ZANCO Journal of Pure and Applied Sciences
The official scientific journal of Salahaddin University-Erbil
https://zancojournals.su.edu.krd/index.php/JPAS

**ISSN (print ):**2218-0230, **ISSN (online):** 2412-3986, **DOI:** **http://dx.doi.org/10.21271/zjpas**

RESEARCH PAPER

# Heavy metals concentrations in some Kurdish rice (*Oryza sativa L.*) short grains cultivated in Iraqi Kurdistan region and its health risk assessment.

Othman Kareem Qadir

[1]Food Science and Quality Control Department, College of Agricultural Engineering Sciences, University of Sulaimani, Sulaymaniyah 46001, Kurdistan Region, Iraq.

**A B S T R A C T:**

The aim of the current research was to evaluate the heavy metals contamination in Kurdish rice from the main rice-producing areas in Kurdistan and its health risk assessment. The Kurdish rice samples were collected from different locations and the concentration of heavy metals was measured by using Inductively Coupled Plasma-optical emission spectrometry (ICP-OES). The Estimated Daily Intake (EDI) was also calculated to evaluate the potential health risk assessment for the Kurdish local population through rice consumption. The mean EDI values from the rice consumption of most Kurdish rice samples were significantly higher than the safe limits set by FAO/WHO. The heavy metals were detected in the descending order Fe > Mn > Zn > Cu > Cr > Ni > As > Co > Cd in the rice samples. The results demonstrate that Kurdish rice from the investigated region has been contaminated with some heavy metals (As, Cr, Mn and Ni) which is probably linked to the used wastewater for irrigation, fertilisers and soil contamination. Overall, the local population's health might be at risk due to the combination of various metals. Therefore, strict food safety regulations are recommended for cereal crops, as well as, regular monitoring of soil contamination, water quality, application of fertilisers and pesticides in the agricultural areas in Iraqi Kurdistan.

KEY WORDS: Heavy metals, Kurdish rice, Contamination, Estimated Daily Intake, Health risk assessment
DOI: http://dx.doi.org/10.21271/ZJPAS.35.3.10
ZJPAS (2023) , 35(3);110-118 .

## 1. INTRODUCTION:

Rice is a staple and is considered an important of Iraqi food component. Rice is mainly consists of carbohydrates, fiber, proteins, and fat. heavy metals and vitamins (Sumczynski *et al.*, 2018). Moreover, also contain a number of toxic elements depending on the environment, genetics, crop management, and soil characteristics (Lange *et al.*, 2019) which could be hazardous to consumers' health (Rittirong and Saenboonruang, 2018). Heavy metal contamination of food has become a major concern in recent years due to the possibility of their accumulation in bio-systems through water and soil pollution (Lokeshwari and Chandrappa, 2006).

Kurdish rice (*Oryza sativa* L.) is one of the agricultural products in Iraqi Kurdistan. Even though Iraq is primarily a market for long grain milled rice but the Kurdish community prefers short grain rice. The Food and Agriculture Organization (FAO) reported that the average of rice consumption for Iraqi population was 36.8 kg per capita per year in 2022 (FAOSTAT report, 2022). According to KRG Ministry of Planning, 2019, rice consumption in Iraqi Kurdistan increased from 32 kg per capita in 2016 to 38.5 kg per capita in 2017. While, rice production has decreased by 50% from 22,262 to 11,838 metric tons in 2020 and 2021, respectively on a planted area of 1408.9 hectare, due to the prolonged water crisis in Kurdistan region (KRSO, 2021). The local production of rice currently covers only

* **Corresponding Author:**
Othman Kareem Qadir
E-mail: othman.qadir@univsul.edu.iq
**Article History:**
Received: 21/09/2022
Accepted: 22/10/2022
Published: 15/06 /2023

about 6% of local needs. There are some famous areas in the Kurdistan region with a high reputation for growing top-quality Kurdish rice (Short grains) such as Akre, Harir and Batas, and Bani Khelan, and this resulting a high demand from buyers.

Numerous studies have examined the levels of heavy metals in rice grains from various countries, particularly As, Cd, Pb, Ni, Mn, Cu, Cr, and Zn. Then, consuming polluted rice grain causes the transfer of heavy metals from the rice to the human body, causes serious health hazards (Zulkafflee *et al.*, 2022). For instance, High levels of As in rice can lead to severe skin problems and serious cancers (Kalita *et al.*, 2018). Thus it is important to determine the amounts of heavy metals in the cultivated Kurdish rice.

In Kurdistan, the accumulation of heavy metals in crops like rice is a serious problem, due to the usage of wastewater for agricultural irrigation, pesticides, and using high level of chemical fertilizer. However, the source of irrigation water is varied among the areas in Kurdistan, including watermills, water pumps from rivers, wellsprings, artesian wells, and rainfall (Mahmood and Akbay, 2016). The public is concerned about exposure to heavy metals through the consumption of contaminated food crops. To the best our knowledge, very few researches have been published that examine the heavy metals in Kurdish rice cultivars (Wahab and Abdulazeez, 2015).

Therefore, the aim of this study is to determine (i) the heavy metals in cultivated Kurdish rice (ii) determine estimated daily intake (EDI) in the studied Kurdish rice samples, and (iii) determine maximum tolerable daily intake (MTDI) according to the recommendations by the Joint FAO/WHO Expert Committee on Food Additives compared to the safe limits set by FAO/WHO. The results of this study on Kurdish rice could be considered safe for consumption by the Kurdish population as far as the content of heavy metals are concerned.

## 2. Materials and Methods

### The study area and sample collection

Fourteen Kurdish short grain rice samples [Akre (Se Mahi), Akre (Shash Mahi), Akre Ruta or (Tahalf), Bani Khelan, Bansnduq, Baqubara, Shaqllawa Batas, Bazian, Belula, Daradoen, Kani Krmanj, Niska Jo, Salah Agha, and Shex Tawil] were collected from different locations in Iraqi Kurdistan between June and August 2022. Besides, 1 kg of polished rice samples belonging to the sampling sites were collected from different areas in Iraqi Kurdistan. The samples were separately kept into clean plastic bags, labelled and brought to the laboratory for further analysis. The study areas in Iraqi Kurdistan are showed on the map based on the latitudes and longitudes of each location. These areas were selected based on predominant potential areas of rice production (Figure 1).

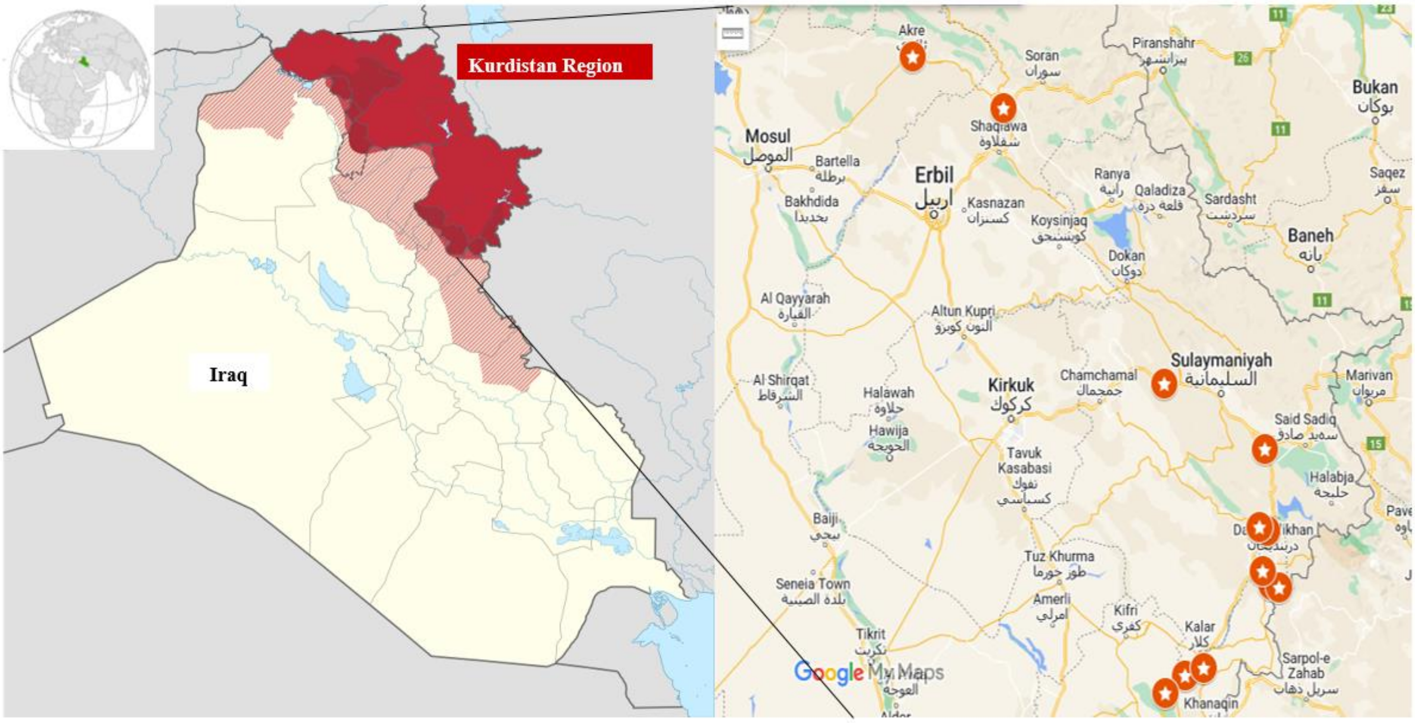


Figure 1. Map of sampling site of Kurdish rice cultivated in Kurdistan Region, Iraq.

**Samples preparation**

The collected rice samples were cleaned from husk and then sieved through a 355 µm sieve (prufsieb – ISO 3310-1) to reduce flour to remain fine fractions to verify that no defects were visible, which was then sifted to obtain the appropriate flour. All samples were dried in oven at 105 °C for 2h, and then they were finely powdered using a stainless steel grinder (COF-3820). The samples were kept in room temperature storage until analysis.

**Determination of heavy metal concentrations**

A microwave digestion system [Multiwave GO Plus – Anton Paar, Austria] was used for sample digestion. . Briefly, about 0.5g of sample weighted directly into PTFE-TFM vessels, acid mixture of 8mL $HNO_3$ + 1 mL $H_2O_2$ was added to vessels and closed immediately. The operational conditions and the heating program used were performed according to these conditions: a ramp time of 20 min to reach 200°C and a hold time of 20 min at 200°C. The vessels were opened and vented after being cooled to room temperature. In that moment, the vessels were filled with deionized water from [Barnstead GenPure - Thermofisher], then closed and vigorously shaken to eliminate any remaining colloids that may have been attached to the vessel walls. The resultant was filtered using a Whatman filter paper 41 pore size 20 µm and diluted to a final volume of 25 mL in a volumetric flask with Deionized water and stored at 4 °C.

The heavy metals concentrations were determined in digested samples using Inductivity Coupled Plasma Optical Emission Spectrometry (A Thermo Scientific iCAP 7600 ICP-OES Duo with Intelligent Scientific Data Solution™ (ISDS).

**Health risk assessment**

The EDI of heavy metals has been calculated in order to assess the possible human health risk assessment. The calculated values were compared to the PTWI in order to determine the possible harm to human health of heavy metals from eating rice. The EDI was calculated by the following equation: (Chamannejadian *et al.*, 2013)

$$EDI = C * \frac{DC}{BW} \text{ ………………….eq.1}$$

Where, EDI is estimated daily intake (mg $kg^{-1}$ body weight), C is the average of heavy metal concentrations in rice (mg $kg^{-1}$ dry weight), DC is daily rice consumption (g $day^{-1}$) per capita. For the Kurdistan population 100.82 g per capita per day was taken based on a database published by FAO (FAOSTAT database, 2022), BW is the average of body weight (kg), An average body weight of 70 kg was taken for adults in the current research zones of Iraqi Kurdistan.

**Statistical analysis**

The data ware analyzed by ANOVA using XLSTAT-pro (version 7.5.2) with for the CRD-factorial design. Fisher Least of Significant

Difference (LSD) was used to determine the significant differences between the studied rice samples at P≤ 0.05.

## 3. Results and Discussion

In this experiment, the concentration of heavy metals in the grains of selected Kurdish rice cultivars were analyzed using ICP, and the EDI for rice consumption by the local population was calculated based on the heavy metal levels in the rice samples. The obtained results of heavy metals (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, and Zn) found in 14 Kurdish rice samples from various areas are shown in Tables 1, and the EDI of heavy metals from Kurdish rice consumption was presented in Table 2.

### *Arsenic*

Arsenic, as a metalloid, it is poisonous to both plants and animals. Compared to other cereals, rice absorbs As more effectively, mostly from polluted irrigation water paddy soil, pesticides and fertilizers. The high amounts of As can accumulate in rice which is cultivated in paddy soil and be transferred to rice more efficiently (Chu *et al.*, 2021). The As only detected the rice sample which is cultivated in Salah Agha site 0.40 mg $kg^{-1}$ which is twofold higher than the FAO/WHO safe limit 0.2 mg $kg^{-1}$. According to (Polizzotto *et al.*, 2013, Kormoker *et al.*, 2022), the use of excessive amounts of chemical fertilizer and polluted groundwater for irrigation during crop cultivation cause the transfer of As from soil to plant. Therefore, to some point, it is undesirable to use the Sirwan River without treatment directly for agricultural purposes (Issa and Alshatteri, 2021). The EDI for As was 0.58 mg $kg^{-1}$ BW, which was higher than the maximum tolerable daily intake MTDI of As (0.126) in Kurdish rice cultivated in the Salah Agha area.

### *Cadmium*

Cadmium is a toxic element that is generally spread through industrial manufacturing and agricultural activities (Lien *et al.*, 2021). The concentration of Cd in in the studied Kurdish rice samples ranged between 0.01 to 0.02 mg $kg^{-1}$, and only the Baqubara contained about 0.07 mg $kg^{-1}$ which was higher than another studied samples. The Cd concentration in all the rice samples were lower than the safe limit of Cd set by FAO/WHO (0.4 mg $kg^{-1}$). According to several study, the concentration of Cd in rice grain in Thailand and Bangladesh was between0.014-0.055 and 0.98-1.61 mg $kg^{-1}$ respectively (Srinuttrakul *et al.*, 2018, Hasan *et al.*, 2022). The mean EDI of Cd was 0.10 mg $kg^{-1}$ BW for Baqubara rice samples, which is the only EDI value for rice consumption higher than the MTDI set by WHO/FAO (0.46 mg $kg^{-1}$ BW) among the other Kurdish rice samples.

### *Cobalt*

It was observed that the lowest concentration of Co was found in Baqubara (0.00 mg $kg^{-1}$) whereas, the highest concentration of Co was found in Akre Se Mahi rice 0.09 mg $kg^{-1}$. Meanwhile, there is no safe limit for Cobalt in rice grain. In addition, the concentration of Co for the Kurdish rice cultivated at Akre Ruta or (Tahalf), Belula, Daradoen, and Salah Agha were lower than the detection limits of the technique (LOD of Co was 0.0008 ppm). These results are slightly in line with results from the findings of a study from Iran, which obtained concentration for Co between 0.13 to 0.41 mg $kg^{-1}$ in domestic rice (Naseri *et al.*, 2015). However, there is no provisional tolerable daily intake (PTDI) set for Co, but the mean EDI value of Co was calculated for all the Kurdish rice cultivars, and the EDI values were between 0.00 to 0.09 mg $kg^{-1}$ BW, which lower than the MTDI (0.1 mg $kg^{-1}$), except for Akre rice (Se Mahi), the EDI of Co was 0.13 mg $kg^{-1}$ BW which was higher than MTDI for Co 0.1 mg $kg^{-1}$ BW.

### *Chromium*

The Cr concentration in the studied values different between samples significantly, the lowest value was recorded for Bani Khelan rice (0.81 mg $kg^{-1}$) followed by Kani Krmanj > Daradoen > Baqubara > Akre Ruta or (Tahalf) > Salah Agha > Shex Tawil > Bansnduq > Akre Se Mahi > Belula > Niska Jo > Batas > Bazian > Akre Shash Mahi. The result indicate that the Cr concentration in the all studied samples higher than safe limit set by FAO/WHO (1 mg $kg^{-1}$) expect for Bani Khelan rice sample. Our result is in contrast with a study conducted in Bangladesh, which have been found for that Cr concentration ranged between 11.54 and 23.67 mg $kg^{-1}$ (Hasan *et al.*, 2022). This might be a result of absorbing Cr ions through the irrigation water and soil to the rice plants (Mohanty *et al.*, 2011, Majhi and Samantaray, 2020). In addition the mean EDI values of Cr in all rice samples were higher than the safe intake limit of adults for Cr 0.020 to 0.035 mg $kg^{-1}$ (Dietary Reference Intakes (DRIs) from National Academies) (Zulkafflee *et al.*, 2022).

### *Copper*

Excessive consumption of Cu could be harm to liver and kidneys (Barber *et al.*, 2021). The lowest was in Bani Khelan (2.18 mg $kg^{-1}$) and the highest concentration of Cu was achieved in Bansnduq

(5.49 mg kg$^{-1}$), which lower than the FAO/WHO codex safe limit of Cu in rice (20 mg kg$^{-1}$). The range of Cu concentration in Kurdish rice samples was lower than the results found in collected rice samples in Bangladesh (Kormoker *et al.*, 2022), Tanzania (Machiwa, 2010), and Ethiopia (Guadie *et al.*, 2022). This may be due to the high content of lime content in Kurdistan's soil (Dalshad *et al.*), which can raise soil pH and improve the ability of soil to absorb of heavy metal ions. Additionally, it may promote the precipitation of heavy metal hydroxide or carbonate minerals which is conducive to reduce the bioavailability of heavy metals in soil (Wang *et al.*, 2012). In regards to health risk, the EDI value for Bansnduq and Bani Khelan Kurdish rice were 7.90 and 3.13 mg kg$^{-1}$ BW, respectively, which was lower than MTDI (30 mg kg-1 BW) set by (FAO/WHO, 2003). Thus, there is no risk from the Kurdish rice consumption for this metal.

***Iron***

Rice is the only cereal crop that can be cultivated on flooded soil for a long period of time. According to the data obtained from the studied rice samples, the Fe concentrations ranges from the lowest of 6.60 mg kg$^{-1}$) to the highest (of 49.02 mg kg$^{-1}$) for Daradoen and Akre Shash Mahi, respectively. The Fe concentration in all the studied rice samples were much lower than the FAO/WHO safe level. Similarly, the concentrations of Fe in the rice samples ranged from 10.8 to 45.3 mg kg$^{-1}$ in two type of rice studied by (Salih *et al.*, 2021). This might be due to presence low content of Fe in rice grain grown in Kurdistan region which the soils are calcareous and contain low amount of available Fe (Rasheed and Salih, 2020). Additionally, it was determined that the mean EDI of Fe from the rice samples was greater than the MTDI set by FAO/WHO (0.8 mg kg$^{-1}$ BW).

***Manganese***

Regarding Mn, the lowest concentration and its EDI were found in Belula (8.36 mg kg$^{-1}$ and 12.04 mg kg$^{-1}$ BW), and the highest concentration were found in Niska Jo (29.46 mg kg$^{-1}$ and 42.43 mg kg$^{-1}$ BW). The concentration of Mn in all analyzed rice samples was much higher than MTDI and the safe limit set by FAO/WHO (1 mg kg$^{-1}$). Our results are in accordance with the results reported by (Oliveira *et al.* (2012), the concentration of Mn were ranged from 4.6 to 19 mg kg$^{-1}$ in three rice samples collected in Barazil. Additionally, the Mn Concentrations was 2.9 to 40.8 mg kg$^{-1}$ in eighteen rice samples were evaluated in Pakistan (Wasim *et al.*, 2019) , and 3.56 to 27.28 mg kg$^{-1}$ were found in three different rice samples in China (Zeng *et al.*, 2015). Compared to those, the concentration of Mn in the studied rice samples is in the range reported globally. This might be due to the high concentration of Mn in the soil of Kurdistan (Kassim *et al.*, 2013).

***Nickel***

Nickel is also considered as a hazardous heavy metal that has been linked to human cancer and several health issues (Denkhaus and Salnikow, 2002). The concentration of Ni was ranged from the lowest in Bani Khelan (0.13 mg kg$^{-1}$) to the highest in Bansnduq (1.29 mg kg$^{-1}$), which were higher than the safe limit set by FAO/WHO (0.1 mg kg$^{-1}$). Among all sampling sites, Ni concentrations and its EDI value in all Kurdish rice samples were above the safe limit of Ni (0.3 mg kg$^{-1}$) for rice consumption set by WHO, 1996, except for Bani Khelan rice, this indicating the possibility of rice contamination from the water resources used for irrigation (Majid *et al.*, 2018), and the high content of Ni found in soil samples in Kurdistan (Kassim *et al.*, 2013, Khudhur *et al.*, 2018). According to previous studies on cereal crops found that nickel tends to accumulate in soils, this might due to the external sources such as fertilizers and pesticides (Martínez-Cortijo and Ruiz-Canales, 2018). Compared to the results from this study, Kormoker *et al.* (2022) reported that the average concentration of Ni was ranged from 3.81 to 13.23 mg kg$^{-1}$ in rice samples gathered from ten sampling sites in Bangladesh. Nickel can be flushed from the human system after intake, however food contamination with Ni should still be regarded. Seriously since mixing Ni with other harmful active compounds in the human system can cause serious toxicity (Abd Rashid *et al.*, 2018).

***Zinc***

Kurdish rice cultivated in Akre (Shash Mahi) had the lowest Zn content (12.26 mg kg$^{-1}$), while rice in Bansnduq had the highest Zn level (18.38 mg kg$^{-1}$). For Zn in rice grains, the FAO/WHO has established a safe level of 60 mg kg$^{-1}$. Similarly, the results revealed that rice samples from Bansnduq had the greatest EDI of Zn, while Akre rice (Shash Mahi) samples had the lowest. These results generally demonstrated that the EDI of Zn was lower than the safe limit set by WHO/FAO

(40 mg kg$^{-1}$). It has been confirmed that the zinc toxicity decreases with increasing pH, as the origin of Zinc contamination is mainly refers to the irrigation water than the soil (Martínez-Cortijo and Ruiz-Canales, 2018). In compare, the range of Zn concentration ranged from 97.34 to 121.76 mg kg$^{-1}$ in the rice samples from the main industrial areas of Bangladesh (Hasan *et al.*, 2022). In accordance with our results, the concentrations of Zn in the rice samples ranged from 8.66 to 17.4 in two type of rice (Salih *et al.*, 2021). This might due to the high capacity of Zn absorption, which causes a decrease in the availability of Zn in calcareous soils in Iraqi Kurdistan (Mam-Rasul, 2019).

## 4. Conclusions

The findings of this study showed that As, Cd, Co, Cr, Cu, Fe, Mn, Ni, and Zn, were present in rice samples from the main Kurdish rice-growing regions in Kurdistan. Some of the heavy metals (As, Cr, Mn, and Ni) concentrations were higher than the safe limit set by FAO/WHO. The effects of heavy metals on human health are based on concentrations that have built up over time via dietary consumption. Morover, health issues might arise as a result of dangerous heavy metals being present in food crops like rice. therefore, the presence of the heavy metal contents in the rice represents the level of contamination in different selected areas. Since rice is the primary staple in the Kurdish diet and can be consumed once or twice a day. Thus, more precautions should be assumed for Kurdish rice and control measures should be taken. As a result, it's critical to measure and keep an eye on the heavy metal content in Kurdish rice. Furthermore, the analysis of soil contamination and irrigation water should be conducted in order to obtain reliable evidence to confirm.

## Acknowledgments

The author would like to thank Dr. Zardasht for statistical analysis. Mr. Harem for analyzing the sample using ICP from Lox Agency company for quality control and Dr. Omed Qadir for his great help. Mr. Bawar and Mr. Irfan Ahmed during the sample collections.

## Conflicts of Interest

The author declares that there is no conflict of interest.

## References

Abd Rashid, R., Muda, N., Saaid, M., Halim, M. A. & Mohamed, K. 2018. Determination of Cd, Cu, Ni and Pb in Selected rice Grain Available in Malaysia. *International Journal of Engineering & Technology,* 7**,** 232-236.

Barber, R., Grenier, Z. A. & Burkhead, J. L. 2021. Copper toxicity is not just oxidative damage: Zinc systems and insight from Wilson disease. *Biomedicines,* 9**,** 316.

Chamannejadian, A., Sayyad, G., Moezzi, A. & Jahangiri, A. 2013. Evaluation of estimated daily intake (EDI) of cadmium and lead for rice (Oryza sativa L.) in calcareous soils. *Iranian Journal of Environmental Health Science and Engineering,* 10**,** 1-5.

Chu, D. B., Duong, H. T., Nguyet Luu, M. T., Vu-Thi, H.-A., Ly, B.-T. & Loi, V. D. 2021. Arsenic and heavy metals in Vietnamese rice: assessment of human exposure to these elements through rice consumption. *Journal of analytical methods in chemistry,* 2021.

Dalshad, R. A., Bayan, R. R. & Zhino, K. M. CLIMOSEQUENCE EFFECTS ON DEVELOPMENT OF SOME SOILS FROM IRAQI KURDISTAN REGION.

Denkhaus, E. & Salnikow, K. 2002. Nickel essentiality, toxicity, and carcinogenicity. *Critical reviews in oncology/hematology,* 42**,** 35-56.

FAO/WHO 2003. Joint, FAO/WHO Expert Committee on Food Additives, Sixty-first meeting Rome, 10-19 June 2003. Summary and conclusions. http://www.who.int/pcs/jecfa/Summaries.htm.

Guadie, A., Mohammed, I., Beshaw, T. & Tefera, M. 2022. Analysis and health risk assessments of some trace metals in Ethiopian rice (white and red) and imported rice. *Heliyon,* 8**,** e09374.

Hasan, G., Das, A. K. & Satter, M. A. 2022. Accumulation of Heavy Metals in Rice (Oryza sativa. L) Grains Cultivated in Three Major Industrial Areas of Bangladesh. *Journal of Environmental and Public Health,* 2022.

Issa, H. M. & Alshatteri, A. H. 2021. Impacts of wastewater discharge from Kalar city on Diyala-Sirwan river water quality, Iraq: pollution evaluation, health risks of heavy metals contamination. *Applied Water Science,* 11**,** 1-13.

Kalita, J., Pradhan, A. K., Shandilya, Z. M. & Tanti, B. 2018. Arsenic stress responses and tolerance in rice: physiological, cellular and molecular approaches. *Rice Science,* 25**,** 235-249.

Kassim, J., Kareem, M. & Mohammed, Z. 2013. Nickel, Co, Cr, and Mn metals uptake by wheat and grass plants from serpentinitic soils of Penjwin, Kurdistan Region-Iraq. *International Journal of Plant, Animal and Environmental Sciences,* 3**,** 76-84.

Khudhur, N. S., Khudhur, S. M. & Ahmad, I. N. 2018. An Assessment of heavy metal soil contamination in a Steel Factory and the surrounding area in Erbil City. *Jordan Journal of Earth and Environmental Sciences,* 9**,** 1-11.

Kormoker, T., Proshad, R., Islam, M. S., Tusher, T. R., Uddin, M., Khadka, S., Chandra, K. & Sayeed, A. 2022. Presence of toxic metals in rice with human health hazards in Tangail district of Bangladesh. *International journal of environmental health research,* 32**,** 40-60.

KRSO. 2021. Kurdistan Region Statistics Office. *Production of Rice in Kurdistan Region /Ton.*

Kurdistan Regional Government, Ministry of Planning
Lange, C. N., Monteiro, L. R., Freire, B. M., Franco, D. F., De Souza, R. O., Dos Reis Ferreira, C. S., Da Silva, J. J. C. & Batista, B. L. 2019. Mineral profile exploratory analysis for rice grains traceability. *Food chemistry,* 300**,** 125145.
Lien, K.-W., Pan, M.-H. & Ling, M.-P. 2021. Levels of heavy metal cadmium in rice (Oryza sativa L.) produced in Taiwan and probabilistic risk assessment for the Taiwanese population. *Environmental Science and Pollution Research,* 28**,** 28381-28390.
Lokeshwari, H. & Chandrappa, G. J. C. S. 2006. Impact of heavy metal contamination of Bellandur Lake on soil and cultivated vegetation. 622-627.
Machiwa, J. F. 2010. Heavy metal levels in paddy soils and rice (Oryza sativa (L)) from wetlands of Lake Victoria Basin, Tanzania. *Tanzania Journal of Science,* 36.
Mahmood, M. & Akbay, C. 2016. *Economic analysis of rice production in Akre city, Northern Region of Iraq.* Fen Bilimleri Enstitüsü.
Majhi, P. & Samantaray, S. M. 2020. Effect of hexavalent chromium on paddy crops (Oryza sativa). *Journal of Pharmacognosy and Phytochemistry,* 9**,** 1301-5.
Majid, S. N., Khwakaram, A. I., Gado, C. & Majeed, B. K. 2018. Pollution status evaluation of some heavy metals along some surface water sources by multivariate data analysis at Sulaimani governorate. *J. Zankoy Sulaimani,* 20**,** 63-80.
Mam-Rasul, G. A. 2019. Zinc Sorption in Calcareous Soils of the Kurdistan Region of Iraq. *Soil Science,* 184**,** 60-68.
Martínez-Cortijo, J. & Ruiz-Canales, A. 2018. Effect of heavy metals on rice irrigated fields with waste water in high pH Mediterranean soils: The particular case of the Valencia area in Spain. *Agricultural Water Management,* 210**,** 108-123.
Mohanty, M., Pattnaik, M. M., Mishra, A. K. & Patra, H. K. 2011. Chromium bioaccumulation in rice grown in contaminated soil and irrigated mine wastewater—a case study at South Kaliapani chromite mine area, Orissa, India. *International journal of phytoremediation,* 13**,** 397-409.
Naseri, M., Rahmanikhah, Z., Beiygloo, V. & Ranjbar, S. 2014. Effects of two cooking methods on the concentrations of some heavy metals (cadmium, lead, chromium, nickel and cobalt) in some rice brands available in Iranian Market. *Journal of Chemical Health Risks,* 4**,** 65-72.
Naseri, M., Vazirzadeh, A., Kazemi, R. & Zaheri, F. 2015. Concentration of some heavy metals in rice types available in Shiraz market and human health risk assessment. *Food chemistry,* 175**,** 243-248.
Oliveira, A., Baccan, N. & Cadore, S. 2012. Evaluation of metal ions in rice samples: extraction and direct determination by ICP OES. *Journal of the Brazilian Chemical Society,* 23**,** 838-845.
Polizzotto, M. L., Lineberger, E. M., Matteson, A. R., Neumann, R. B., Badruzzaman, A. B. M. & Ali, M. A. 2013. Arsenic transport in irrigation water across rice-field soils in Bangladesh. *Environmental pollution,* 179**,** 210-217.
Rasheed, M. S. & Salih, K. H. K. H. 2020. IRON CONCENTRATION IN DIFFERENT BREAD CONSUMED IN SULAYMANIYAH PROVINCE, IRAQI KURDISTAN. *Plant Archives,* 20**,** 832-835.
Rittirong, A. & Saenboonruang, K. 2018. Quantification of aluminum and heavy metal contents in cooked rice samples from Thailand markets using inductively coupled plasma mass spectrometry (ICP-MS) and potential health risk assessment. *Emirates Journal of Food and Agriculture***,** 372-380.
Salih, K. H. H., Rasheed, M. S., Mohammed, H. J. & Saeed, A. A. The Estimation of Iron, Zinc, Phytic Acid Contents and Their Molar Ratios in Different Types of Bread and Rice Consumed in Halabja City, Iraqi Kurdistan. IOP Conference Series: Earth and Environmental Science, 2021. IOP Publishing, 012131.
Srinuttrakul, W., Permnamtip, V. & Yoshida, S. 2018. Heavy metals in Sangyod rice samples cultivated in Phatthalung, Thailand. *Food and Applied Bioscience Journal,* 6**,** 45-54.
Sumczynski, D., Koubová, E., Šenkárová, L. & Orsavová, J. 2018. Rice flakes produced from commercial wild rice: Chemical compositions, vitamin B compounds, mineral and trace element contents and their dietary intake evaluation. *Food chemistry,* 264**,** 386-392.
Wahab, M. F. & Abdulazeez, Z. M. 2015. Comparison Study of Trace and Toxic Minerals in Local and Imported Rice in Sulaimani - Iraq. *Asian Journal of Agriculture and Food Sciences,* 3.
Wang, L., Xu, Y., Liang, X., Sun, G., Sun, Y. & Lin, D. 2012. Remediation of contaminated paddy soil by immobilization of pollutants in the Diaojiang catchment, Guangxi Province. *Journal of Ecology and Rural Environment,* 28**,** 563-568.
Wasim, A. A., Naz, S., Khan, M. N. & Fazalurrehman, S. 2019. Assessment of heavy metals in rice using atomic absorption spectrophotometry–a study of different rice varieties in Pakistan. *Pakistan Journal of Analytical & Environmental Chemistry,* 20**,** 67-74.
Zeng, F., Wei, W., Li, M., Huang, R., Yang, F. & Duan, Y. 2015. Heavy metal contamination in rice-producing soils of Hunan province, China and potential health risks. *International Journal of Environmental Research and Public Health,* 12**,** 15584-15593.
Zulkafflee, N. S., Mohd Redzuan, N. A., Nematbakhsh, S., Selamat, J., Ismail, M. R., Praveena, S. M., Yee Lee, S. & Abdull Razis, A. F. 2022. Heavy metal contamination in Oryza sativa L. at the eastern region of Malaysia and its risk assessment. *International Journal of Environmental Research and Public Health,* 19**,** 739.

.

**Table 1. Heavy metals concentrations in Kurdish rice sample (Means ± SD) in mg $kg^{-1}$, n=3**

| Rice cultivars | As | Cd | Co | Cr | Cu | Fe | Mn | Ni | Zn |
|---|---|---|---|---|---|---|---|---|---|
| Akre (Se Mahi) | ND | 0.01 ± 0.01 de | 0.09 ± 0.02 a | 1.26 ± 0.02 f | 2.40 ± 0.04 k | 16.63 ± 0.21 d | 12.08 ± 0.14 h | 0.90 ± 0.01 d | 16.77 ± 0.04 d |
| Akre (Shash Mahi) | ND | 0.02 ± 0.00 bc | 0.05 ± 0.00 b | 5.81 ± 0.04 a | 2.85 ± 0.01 i | 49.02 ± 0.21 a | 13.05 ± 0.09 g | 0.84 ± 0.01 e | 12.26 ± 0.03 n |
| Akre Ruta (Tahalf) | ND | 0.01 ± 0.00 cde | ND | 1.08 ± 0.02 gh | 3.10 ± 0.02 g | 10.72 ± 0.13 h | 21.27 ± 0.09 d | 0.60 ± 0.02 h | 16.09 ± 0.06 g |
| Bani Khelan | ND | 0.01 ± 0.01 bcde | 0.02 ± 0.00 c | 0.81 ± 0.03 j | 2.18 ± 0.05 l | 10.71 ± 0.29 h | 8.90 ± 0.10 l | 0.13 ± 0.02 l | 13.69 ± 0.05 m |
| Bansnduq | ND | 0.02 ± 0.01 bc | 0.02 ± 0.01 c | 1.24 ± 0.03 f | 5.49 ± 0.06 a | 9.81 ± 0.09 i | 22.47 ± 0.14 c | 1.29 ± 0.01 a | 18.38 ± 0.04 a |
| Baqubara | ND | 0.07 ± 0.01 a | 0.00 ± 0.00 d | 1.07 ± 0.02 gh | 3.11 ± 0.02 g | 13.80 ± 0.14 f | 17.74 ± 0.13 e | 1.24 ± 0.02 b | 16.65 ± 0.07 e |
| Batas | ND | 0.02 ± 0.00 b | 0.02 ± 0.01 c | 1.49 ± 0.03 c | 4.69 ± 0.05 c | 13.76 ± 0.11 f | 11.80 ± 0.14 i | 0.52 ± 0.00 j | 14.10 ± 0.03 k |
| Bazian | ND | 0.01 ± 0.01 bcde | 0.06 ± 0.01 b | 2.10 ± 0.02 b | 5.08 ± 0.04 b | 34.23 ± 0.46 b | 17.79 ± 0.21 e | 0.94 ± 0.01 c | 17.49 ± 0.02 c |
| Belula | ND | 0.02 ± 0.01 bc | ND | 1.32 ± 0.01 e | 2.97 ± 0.06 h | 15.06 ± 0.12 e | 8.36 ± 0.04 m | 0.57 ± 0.01 i | 13.92 ± 0.05 l |
| Daradoen | ND | 0.01 ± 0.00 bced | ND | 1.06 ± 0.01 h | 2.70 ± 0.03 j | 6.60 ± 0.07 k | 14.82 ± 0.13 f | 0.44 ± 0.01 k | 16.51 ± 0.04 f |
| Kani Krmanj | ND | 0.01 ± 0.00 e | 0.03 ± 0.01 c | 1.01 ± 0.02 i | 3.57 ± 0.05 e | 10.65 ± 0.17 h | 11.00 ± 0.13 k | 0.64 ± 0.02 g | 14.95 ± 0.02 j |
| Niska Jo | ND | 0.01 ± 0.00 bcede | 0.05 ± 0.00 b | 1.38 ± 0.03 d | 4.49 ± 0.05 d | 18.70 ± 0.15 c | 29.46 ± 0.15 a | 0.80 ± 0.01 f | 15.77 ± 0.06 h |
| Salah Agha | 0.40 ± 0.02 a | 0.02 ± 0.00 bc | ND | 1.10 ± 0.01 gh | 3.39 ± 0.04 f | 11.11 ± 0.10 g | 11.31 ± 0.07 j | 0.94 ± 0.01 c | 15.69 ± 0.04 i |
| Shex Tawil | ND | 0.02 ± 0.00 bc | 0.02 ± 0.01 c | 1.11 ± 0.01 g | 2.47 ± 0.06 k | 9.29 ± 0.05 j | 23.26 ± 0.11 b | 0.43 ± 0.03 k | 17.84 ± 0.04 b |
| **FAO/WHO safe limits | 0.2 | 0.4 | Not set | 1.0 | 20 | 450 | 1.0 | 0.1 | 60 |

Different Letters inside the column indicates significant differences in treatment according to LSD test at ($P \leq 0.05$).
*ND; Not detected, ** From the Codex Alimentarius Commission (CAC) Standard Codex Standard 193-1995; amended in 2019.
***According to the tolerance limit of copper in food (Chinese GB Standards, 15199-1994).

**Table 2. The Estimated daily intake (Means ± SD) of heavy metals from the Kudish rice samples in mg $kg^{-1}$ body weight for an adult with 70 kg body weight.**

| Rice cultivars | As | Cd | Co | Cr | Cu | Fe | Mn | Ni | Zn |
|---|---|---|---|---|---|---|---|---|---|
| Akre (Se Mahi) | ND | 0.01 ± 0.01 de | 0.13 ± 0.02 a | 1.81 ± 0.03 f | 3.46 ± 0.06 k | 23.95 ± 0.30 d | 17.39 ± 0.20 h | 1.29 ± 0.02 d | 24.16 ± 0.06 d |
| Akre (Shash Mahi) | ND | 0.02 ± 0.01 bc | 0.07 ± 0.00 b | 8.36 ± 0.05 a | 4.11 ± 0.01 i | 70.60 ± 0.30 a | 18.79 ± 0.14 g | 1.21 ± 0.01 e | 17.66 ± 0.04 n |
| Akre Ruta or (Tahalf) | ND | 0.01 ± 0.00 cde | ND | 1.55 ± 0.03 gh | 4.47 ± 0.03 g | 15.44 ± 0.19 h | 30.63 ± 0.13 d | 0.87 ± 0.03 h | 23.17 ± 0.08 g |
| Bani Khelan | ND | 0.02 ± 0.01 bcde | 0.03 ± 0.01 c | 1.16 ± 0.05 j | 3.13 ± 0.07 l | 15.43 ± 0.42 h | 12.82 ± 0.15 l | 0.19 ± 0.03 l | 19.71 ± 0.07 m |
| Bansnduq | ND | 0.02 ± 0.01 bc | 0.03 ± 0.02 c | 1.78 ± 0.05 f | 7.90 ± 0.09 a | 14.12 ± 0.13 i | 32.36 ± 0.20 c | 1.86 ± 0.02 a | 26.48 ± 0.06 a |
| Baqubara | ND | 0.10 ± 0.01 a | 0.00 ± 0.00 d | 1.54 ± 0.03 gh | 4.48 ± 0.03 g | 19.87 ± 0.20 f | 25.55 ± 0.19 e | 1.79 ± 0.02 b | 23.99 ± 0.10 e |
| Batas | ND | 0.03 ± 0.01 b | 0.03 ± 0.01 c | 2.15 ± 0.04 c | 6.76 ± 0.08 c | 19.82 ± 0.16 f | 17.00 ± 0.20 i | 0.74 ± 0.00 j | 20.31 ± 0.05 k |
| Bazian | ND | 0.02 ± 0.01 bcde | 0.09 ± 0.01 b | 3.03 ± 0.03 b | 7.32 ± 0.05 b | 49.30 ± 0.66 b | 25.62 ± 0.30 e | 1.35 ± 0.01 c | 25.19 ± 0.04 c |
| Belula | ND | 0.02 ± 0.01 bc | ND | 1.90 ± 0.01 e | 4.28 ± 0.09 h | 21.68 ± 0.17 e | 12.04 ± 0.05 m | 0.83 ± 0.01 i | 20.05 ± 0.07 l |
| Daradoen | ND | 0.02 ± 0.01 bced | ND | 1.53 ± 0.01 h | 3.89 ± 0.05 j | 9.50 ± 0.10 k | 21.35 ± 0.19 f | 0.63 ± 0.01 k | 23.78 ± 0.05 f |
| Kani Krmanj | ND | 0.01 ± 0.00 e | 0.04 ± 0.01 c | 1.46 ± 0.03 i | 5.14 ± 0.07 e | 15.34 ± 0.25 h | 15.84 ± 0.19 k | 0.91 ± 0.03 g | 21.53 ± 0.03 j |
| Niska Jo | ND | 0.02 ± 0.00 bcede | 0.08 ± 0.00 b | 1.98 ± 0.04 d | 6.46 ± 0.07 d | 26.94 ± 0.22 c | 42.43 ± 0.21 a | 1.15 ± 0.02 f | 22.71 ± 0.08 h |
| Salah Agha | 0.58 ± 0.02 a | 0.02 ± 0.01 bc | ND | 1.58 ± 0.02 gh | 4.88 ± 0.05 f | 16.00 ± 0.15 g | 16.29 ± 0.10 j | 1.36 ± 0.02 c | 22.59 ± 0.05 i |
| Shex Tawil | ND | 0.02 ± 0.00 bc | 0.02 ± 0.01 c | 1.60 ± 0.01 g | 3.55 ± 0.09 k | 13.38 ± 0.08 j | 33.51 ± 0.16 b | 0.62 ± 0.04 k | 25.69 ± 0.06 b |
| | 0.126[c] | 0.046[c] | Not set [e] | 0.035[f] | 30[c] | 0.8[d] | 5.0 | 0.3[b] | 40[c] |

Different Letters inside the column indicates significant differences in treatment according to LSD test at ($P \leq 0.05$).
*ND; Not detected.
[a](RDA 1989), [b](WHO 1996), [c](JECFA 2003), MTDI =Maximum tolerable daily intake, [d]EFSA, FAO/WHO, 2010, [e] No PTDI set for Co has been provided there Maximum Tolerable Daily Intake is (MTDI) value of 0.1 mg $kg^{-1}$ body weight (Naseri *et al.*, 2014). [f]Dietary Reference Intakes (DRIs) from National Academies, the safe intake limit of adults for Cr is in the ranges 0.020 to 0.035 mg/kg/day.