PLANT SCIENCE TODAY
Vol x(x): xx–xx
https://doi.org/10.14719/pst.8787

eISSN 2348-1900

RESEARCH ARTICLE

Evaluation of health hazards linked to heavy metal concentrations in date palm (*Phoenix dactylifera* L.) fruits from Basrah, Iraq

Ali S Mahdi, Hazim M Ali, Firas M Al-Hamoud, Osama N Jaffer & Khairullah M Awad*

Date palm Research Centre, University of Basrah, Basrah 61001, Iraq

*Correspondence email - khearallah.awad@uobasrah.edu.iq

Received: 10 April 2025; Accepted: 30 October 2025; Available online: Version 1.0: 31 December 2025

Cite this article: Ali SM, Hazim MA, Firas MAH, Osama NJ, Khairullah M. Evaluation of health hazards linked to heavy metal concentrations in date palm (*Phoenix dactylifera* L.) fruits from Basrah, Iraq. Plant Science Today (Early Access). https://doi.org/10.14719/pst.8787

Abstract

This study aims to determine the levels of heavy metals, namely lead (Pb), cadmium (Cd) and chromium (Cr), in date palm fruits (Barhi cultivar) grown in the Basrah Governorate, Iraq. It also assesses the health risks associated with the consumption of date fruits, including estimated dietary intake (EDI), hazard quotients (HQ), hazard index (HI) and cancer risk (CR) indices. Fruit samples were collected from four sites, namely, Al-Qurna, Shatt Al-Arab, Abu Al-Khaseeb and Zubair, during different ripening stages, such as Khalal (Bisr), Rutab and Tamar. Results demonstrate that the concentrations of heavy metals in date palm fruits increased as the fruits ripened. Moreover, the mean values of Cd and Cr were below the maximum allowable levels (MAL) set by WHO/FAO in all sites and at all ripening stages. In contrast, the Pb levels exceeded the MAL at all sites and ripening stages. The results of the health risk assessment indicated that the EDI of Pb, Cd and Cr through date consumption (100 g per person per day) was below the provisional maximum tolerable daily intake across all examined sites. The HQ and HI values were below 1 except for HI in the Zubair site. The CR index confirmed that no carcinogenic threats are associated with the consumption of date palm fruits in Basrah Governorate. This study provides valuable insights for improving food safety and protecting public health in Iraq.

Keywords: carcinogenic; dietary intake; food contamination; health risk

Introduction

The date palm (*Phoenix dactylifera* L.) is a tree species native to tropical and subtropical regions, classified under the Arecaceae family and primarily cultivated for its edible fruits. Historically, date palm trees have significantly influenced human life. In many countries of Asia and Africa, locals depend on date palm fruits for both sustenance and trade. They contribute remarkably to the economy, society and environment of these regions (1). Dates are either consumed fresh or undergo various methods of packing and processing, while the other components of the tree serve multiple purposes (2). The fruits of these date palms are highly valued for their rich nutritional content, including sugar, dietary fiber, vitamins and minerals, each of which plays a crucial role in providing numerous health benefits (3). Toxic metals enter the food chain through multiple environmental routes. The introduction of these metals into the soil, air and water is intensified by industrial activities, agricultural practices and urban expansion. When these heavy metals accumulate in agricultural soils, they are taken by plant roots and subsequently translocate to the consumable part of the plants, including fruits and vegetables (4). Heavy metals can build-up in the body through long-term consumption of food containing contaminants and may pose serious health hazards, including toxicity to organs, developmental issues and increased risk of cancer (5). Iraq is regarded as one of the top producers of dates worldwide, with date palm cultivation serving a key role in the country's agricultural sector (6). Iraq hosts approximately 17.35 million date palm trees, of which around 11.24 million are female productive palms, reflecting the significant role of date cultivation in the country's agricultural sector (7). The southern section of Iraq, especially the Basrah Governorate, is famous for its exceptional date production, thriving due to its ideal climate and fertile soils. Basrah stands out for its extensive date palm orchards, which contribute significantly to the annual date yield in the country (8). Monitoring heavy metals in date palms is essential, as these trees thrive in various climatic conditions. Date palms are often found near roads, residential neighbourhoods, rural areas and industrial sites, increasing their susceptibility to pollutant accumulation (9). The evaluation of toxic metal levels in the fruits of date palm and the potential health concerns linked to the consumption of fruits has emerged as a critical concern for many date-producing nations. Several investigations have been carried out in various date-producing countries to estimate the levels of heavy metals in fruit and to evaluate the health risks related to the intake of these fruits. These countries include Saudi Arabia (9-11), Palestine (12), Sudan (13), Libya (14) and Iran (15).

The aim of the recent study is to evaluate the levels of Pb, Cd and Cr in date palm fruits in Iraq, an area where previous research on the subject is limited. The results are compared with the acceptable limits established by international organizations, such as FAO and WHO. The possible health risks linked to the consumption of this fruit are also explored by calculating several indices.

Materials and Methods

Study area

Basrah Governorate is situated in the southeastern corner of Iraq, between the coordinates 47°47'0.5604"E and 30°30'29.1672"N (Fig. 1A). It covers an area of approximately 19.070 km^2, with a population of approximately 2647754. The main activities include oil and gas production (the region is rich in oil fields, comprising the Rumaila, Shi'aiba, Western Al-Qurna and Majnoun fields); maritime transportation and railways; agriculture; food processing industries; heavy industries such as iron and steel; fertilizers; petrochemicals and fishing (16).

Sampling

The fruits of the Barhi date palm cultivar were gathered from four separate locations within the Basrah Governorate, each representing a different cardinal direction as shown in Fig. 1B:

(1) Al-Qurna (North).

(2) Shatt Al-Arab (East).

(3) Abu Al-Khaseeb (South).

(4) Zubair (West).

The collection occurred at three distinct developmental stages, with three replications taken from each location for each stage:

(1) Khalal (Bisr) (approximately 14 weeks post-pollination, unripe).

(2) Rutab (approximately 21 weeks post-pollination, semi-ripe).

(3) Tamar (approximately 25 weeks post-pollination, fully ripe).

These stages were selected because they represent the edible phases of the date palm fruit.

Sample preparation

Heavy metals were analysed using a standard acid-extraction procedure (10). Pitted date palm fruits (cv. Barhi) weighed 1 g was transferred into a 250 mL digestion tube. Subsequently, 10 mL of a concentrated acid mixture, prepared in a 2:1 ratio of nitric acid and perchloric acid, was added. The samples were subjected to heating at 90 °C for 45 min, after which the heat was raised to 150 °C, allowing them to boil for a minimum of 2-3 hr, resulting in a transparent solution. After that, 5 mL of a mixture consisting of nitric acid, perchloric acid and hydrogen peroxide was introduced to the sample at least three times. The volume was reduced gradually to about 1 mL through continued digestion. To maintain the tubes' cleanliness and avoid sample loss, the insides were cleaned with a small amount of deionized distilled water (DDW) during the digesting process. Nitric acid (1 %, 5 mL) was added to the sample after it was cooled. The mixture was filtered using a Whatman No. 42 filter. Then, the resulting filtrate was transferred to a 25 mL volumetric flask and the volume was adjusted using distilled water.

The atomic absorption spectrophotometer model Perkin Elmer AAS 300, USA, was used to determine heavy metal concentrations.

Health risk indices

Estimated dietary intake

The EDI index was computed using the following equation:

$EDI\ (mg\ kg^{-1}\ day^{-1}) = (C*F)/BW$

Where C stands for the sample's average concentration of each specific heavy metal (mg kg^{-1}) and F indicates the per person

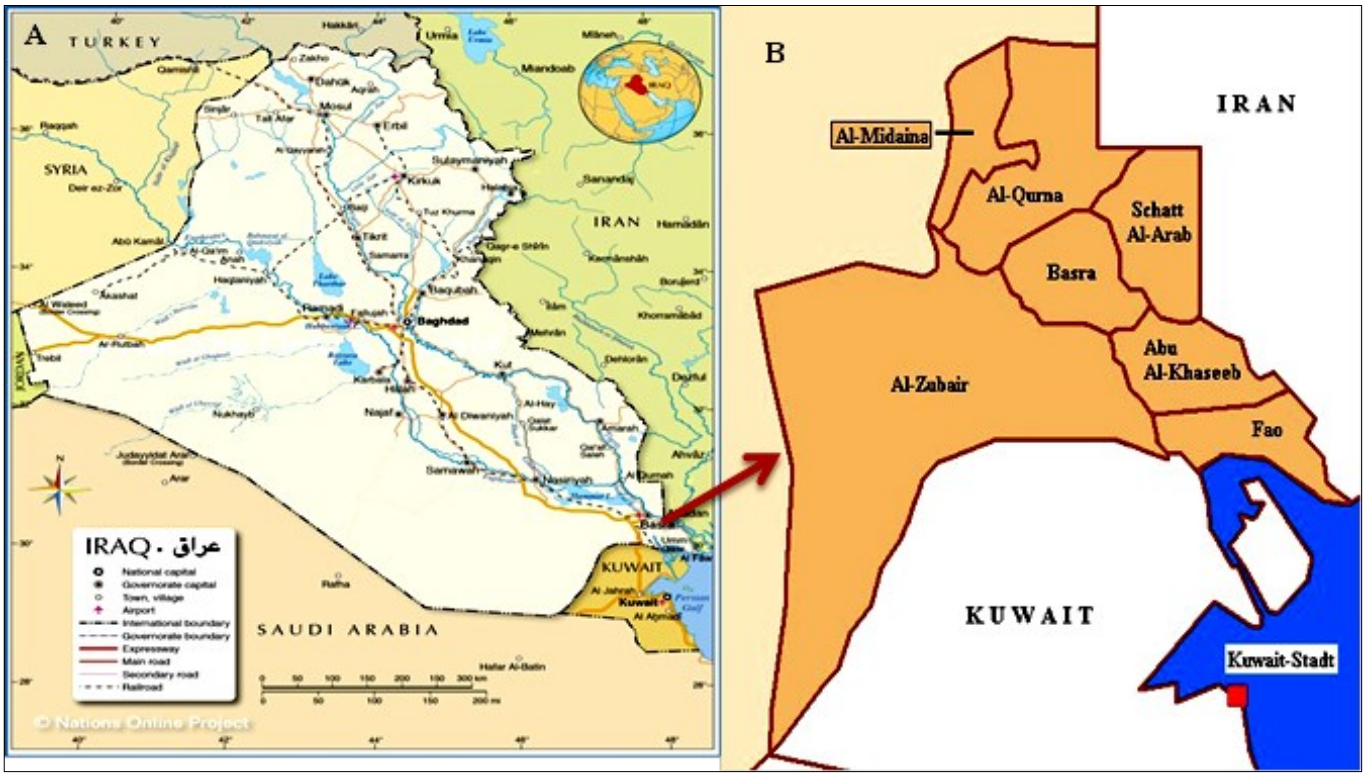

Fig. 1. (A) Location map of Basrah Governorate in Iraq. (B) Map of Basrah Governorate showing collection sites of the samples (adapted from Nations online project https://www.nationsonline.org).

consumption of date palm fruits for adults in Iraq, this study assumed a value of 100 g person^{-1} day^{-1} (0.1 kg person^{-1} day^{-1}). BW denotes the average body weight of adult Iraqi citizens, i.e., 70 kg. A comparison was made between EDI values and the provisional maximum tolerable daily intake (PMTDI) (17).

Hazard quotient (HQ) and hazard index (HI)

HQ assesses the possible non-carcinogenic health effects linked to exposure to a specific toxic substance; a value less than 1 suggests no considerable risk involved. As indicated by the following equation, it is computed by dividing the EDI by the reference dose (RfD):

$$HQ = EDI/RfD$$

Where RfD indicates the reference oral dose. The following RfD (mg kg^{-1} day^{-1}) values are used in this assessment: Pb (0.004), Cd (0.0005) and Cr (0.003), provided in the previous studies (18).

HI was calculated as the sum of the HQ of all heavy metals (Pb, Cd and Cr in this study) (19).

Cancer risk (CR)

CR refers to the likelihood of a person's lifetime health risk due to exposure to carcinogens. The following equation can be used to assess CR index:

$$CR = EDI*SF$$

Where SF represents cancer slope factor. The SF values (ingestion) for heavy metals are 0.0085 for Pb, 15 for Cd and 0.5 for Cr (20). A metal poses an acceptable CR if the value is between 10^{-4} and 10^{-6} (21).

Statistical analysis

Each sample was replicated three times. Statistical analysis was performed on the data using SPSS software, version 22 (SPSS Inc., Chicago, IL, USA). With a level of significance of $P < 0.05$, the means were statistically compared using the least significant difference (LSD) test.

Results

Heavy metal content in the date palm fruit samples

The levels of heavy metals (Pb, Cd and Cr) in the date palm fruits gathered from four sites in the Basrah Governorate (Al-Qurna, Shatt Al-Arab, Abu Al-Khaseeb and Zubair) are shown in Tables 1-3.

Table 1 shows the level of Pb found in the date palm fruits that were collected from four different sites in Basrah Governorate and at various growth stages. The findings reveal that, on average, the highest Pb concentration was detected in fruits sourced from the Zubair site, with a value of 1.31 mg kg^{-1}, followed by Al-Qurna at 1.19 mg kg^{-1}, Shatt Al-Arab at 0.71 mg kg^{-1} and the lowest level at Abu Al-Khaseeb with 0.63 mg kg^{-1}. The Pb level in fruits collected from the Zubair site was the highest across all studied stages. In terms of growth stages, the highest average Pb concentration was observed in fruits at the Tamar stage, with a value of 1.33 mg kg^{-1}, followed by the Rutab stage at 0.90 mg kg^{-1} and the lowest concentration at the Khalal stage, with 0.65 mg kg^{-1}.

The data outlined in Table 2 illustrate that the Zubair site consistently had the highest average Cd concentration at 0.123 mg kg^{-1}, followed by Al-Qurna at 0.086 mg kg^{-1}, Abu Al-Khaseeb at 0.021 mg kg^{-1} and Shatt Al-Arab, which had the lowest at 0.016 mg kg^{-1}. The average concentrations by stage were examined and found that the Tamar stage had the highest Cd concentration at 0.101 mg kg^{-1}, compared with the Rutab stage at 0.054 mg kg^{-1} and Khalal (Bisr) at 0.029 mg kg^{-1}.

The average Cr concentration in date palm fruits, as detailed in Table 3, exhibited notable differences across sites and stages. Zubair had the highest average Cr level at 1.39 mg kg^{-1}, which was markedly greater than that of Al-Qurna (0.71 mg kg^{-1}), Abu Al-Khaseeb (0.64 mg kg^{-1}) and Shatt Al-Arab (0.51 mg kg^{-1}). Moreover, the Tamar stage had the highest average Cr content at 1.97 mg kg^{-1}, followed by Rutab at 1.61 mg kg^{-1} and Khalal (Bisr) at 1.30 mg kg^{-1}.

Table 1. Pb (mg kg^{-1}) contents in date palm fruit samples collected from different sites in Basrah Governorate, Iraq

Site	Stages			Mean of site
	Khalal (Bisr)	Rutab	Tamar	
Al-Qurna	*0.75 ± 0.06	1.17 ± 0.05	1.66 ± 0.09	1.19 ± 0.39
Shatt Al-Arab	0.53 ± 0.04	0.72 ± 0.03	0.88 ± 0.03	0.71 ± 0.15
Abu Al-Khaseeb	0.44 ± 0.08	0.53 ± 0.09	0.92 ± 0.05	0.63 ± 0.23
Zubair	0.88 ± 0.03	1.19 ± 0.02	1.87 ± 0.09	1.31 ± 0.44
Mean of stage	0.65 ± 0.18	0.90 ± 0.30	1.33 ± 0.46	

*Each value represents the mean of three replicates (n=3) ± SD. LSD values ($P < 0.05$) for sites, stage and interaction between site and stage are 0.19, 0.16 and 0.34, respectively.

Table 2. Cd (mg kg^{-1}) contents in date palm fruit samples collected from different sites in Basrah Governorate, Iraq

Site	Stages			Mean of site
	Khalal (Bisr)	Rutab	Tamar	
Al-Qurna	*0.028 ± 0.008	0.077 ± 0.008	0.154 ± 0.030	0.086 ± 0.057
Shatt Al-Arab	0.009 ± 0.002	0.012 ± 0.002	0.028 ± 0.003	0.016 ± 0.009
Abu Al-Khaseeb	0.007 ± 0.003	0.021 ± 0.002	0.034 ± 0.003	0.021 ± 0.011
Zubair	0.072 ± 0.003	0.108 ± 0.003	0.188 ± 0.015	0.123 ± 0.052
Mean of heavy metal	0.029 ± 0.027	0.054 ± 0.041	0.101 ± 0.075	

*Each value indicates the mean of three replicates (n = 3) ±SD. LSD values ($P < 0.05$) for sites, stage and interaction between site and stage are 0.01, 0.009 and 0.02, respectively.

Table 3. Cr (mg kg^{-1}) contents in date palm fruit samples collected from different sites in Basrah Governorate, Iraq

Site	Stages			Mean of site
	Khalal (Bisr)	Rutab	Tamar	
Al-Qurna	0.38 ± 0.07*	0.79 ± 0.03	0.95 ± 0.03	0.70 ± 0.26
Shatt Al-Arab	0.27 ± 0.05	0.45 ± 0.06	0.81 ± 0.06	0.51 ± 0.24
Abu Al-Khaseeb	0.32 ± 0.04	0.66 ± 0.06	0.95 ± 0.08	0.64 ± 0.27
Zubair	1.66 ± 0.08	1.13 ± 0.06	1.38 ± 0.06	1.39 ± 0.23
Mean of heavy metal	1.30 ± 0.39	1.61 ± 0.39	1.97 ± 0.44	

*Each value indicates the mean of three replicates (n = 3) ±SD. LSD values (P < 0.05) for sites, stage and interaction between site and stage are 0.05, 0.04 and 0.09, respectively.

Mean concentrations of Pb, Cd and Cr compared with the maximum permissible limits

The results in Table 4 represent the content of heavy metals in date palm fruits for each site across three growth stages: Khalal, Rutab and Tamar. When compared with the maximum permissible limit (MAL), the results show that only Pb surpassed the limit in all sites, whereas Cd and Cr were below the threshold.

Health risk indices

Potential health risk indices, including EDI, HQ, HI and CR, were assessed to evaluate the health risks linked with consuming date palm fruits.

Estimated dietary intake

The data in Table 5 represent the EDIs of heavy metals from date palm fruits collected from four sites in the Basrah Governorate. EDIs have been calculated using the mean concentrations of each heavy metal during three growth stages (Khalal, Rutab and Tamar). Table 5 also shows the PMTDI values for Pb, Cd and Cr. The results demonstrate that all heavy metals investigated in particular sites in the Basrah Governorate (as the mean of all sites) were within PMTDI limits. This finding indicates that Iraqi consumers are not exposed to any health risks from the presence of Pb, Cd and Cr in Barhi cultivar date palm fruits.

Hazard quotients and hazard index

Table 6 illustrates the HQ values for Pb, Cd and Cr in date palm fruit samples obtained from four locations within the Basrah Governorate. The findings indicate that the HQ values for all examined metals were below 1 across all sites, suggesting that the concentrations of heavy metals remain within acceptable limits and do not present significant risks to public health. In addition, the data in Table 6 include the HI values, which represent the cumulative HQ values for the metals under investigation. The analysis demonstrated that the HI value was below 1 for all sites assessed, with the exception of the Zubair site, which recorded a value of 1.03. Furthermore, the results indicated that the HI value at the Basrah Governorate level (representing the average of the studied sites) was below 1. These findings suggest that the consumption of Barhi date palm fruits from the Zubair site could potentially exhibit negative impacts on human health.

Table 5. EDI values for heavy metals in date palm fruits from different sites of Basrah Governorate

Site	EDI (mg/kg)		
	Pb	Cd	Cr
Al-Qurna	1.70	0.122	1.07
Shatt Al-Arab	1.01	0.022	0.72
Abu Al-Khaseeb	0.90	0.030	0.91
Zubair	1.87	0.175	1.22
Mean	1.37	0.087	0.98
PMTDI (µg/Kg BW per day)	3.57	1	100

Table 6. HQ and HI values for heavy metals in date palm fruits from different sites of Basrah Governorate

Site	HQ			HI
	Pb	Cd	Cr	
Al-Qurna	0.42	0.12	0.35	0.89
Shatt Al-Arab	0.25	0.02	0.24	0.51
Abu Al-Khaseeb	0.22	0.03	0.30	0.55
Zubair	0.46	0.17	0.40	1.03
Mean	0.34	0.08	0.32	0.74

Cancer risk

The results in Table 7 show the CR index values associated with the consumption of date palm fruits gathered from different sites within the Basrah Governorate. The CR values for Pb show varying risk levels for the Al-Qurna site (1.45E-05), Shatt Al-Arab (8.62E-06), Abu Al -Khaseeb (7.65E-06) and Zubair (1.59E-05) and the mean for Basrah Governorate was 1.17E-05. These findings suggest that the CR value for Pb is generally within acceptable limits (between 10^{-4} and 10^{-6}), whereas those for Cd are generally low. The CR values of Al-Qurna, Shatt Al-Arab and Abu Al-Khaseeb sites were 7.49E-07, 1.39E-07 and 1.83E-07, respectively, suggesting extremely low CR values, within acceptable limits set by EPA (20). Cr exhibits a moderate level of CR, with values being relatively consistent across the studied sites. Specifically, the average CR values were 4E-05 for Al-Qurna, 3E-05 for Shatt t Al-Arab, 4E-05 for Abu Al-Khaseeb, 5E-05 for Zubair and 4E-05 for Basrah Governorate.

Table 4. Mean Pb, Cd and Cr concentrations in date palm fruits collected from different sites of Basrah Governorate across three growth stages.

Metals	Al-Qurna	Shatt Al-Arab	Abu Al-Khaseeb	Zubair	Mean	*MAL
Pb	1.19	0.71	0.63	1.31	0.96	0.30
Cd	0.08	0.01	0.02	0.12	0.06	0.20
Cr	0.70	0.51	0.64	1.39	0.69	2.30

*MAL indicates maximum allowable limit (mg kg^{-1}) prescribed by WHO/FAO (21).

Table 7. CR values for heavy metals in date palm fruits from different sites of Basrah Governorate

Site	CR		
	Pb	Cd	Cr
Al-Qurna	1.45E-05	7.49E-07	4E-05
Shatt Al-Arab	8.62E-06	1.39E-07	3E-05
Abu Al-Khaseeb	7.65E-06	1.83E-07	4E-05
Zubair	1.59E-05	1.07E-06	5E-05
Mean	1.17E-05	5.36E-07	4E-05

Discussion

In this study, increased levels of heavy metals (Pb, Cd and Cr) were observed as the fruits ripened. The values were higher at Tamar stage than at Rutab and Khalal stages. Plants absorb heavy metals from the soil and water, as well as those deposited from the air. As the fruits develop, metals continue to accumulate within the plant tissues. Consequently, metal concentrations in fruits increase over time (22). The study results revealed that heavy metal concentrations in fruits varied based on the collection site, with the levels following the order: Zubair > Al-Qurna > Abu Al-Khaseeb > Shatt Al-Arab. This variation may be attributed to industrial activities in the Zubair area, particularly traditional oil extraction processes, because it contains the largest oil fields, central to Iraq's economy, along with numerous other oil-related industries. In addition, this site includes several gypsum manufacturing units. However, the Cd and Cr concentrations did not exceed the maximum allowable limits (mg kg^{-1}) prescribed by WHO/FAO (21), whereas Pb levels exceeded the limits at all studied sites. This finding may be attributed to heavy traffic, particularly because Iraq continues to use leaded fuel (23, 24). Plants exhibit physiological mechanisms aimed at limiting the accumulation of contaminants in fruits and other vital parts. These mechanisms work to reduce or prevent the build-up of toxic materials in fruits because their presence can impact plant health and survival. Plants employ a range of strategies to mitigate metal toxicity including compartmentalisation in vacuoles and binding heavy metals with specific proteins (25).

The results of this study revealed no health risk linked to the intake of date palm fruits, particularly the Barhi cultivar gathered from Basrah Governorate for Pb, Cd and Cr. The EDI of all studied heavy metals was less than the PMTDI. Furthermore, HQ and HI as non-CR indices were found to be within the safe levels across all sites. However, the HI value for the Zubair site exceeded the threshold of 1, indicating a potential concern for non-CR at this site. The CR values of the studied heavy metals revealed varied levels of CR. For Cd, the CR values were consistently low across all sites, below the safety threshold of 1E-06 (0.000001), indicating a minimal CR. By contrast, Cr displayed moderate risk levels, with some values approaching or exceeding the acceptable limit. The Zubair site indicated a cancer development probability of 1 in 20000 individuals due to the consumption of date palm fruits from that area. The Al-Qurna and Abu Al-Khaseeb sites exhibited a similar probability of 1 in 25000 individuals. The Shatt Al-Arab site presented the lowest probability, calculated at 1 in 33333 individuals. However, when considering the overall Governorate level, the probability was determined to be 1 in 25000. Pb, on the contrary, showed lower CR values than Cr, indicating a lower potential for carcinogenicity. Our results suggest that the consumption of dates from date palm trees in the Shatt Al-Arab site exhibited the lowest probability of developing cancer due to Pb, i.e., one person per 130718. It was followed by the Abu Al-Khaseeb site by one person per 115990. The probability of one person per 69204 and per 62864 is observed in the Al-Qurna and Zubair sites, respectively and the overall rate of Basrah Governorate reached one person per 85748 (9). A study in Saudi Arabia found that date palm fruits are susceptible to contamination with heavy metals, such as Pb and Cd, during various growth stages. The results showed that majority of the heavy metals were within the safe limits. The EDI for Pb exceeded the PMTDI values at some locations. Despite Cd exceeding the MAL, its EDI remained within safe limits. Pb and Cd concentrations were higher in fruit of five cultivars of date palms collected from the centre of the Palestinian Jericho city than locations far from the city centre (6). Moreover, the concentration of these metals was within the safe limits for human consumption. Concentrations of Pb and Cd in date palm fruit samples were previously evaluated from Ethiopia, Iraq and Saudi Arabia (26). The analysis revealed that the Pb and Cd levels were below detection limits within the linear range. Consequently, health risk assessments showed that chronic daily intake and HQ, and total exposure HI values were below 1.0. These results suggest that Pb and Cd do not pose significant public health risks in the date palm samples studied.

Conclusion

This research investigated the levels of heavy metals, specifically Pb, Cd and Cr, in the date palm fruits (Barhi cultivar) cultivated in various locations within Basrah province, southern Iraq. This study assessed the health risks associated with the consumption of these fruits, due to the presence of heavy metals. The results revealed that the content of Pb in date palm fruit exceeded the MAL established by WHO/FAO across all ripening stages and locations examined. Conversely, the Cd and Cr concentrations remained within acceptable limits. An evaluation of the health risks associated with the consumption of date palm fruits, estimated at 100 g per person per day, indicated no significant public health risks related to their consumption. This conclusion is based on the EDI and assessments of non-CR indices, such as the HQ, HI and CR. However, a marginally increased HI value was observed at the Zubair site. Although the results indicated minimal non-CR and CR, a significant concern arises from the high concentrations of Pb in the Barhi date palm fruits in Basrah Governorate and the combined effect of heavy metals. Thus, studies using more samples of date palm cultivars must be conducted for further investigation and the health risks of date palm fruit consumption must be considered, especially in areas with high heavy metal pollution. This study directly benefits public health by highlighting the risks of heavy metals in date fruits and supporting safer consumption.

Authors' contributions

ASM participated in sample collection, laboratory preparation and contributed to data interpretation. HMA carried out the statistical analysis and contributed to the health risk assessment. FMA performed the heavy metal analysis and helped with data visualization. ONJ conducted the literature review and assisted in drafting parts of the manuscript. KMA conceived the study, coordinated the research activities and finalized the manuscript. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

References

1. Ibrahim KM. The role of date palm tree in improvement of the environment. Acta Hortic. 2010;882:777-8. https://doi.org/10.17660/ActaHortic.2010.882.87
2. Suhim AA, Awad KM, Jaffer ON, Abass MH. The impact of salicylic and jasmonic acid in mitigating salinity stress on date palm *Phoenix dactylifera* L. Barhi cv. Basrah J Agric Sci. 2023;36(1):120-30. https://doi.org/10.37077/25200860.2023.36.1.10
3. Al-Karmadi A, Okoh AI. An overview of date (*Phoenix dactylifera*) fruits as an important global food resource. Foods. 2024;13(7):1024. https://doi.org/10.3390/foods13071024
4. Angon PB, Islam MS, KC S, Das A, Anjum N, Poudel A, et al. Sources, effects and present perspectives of heavy metals contamination: Soil, plants and human food chain. Heliyon. 2024;10(7):e28357. https://doi.org/10.1016/j.heliyon.2024.e28357
5. Afzal A, Mahreen N. Emerging insights into the impacts of heavy metals exposure on health, reproductive and productive performance of livestock. Front Pharmacol. 2024;15. https://doi.org/10.3389/fphar.2024.1375137
6. Khierallah HSM, Bader SM, Ibrahim KM, Al-Jboory IJ. Date palm status and perspective in Iraq. In: Date palm genetic resources and utilization. Dordrecht, Netherlands: Springer; 2015. p. 97-152. https://doi.org/10.1007/978-94-017-9707-8_4
7. Ali HM, Fhaid KA, Awad KM. Effectiveness of nanoparticle-based treatments in controlling *Oligonychus afrasiaticus* (McGregor) (Acari Tetranchidae) infestation in date palm trees. IOP Conf Ser Earth Environ Sci. 2023;1262:032023. https://doi.org/10.1088/1755-1315/1262/3/032023
8. Al-Aradi HJ, Al-Najjar MA, Awad KM, Abass MH. Combination effect between lead and salinity on anatomical structure of date palm *Phoenix dactylifera* L. seedlings. Agrivita. 2020;42(3):487-98. https://doi.org/10.17503/agrivita.v42i3.2511
9. Salama KF, Randhawa MA, Al Mulla AA, Labib OA. Heavy metals in some date palm fruit cultivars in Saudi Arabia and their health risk assessment. Int J Food Prop. 2019;22(1):1684-92. https://doi.org/10.1080/10942912.2019.1671453
10. Aldjain IM, Al-Whaibi MH, Al-Showiman SS, Siddiqui MH. Determination of heavy metals in the fruit of date palm growing at different locations of Riyadh. Saudi J Biol Sci. 2011;18(2):175-80. https://doi.org/10.1016/j.sjbs.2010.12.001
11. Hassan I, Cotrozzi L, Haiba NS. Trace elements in the fruits of date palm (*Phoenix dactylifera* L.) in Jeddah City, Saudi Arabia. Agrochimica. 2017;61(1):75-93. https://doi.org/10.12871/0021857201716
12. Khalilia WM. Assessment of lead, zinc and cadmium contamination in the fruit of Palestinian date palm cultivars growing at Jericho Governorate. J Biol Agric Healthc. 2020;10(2):7-14. https://doi.org/10.7176/JBAH/10-2-02
13. Hamadnalla HMY. Measurement of heavy metals of three cultivars of date (*Phoenix dactylifera* L.) from Sudan. J Plant Biochem Physiol. 2021;9:270. https://doi.org/10.33552/ICBC.2021.01.000524
14. Elsherif KM, Aljaroushi AM. Assessment of major and minor metals levels in selected Libyan palm dates fruits. Appl Sci Environ Stud. 2021;4(3):446-59. https://doi.org/10.48393/IMIST.PRSM/jases-v4i3.27814
15. Achakzai R, Khan N, Kakar AUR, Khan S, Tareen AH. Determination of heavy metals in the dates (*Phoenix dactylifera* L.) of Balochistan (Panjgoor and Turbat). Baghdad J Biochem Appl Biol Sci. 2022;3(3):220-8. https://doi.org/10.47419/bjbabs.v3i03.140
16. El Baz Z, Saieh A. Basra fact finding mission report #1. Norwegian Refugee Council; 2018.
17. Mohamed H, Haris P, Brima E. Estimated dietary intakes of toxic elements from four staple foods in Najran City, Saudi Arabia. Int J Environ Res Public Health. 2017;14(12):1575. https://doi.org/10.3390/ijerph14121575
18. USEPA. Risk-based concentration table. Washington (DC): United States Environmental Protection Agency; 2000.
19. Bermudez GMA, Jasan R, Plá R, Pignata ML. Heavy metal and trace element concentrations in wheat grains: assessment of potential non-carcinogenic health hazard through their consumption. J Hazard Mater. 2011;193:264-71. https://doi.org/10.1016/j.jhazmat.2011.07.058
20. Oni AA, Babalola SO, Adeleye AD, Olagunju TE, Amama IA, Omole EO, et al. Non-carcinogenic and carcinogenic health risks associated with heavy metals and polycyclic aromatic hydrocarbons in well-water samples from an automobile junk market in Ibadan, SW-Nigeria. Heliyon. 2022;8(9):e10688. https://doi.org/10.1016/j.heliyon.2022.e10688
21. WHO/FAO. Joint FAO/WHO Food Standards Programme Codex Committee on Contaminants in Foods. The Netherlands; 2011 (21-25 March).
22. Antonious GF, Snyder JC, Berke T, Jarret RL. Screening Capsicum chinense fruits for heavy metals bioaccumulation. J Environ Sci Health B. 2010;45(6):562-71. https://doi.org/10.1080/03601234.2010.493495
23. Abass M, Hassan Z, Al-Jabary K. Assessment of heavy metals pollution in soil and date palm (*Phoenix dactylifera* L.) leaves sampled from Basra/Iraq Governorate. AES Bioflux. 2015;7:52-9.
24. Al-Jabary KMA, Neama JD, Abass MH. Seasonal variation of heavy metals pollution in soil and date palm *Phoenix dactylifera* L. leaves at Basra Governorate, Iraq. Int J Sci Res Environ Sci. 2016;4(6):186-95. https://doi.org/10.12983/ijsres-2016-p0186-0195
25. Gupta M, Dwivedi V, Kumar S, Patel A, Niazi P, Yadav VK. Lead toxicity in plants: mechanistic insights into toxicity, physiological responses of plants and mitigation strategies. Plant Signal Behav. 2024;19(1). https://doi.org/10.1080/15592324.2024.2365576
26. Tamirat F, Adane WD, Tessema M, Tesfaye E, Tesfaye G. Determination of major and trace metals in date palm fruit (*Phoenix dactylifera*) samples using flame atomic absorption spectrometry and assessment of the associated public health risks. Int J Anal Chem. 2024:2024(1):9914300. https://doi.org/10.1155/2024/9914300

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.