانًا، مثل بقايا الطعام، لتقليل المخاطر الصحية.

الكلمات الدالة: تقنية XRF، تركيز المعادن الثقيلة، أعلاف الدواجن، محافظة أربيل.