ORIGINAL ARTICLE OPEN ACCESS

Estimation of Heavy Metals in Canned Foods Sold in the Markets of Peshawar, Khyber Pakhtunkhwa, Pakistan

Shaista Nooreen[1], Kashif Ur Rehman Khalil[1], Rozina Rehman[1], Sarfaraz Khan Afridi[1], Baber Awan[2], Azra Shaheen[3]
[1]Department of Community Medicine, Khyber Medical College, Peshawar, [2]Department of Community Medicine, Pak International Medical College, Peshawar, [3]Department of Community Medicine, Nishter Medical College, Multan, Pakistan.

ABSTRACT

Background: Heavy metals in food are an emerging public health issue in the modern food industry. The toxicity of heavy metals can have serious effects on human health. Therefore, the present study was conducted to measure the concentration of heavy metals in branded canned foods.

Methods: A cross-sectional analytical study was conducted from January 2021 to July 2022. A total of 60 samples consisting of 42 International and 18 Pakistani canned foods. Collected samples were analyzed by an atomic absorption spectrometer present in the Public Health laboratory, Khyber Medical College, Peshawar. Data was analyzed using SPSS version 23 for Windows. The p-value less than 0.05 was taken as significant.

Results: Tested samples were selected from 4 food types; i.e., fruits 19, lentils and legumes 18, vegetables 17, and 6 fish cans. Eighteen were preserved in sugary syrup and 42 in brine. International branded cans had upper normal levels of Cd, Cr, and Cu. While Pakistani cans showed upper normal Pb levels in the recommended set point by FAO/WHO, i.e., 0.1 mg/L Cd, 1 mg/L Cr, 0.4mg/L Cu, and 0.5 mg/L Pb. Pb, Cd, Cu and Cd levels in Pakistani canned food were in a range of 0.29-0.0183 mg/L, 0.001- 0.047 mg/L, 0.008-0.022mgL and -0.069-0.123mg/L. Metals in International branded cans were in the range of -0.001- 0.198 mg/L, 0.001-0.065mg/L, -0.00-0.049mg/L and -0.004-0.137mg/L. This study revealed the upper normal limit for Pb and exceeding Cd levels in the tested samples.

Conclusion: The present study concluded that heavy metal concentrations are well above the permissible level stated by the WHO. Therefore, canned food should be consumed consciously.

Keywords: Heavy Metals, Canned Food, Pakistani, International

Corresponding Author:
Dr. Kashif Ur Rehman Khalil,
Department of Community Medicine,
Khyber Medical College,
Peshawar, Pakistan.
Email: dr.kashif.khalil@gmail.com
Doi: https://doi.org/10.36283/ziun-pjmd14-2/039

How to cite: Nooreen S, Khalil KUR, Rehman R, Afridi SK, Awan B, Shaheen A Estimation of Heavy Metals in Pakistani and International Branded Canned Foods in the Markets of Peshawar, Khyber Pakhtunkhwa, Pakistan. Pak J Med Dent. 2025 April ;14(2): 251-257. Doi: https://doi.org/10.36283/ziun-pjmd14-2/039.

Received: Wed, September 18, 2024 **Accepted:** Sat, March 29, 2025 **Published:** Sun, April 13, 2025

INTRODUCTION

Food is a basic necessity of life. With growing food industries and the development of new preservative methods, the use of canned food is increasing all over the world[1]. The delicious nature of these products has made them popular day by day[2]. Although popular but these foods are risky to human health at the same time[3]. Canned food manufactured in unhygienic methods and processing is prone to numerous health effects[4]. Some of these effects are acute, like food poisoning, and others are chronic, e.g., toxicity by heavy metals contamination from cans[5].

Heavy metals like cadmium, chromium, mercury, and arsenic are potentially dangerous and have life-threatening complications like cancers, chronic kidney disease, memory impairment etc[6]. Heavy metal contamination, especially from canned food, is usually ignored due to chronic effects, and if particularly used for longer periods[7]. Globally, the use of canned food has increased because of the easy availability and delicious nature of these foods and their availability throughout the seasons. International trading and globalization have made canned food available in almost every country[8].

Pakistan is an agricultural country, and fresh food and vegetables are available throughout the season[9]. Canned foods are becoming popular in Pakistan because of their deliciousness and use of artificial flavors and colors. Media has a great role in promoting these items and bringing them close to us[10]. Children who are our future are particularly addicted to these food items. In Pakistan, both locally manufactured and international canned foods are liked by people, especially children [11,12].
In Pakistan, very few studies have been done to estimate the concentration of heavy metals in canned food items. In Peshawar, KPK, very few studies were found in the literature. The present study is, therefore, novel and important because it will provide us with baseline data about the concentration of heavy metals in both local and international branded canned food items. The results of this study will be shared with the food authority for strict legislation against contaminated canned foods.

METHODS

A cross-sectional analytical study was conducted from January 2021 to July 2022.
The sample size was calculated using the following formula:

$$N = \frac{(1.96)^2 \times (s)^2}{(d)^2}$$

N= Sample size
S =Maximum standard deviation, which was taken as 0.20 from a previous study[18]
d = Margin of error, which was taken as 5% in this study
The calculated sample size after inputting the data was 60 samples for this study.

Canned foods were selected using a non-probability convenience sampling technique. Fruit, vegetables, fish, and legumes are proportionately distributed into Pakistani and internationally branded canned food.
Data was collected after ethical approval was granted by the institute's Graduate Committee and Institutional Review Board **(**No=DIR/KMU-AS&RB/EH/00029). Samples of canned food were analyzed using the wet digestion technique and analyzed in the Atomic Absorption Spectrometer.

The sample was prepared by the "Acid digestion technique. A ground sample of 2gm weight was taken in a volumetric glass flask containing perchloric acid ($HClO_4$) and Nitric acid (HNO_3) in a ratio of 1:3, i.e., for every 5ml of perchloric acid ($HClO_4$) and 15 ml of Nitric acid (HNO_3) was added in a flask. It was kept over a hot plate for about 2 hours till white fumes appeared and the volume reduced to half, i.e., 10 ml. This procedure was repeated to ensure complete digestion. The flask was then filled with de-ionized water for dilution to the mark of 100ml. It was then filtered through Whatman filter paper No. 40, and the sample was ready for the estimation of concentration of the elements on an atomic Absorption Spectrometer.
Data was analyzed using SPSS version 23 for Windows. A t-test was used to find any statistically significant differences between variables. A value less than 0.05 was considered significant.

RESULTS

Table 1: Metal Concentration According to the Manufacturer's Country

Manufacturer		Lead	Cadmium	Copper	Chromium
International Branded Canned Food 42	Mean	0.063081	0.014548	0.005024	0.034000
	Std. Deviation	0.0636602	0.0304480	0.0133444	0.0605761

Pakistani 18	Mean	0.076611	0.008833	0.001222	-0.003056
	Std. Deviation	0.0453913	0.0067323	0.0075658	0.0641281
Total	**Mean**	**0.067140**	**0.012833**	**0.003883**	**0.022883**
	N	**60**	**60**	**60**	**60**
	Std. Deviation	**0.0587281**	**0.0257736**	**0.0119718**	**0.0634676**

This study was carried out to estimate the concentration of heavy metals Lead (Pb), Cadmium (Cd), Chromium (Cr), and copper (Cu). A total of 60 samples were collected, which included 42 international branded cans and 18 Pakistani branded cans.

Among all 60 samples, 19 were fruit samples, 18 were lentil and legume cans, and 17 were cans of vegeta. Of these 60 samples, 18 were preserved in sugar syrup. while brine was used as a preservative for 42 samples bles and 6 cans containing fish product.

Heavy metal concentration was within upper normal limits in International branded canned food in comparison to Pakistani branded canned foods, except for the Pb level. Pb levels were found at high upper limits in Pakistani canned food, as shown in **Table 1.**

Table 2: Mean Concentration of Heavy Metals in Different types of canned foods.

Type of food cans		Lead	Cadmium	Copper	Chromium
Vegetable 17	Mean	0.052118	0.012765	0.002353	0.006824
	Std. Deviation	0.0327851	0.0103412	0.0076644	0.0682012
Fruit 19	Mean	0.085526	0.018632	0.004105	0.014579
	Std. Deviation	0.0622695	0.0434373	0.0119810	0.0642740
Lentil & Legumes 18	Mean	0.045133	0.008889	0.006389	0.035167
	Std. Deviation	0.0550629	0.0117368	0.0164822	0.0548434
Fish 6	Mean	0.117500	0.006500	0.000000	0.057833
	Std. Deviation	0.0784366	0.0018708	0.0037417	0.0663398
Total	**Mean**	**0.067140**	**0.012833**	**0.003883**	**0.022883**
	N	**60**	**60**	**60**	**60**
	Std. Deviation	**0.0587281**	**0.0257736**	**0.0119718**	**0.0634676**

Amongst all 60 samples, vegetables and canned food samples were found to be low in concentration of Pb, Cd, Cu, and Cr. Fruit samples had upper limits in Cd and Pb contents, but their Pb level were less than fish Pb levels. Legumes and lentils were low in Pb, Cd, and Cu, but their Cr levels were in the upper normal limit, next to fish Cr levels. Upper normal limits of Pb and Cr concentrations were obtained in fish samples. Altogether, all tested heavy metals were within normal limits. As summarized in **Table 2.**

Upper normal Pb levels were observed in sardine fish products. While Cr levels, within upper normal limits, were found in tuna fish canned products. One product, i.e. tuna chunks of CalG, had high lead levels but within recommended permissible levels. Two diamond sardine brands had very low lead levels, but their Cr levels were higher than other sardine fish cans, although within permissible set points.

Table 3: Independent Sample T-tests for Pakistani and International Branded Canned Food

Chromium		Copper		Cadmium		Lead				
Equal variances not assumed	Equal variances assumed	Equal variances not assumed	Equal variances assumed	Equal variances not assumed	Equal variances assumed	Equal variances not assumed	Equal variances assumed			
	.053		1.764		2.429		2.243	F	Levene's Test for Equality of Variances	
	.818		.189		.125		.140	Sig		
2.085	2.134	1.396	1.130	1.152	.784	-.932	-.815	T	t-test for Equality of Means	
30.631	58	53.280	58	49.339	58	44.600	58	Df		
.045	.037	.169	.263	.255	.436	.357	.418	Sig.(2 tailed)		
.0370556	.0370556	.0038016	.0038016	.0057143	.0057143	-.0135302	-.0135302	Mean Difference		
.0177718	.0173647	.0027240	.0033648	.0049590	.0072847	.0145243	.0165919	Std. Error Difference		
.0007921	.0022964	-.0016613	-.0029338	-.0042494	-.0088676	-.0427909	-.0467425	95% Confidence Interval of the Difference	Lower	
.0733190	.0718147	.0092645	.0105370	.0156780	.0202961	.0157306	.0196822		Upper	

P Value of Pb, Cd and Cu was more than 0.05, its mean that there was no difference in mentioned concentration of theses metals between Pakistani and International branded canned food. As the P Value of Cr was less than 0.05. Which mean that there was significant difference in concentration of Chromium in Pakistani and International branded canned food as shown in **Table 3.**

DISCUSSION

The present study was conducted to estimate the concentration of heavy metals in canned foods. The present study showed mean concentrations of lead, Cadmium, Copper and Chromium in international branded cans were 0.063mg\L, 0.014mg\L, 0.005mg\L, and 0.034mg\L, respectively. Moreover, in Pakistani brands, the levels of these heavy metals were 0.076mg\L, 0.008mg\L, 0.0012 mg\L, and -0.003056mg\L, respectively.

A study was done to estimate the concentration of lead, cadmium, and copper in 16 different types of canned food manufactured by four different companies[13]. Their study showed the highest concentration of zinc in the canned food of different brands. Cadmium was one of the metals found in the lowest concentration. However, the highest concentration of Cadmium was found in canned beans, followed by canned chickpeas. The reverse was found true for our study as high levels of Cd were found in bajela beans, followed by chick peas, respectively[14]. The limitations of their study were the small sample size and the testing of metal cans only. Although in our study, all elements were found below permissible levels, high levels of lead, i.e., 0.17 mg\L, and Cr, i.e., 0.057 mg\L, were found in canned fish samples. However, the fruit had a high level of Cd, i.e., 0.018 mg\L. One of the International branded canned fruit samples, i.e., olives, was found with Cd limit exceeding the normal limits of 0.188mg\L. Lead levels were also found high in FIGARO olives, i.e., 0.188mg\L. This is of concern to public health and food safety. While a high level of copper, i.e., 0.006mg\L, was found in legumes and lentils.

Scientists conducted an interesting study in Irbid city, Jordan[15]. Their study sample included canned tomato sauce, canned green beans, canned whole carrots, and canned pineapple. Their findings showed significant variations in the metal

concentrations between the same types of food cans of different brands. They attributed these variations to the type of can, the source of food itself, or the possibility of corrosion or leaching. The highest concentration of lead and arsenic and the lowest concentration of cadmium were detected. Whereas, in our study, chick peas and beans were found with high levels of Cadmium, which is inconsistent of the abovementioned study findings.

A similar study was conducted in Irbid city, Jordan. The food types in the sample consisted of tuna, beef, sardines, and mushrooms, taking 44 samples of each type[16]. These samples were evaluated for seven heavy metals: As, Cd, Ni, Cr, Cu, Zn, and Pb in imported canned food samples of different brands. Results revealed that As has had the highest concentration, preceded by Pb in all samples analyzed, whereas the lowest concentrations obtained were in Cd. These findings were similar to Fiamegkos Betal's finding. Similarly, high Pb levels were also obtained from canned fish products in our study, although our study levels were far below the permissible limits[17].

A study done in the Lebanese market assessed the metal content (Fe, Al, As, Cr, Zc, Hg, Cu, Cd, Pb, and Sn) in different canned food brands and categories but also used the XRF technique to determine the impact of metal cans on food quality[18]. They took 45 samples in three categories, including fish in category one; beef, chicken, and pork in category two; and legumes and vegetables in category three. The Highest Lead levels were found in corn and fava beans, and mercury in fish, although these elements were below permissible levels. Thirty percent of vegetables and legumes and 45% of fish samples had Cd levels above permissible levels (0.1ug/g)[19]. Furthermore, the correlation of Sn and Al levels in cans and the acid-digested food indicated corrosion or leaching of Al and Sn from metal cans into food detected by XRF scanning. In their study, 31% of vegetable and legume cans and 45% of fish cans had Cd levels above permissible levels. In our study, legumes, lentils, and fruits had high Cd levels, and fish cans had high Pb levels[20]. They recommended continuous Cd level monitoring for the provision of safe food, careful practices of handling and processing of raw material, an analysis for toxic elements before processing, and control on the phosphate fertilizers usage[21].

Research has done a comparative study on metal concentration of fresh food and canned food. The result of the analysis showed a considerable difference in the metal content of selected cans and fresh food[22]. The canned food products were recorded as low in heavy metal concentrations as compared to their fresh counterparts. Again, Pb and Cd were found high in some fresh fish and meat samples, and the canned food sample. According to this study, canned foods were safer to consume. In our study, Pb and Cd were near their permissible limits and are of concern and is imperative to monitor their level in respective food categories.

Rahmani J etal Human conducted a meta-analysis in Iran regarding the concentration of metals in seafood, including copper (Cu), zinc (Zn), mercury (Hg), tin (Sn), lead (Pb), nickel (Ni), selenium (Se)chromium (Cr), arsenic (As), iron (Fe), and cadmium (Cd) in canned tuna fish[23]. The main aim was to evaluate their non-carcinogenic and carcinogenic risks in children and adult consumers. Data from 23 articles and 1295 samples were searched between 1983 and November 2017. Data were assessed and extracted. Except for Cd and Se, concentrations of other metals in the canned tuna fish were lower than the recommended limits. From the review, it was obvious that children and adults of Iran who were consuming tuna fish were not at non-carcinogenic risk but were at carcinogenic risk. An interesting relationship between the migration of metal content from metal cans and the corrosion or leaching of metal ions from metallic containers into food was assessed by literature[24,25]. In their study, they revealed that the corrosion rate of metal plate increases significantly with an increase in sodium chloride concentration. The leaching of certain metals like Zn, Al, and Sn was observed with the rise in the pH of the solution. However, the high concentrations of metals indicate that electro-activated brine solutions had a significant corrosive effect on certain types of tinplate, depending on the nature and efficacy of the inner coating used in the manufacturing process. Moreover, when neutral or acidic chlorine-free electro-activated brine solution was used. No difference was observed in comparison with the corrosiveness of standard brine. In our study, high Cd and Cr levels were observed in canned food preserved with brine. Regarding sugar syrup, they were found to have high Pb levels[26].

Like any other short sample study, the limitation of resources was the reason for picking food samples. Therefore, many other canned foods of the same type or other companies' brands were not missed in the evaluation. Lack of funds and non-availability of sensors of spectrometers were factors for testing only 4 heavy metals. Certain other dangerous chemicals, including hydrocarbons and poisonous heavy metals, could not be measured because of a lack of resources and time. It was noteworthy that none of the selected samples was expired, but they were near expiration in a range of two months. This study didn't correlate or assess the environmental exposure of toxic heavy metals to the health of people and their related adverse effects. So, cautious conclusions must be drawn about the

toxicity of these metals.

CONCLUSIONS

This study was fruitful as it provided optimal information in the form of baseline data about heavy metal levels in canned food. The conclusions drawn from this study were that heavy metals were present in both Pakistani and internationally branded canned food. Pb levels were high in Pakistani food cans, while Cd and Cr levels were high in internationally branded canned foods. Cd was detected in alarming concentration in all samples of fruit cock tail and pineapples cans. Upper normal limits of Cd and Pb were obtained in canned fruit, including Pakistani and International brands. Upper normal limits of Pb and Cr were found in tuna fish cans and sardine cans, respectively.

CONFLICT OF INTEREST

None

FUNDING

None

ETHICAL APPROVAL

The study received approval from the Institutional Review Board, under reference number (DIR/KMU-AS&RB/EH/00029).

AUTHORS' CONTRIBUTIONS

All authors contributed equally.

REFERENCES

1. Sonone SS, Jadhav S, Sankhla MS, Kumar R. Water contamination by heavy metals and their toxic effect on aquaculture and human health through food Chain. Lett. Appl. NanoBioScience. 2020 Oct;10(2):2148-66 https://doi.org/10.33263/LIANBS102.21482166.

2. Di Bella C, Calagna A, Cammilleri G, Schembri P, Lo Monaco D, Cipri V, Battaglia L, Barbera G, Ferrantelli V, Sadok S, Tliba I. Risk assessment of cadmium, lead, and mercury on human health in relation to the consumption of farmed sea bass in Italy: a meta-analytical approach. Frontiers in Marine Science. 2021 Feb 22;8:616488. https://doi.org/10.3389/fmars.2021.616488.

3. Kiani B, Hashemi Amin F, Bagheri N, Bergquist R, Mohammadi AA, Yousefi M, Faraji H, Roshandel G, Beirami S, Rahimzadeh H, Hoseini B. Association between heavy metals and colon cancer: an ecological study based on geographical information systems in North-Eastern Iran. BMC cancer. 2021 Dec;21:1-2. DOI: 10.1186/s12885-021-08148-1

4. Altarawneh RM. Levels of selected heavy metals (Pb, Ni, Cd, and Cr) in various widely consumed fruits and vegetables in Jordan. International Journal of Environmental Analytical Chemistry. 2021 May 28;101(7):1026-33. https://doi.org/10.1080/03067319.2019.1675653

5. Yabanli M, Tay S. Selenium and mercury balance in sea bream obtained from different living environments in Turkey: a risk assessment for the consumer health. Environmental Science and Pollution Research. 2021 Jul;28(27):36069-75. https://doi.org/10.1007/s11356-021-13257-4

6. Lounas R, Kasmi H, Chernai S, Amarni N, Ghebriout L, Hamdi B. Heavy metal concentrations in wild and farmed gilthead sea bream from southern Mediterranean Sea—human health risk assessment. Environmental science and pollution research. 2021 Jun;28:30732-42. https://doi.org/10.1007/s11356-021-12935-5.

7. Maria B, Maria MC, Antonio B, Simona M, Rosaria A, Andrea S, Giulia M, Mario S. Chemical and biochemical responses to sub− lethal doses of mercury and cadmium in gilthead seabream (Sparus aurata). Chemosphere. 2022 Nov 1;307:135822 https://doi.org/10.1016/j.chemosphere.2022.135822

8. Balali-Mood M, Naseri K, Tahergorabi Z, Khazdair MR, Sadeghi M. Toxic mechanisms of five heavy metals: mercury, lead, chromium, cadmium, and arsenic. Frontiers in pharmacology. 2021 Apr 13;12:643972. https://doi.org/10.3389/fphar.2021.643972

9. Zaynab M, Al-Yahyai R, Ameen A, Sharif Y, Ali L, Fatima M, Khan KA, Li S. Health and environmental effects of heavy metals. Journal of King Saud University-Science. 2022 Jan 1;34(1):101653. https://doi.org/10.1016/j.jksus.2021.101653

10. Sarker A, Kim JE, Islam AR, Bilal M, Rakib MR, Nandi R, Rahman MM, Islam T. Heavy metals contamination and associated health risks in food webs—a review focuses on food safety and environmental sustainability in Bangladesh. Environmental Science and Pollution Research. 2022 Jan;29(3):3230-45. https://doi.org/10.1007/s11356-021-15901-3

11. Jalili C, Kazemi M, Cheng H, Mohammadi H, Babaei A, Taheri E, Moradi S. Associations between exposure to heavy metals and the risk of chronic kidney disease: a systematic review and meta-analysis. Critical Reviews in Toxicology. 2021 Feb 7;51(2):165-82. https://doi.org/10.1080/10408444.2021.1886891

12. Pipoyan D, Stepanyan S, Beglaryan M, Stepanyan S, Asmaryan S, Hovsepyan A, Merendino N. Carcinogenic and non-carcinogenic risk assessment of trace elements and POPs in honey from Shirak and Syunik regions of Armenia. Chemosphere. 2020 Jan 1;239:124809. https://doi.org/10.1016/j.chemosphere.2019.124809

13. Renu K, Chakraborty R, Myakala H, Koti R, Famurewa AC, Madhyastha H, Vellingiri B, George A, Gopalakrishnan AV. Molecular mechanism of heavy metals (Lead, Chromium, Arsenic, Mercury, Nickel and Cadmium)-induced hepatotoxicity–A review. Chemosphere. 2021 May 1;271:129735.

https://doi.org/10.1016/j.chemosphere.2020.129735
14. Rashaid AH, Nusair SD, Alqhazo MT, Adams JB, Abu-Dalo MA, Bashtawi MA. Heavy metals and trace elements in scalp hair samples of children with severe autism spectrum disorder: A case-control study on Jordanian children. Journal of Trace Elements in Medicine and Biology. 2021 Sep 1;67:126790. https://doi.org/10.1016/j.jtemb.2021.126790
15. Munir N, Jahangeer M, Bouyahya A, El Omari N, Ghchime R, Balahbib A, Aboulaghras S, Mahmood Z, Akram M, Ali Shah SM, Mikolaychik IN. Heavy metal contamination of natural foods is a serious health issue: A review. Sustainability. 2021 Dec 24;14(1):161. https://doi.org/10.3390/su14010161
16. Kortei NK, Heymann ME, Essuman EK, Kpodo FM, Akonor PT, Lokpo SY, Boadi NO, Ayim-Akonor M, Tettey C. Health risk assessment and levels of toxic metals in fishes (Oreochromis noliticus and Clarias anguillaris) from Ankobrah and Pra basins: Impact of illegal mining activities on food safety. Toxicology Reports. 2020 Jan 1;7:360-9. https://doi.org/10.1016/j.toxrep.2020.01.007
17. Hembrom S, Singh B, Gupta SK, Nema AK. A comprehensive evaluation of heavy metal contamination in foodstuff and associated human health risk: a global perspective. Contemporary environmental issues and challenges in era of climate change. 2020:33-63. https://doi.org/10.1007/978-981-32-9595-7_2
18. Sanaei F, Amin MM, Alavijeh ZP, Esfahani RA, Sadeghi M, Bandarrig NS, Fatehizadeh A, Taheri E, Rezakazemi M. Health risk assessment of potentially toxic elements intake via food crops consumption: Monte Carlo simulation-based probabilistic and heavy metal pollution index. Environmental Science and Pollution Research. 2021 Jan;28:1479-90. https://doi.org/10.1007/s11356-020-10450-7
19. Ali F, Israr M, Ur Rehman S, Azizullah A, Gulab H, Idrees M, Iqbal R, Khattak A, Hussain M, Al-Zuaibr FM. Health risk assessment of heavy metals via consumption of dietary vegetables using wastewater for irrigation in Swabi, Khyber Pakhtunkhwa, Pakistan. Plos one. 2021 Aug 11;16(8):e0255853. https://doi.org/10.1371/journal.pone.0255853
20. Yaqub G, Khan A, Zishan Ahmad M, Irshad U. Determination of concentration of heavy metals in fruits, vegetables, groundwater, and soil samples of the cement industry and nearby communities and assessment of associated health risks. Journal of Food Quality. 2021;2021(1):3354867. https://doi.org/10.1155/2021/3354867
21. Iqbal Z, Abbas F, Ibrahim M, Qureshi TI, Gul M, Mahmood A. Human health risk assessment of heavy metals in raw milk of buffalo feeding at wastewater-irrigated agricultural farms in Pakistan. Environmental Science and Pollution Research. 2020 Aug;27:29567-79. https://doi.org/10.1007/s11356-020-09299-1
22. Khaleeq A, Ahmed M, Huma R, Mujtaba A, Noor S, Rehman R, Sheikh TA, Qamar S, Iqbal DN, Alharthy RD, Hameed A. Evaluation of trace and heavy metals in different varieties of sauces to characterize their impact on human health. Journal of Food Composition and Analysis. 2022 Dec 1;114:104789. https://doi.org/10.1016/j.jfca.2022.104789
23. Essien JP, Ikpe DI, Inam ED, Okon AO, Ebong GA, Benson NU. Occurrence and spatial distribution of heavy metals in landfill leachates and impacted freshwater ecosystem: An environmental and human health threat. Plos one. 2022 Feb 3;17(2):e0263279. https://doi.org/10.1371/journal.pone.0263279
24. Jehan S, Muhammad S, Ali W, Hussain ML. Potential risks assessment of heavy metal (loid) s contaminated vegetables in Pakistan: a review. Geocarto International. 2022 Dec 12;37(24):7287-302. https://doi.org/10.1080/10106049.2021.1969449
25. Abbasi H, Shah MH, Mohiuddin M, Elshikh MS, Hussain Z, Alkahtani J, Ullah W, Alwahibi MS, Abbasi AM. Quantification of heavy metals and health risk assessment in processed fruits' products. Arabian Journal of Chemistry. 2020 Dec 1;13(12):8965-78. https://doi.org/10.1016/j.arabjc.2020.09.004
26. Sharma S, Kumar S, Singh D. Seasonal variations in proximate composition and metallic elements of three cyprinids from a Central Himalayan river Alaknanda in Garhwal Himalaya, India. Journal of Applied and Natural Science. 2020 Dec 13;12(4):661-9. https://doi.org/10.31018/jans.v12i4.2413.