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Original research

Health risk assessment of heavy metals (Cd, Pb, and Cr) in cultivated rice of Kor River basin in Kamfiruz District, Fars Province, Iran

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ABSTRACT

The dangers of heavy metals in rice have received much attention in the world. The present study was conducted with the aim of investigating the contamination status and health risk of Kamfiruz rice in Fars province, Iran. The results showed that the average concentrations of cadmium (Cd), lead (Pb), and Chromium (Cr) in rice were (0.034-0.069), (0.129-0.186), and (0.354-0.426) mg kg^{-1} respectively. Among them, the concentration of Pb in rice grown in the lower reaches of the Kor River was 20% higher than the Iranian standard. The consumption of rice didn't have a specific non-carcinogenic risk for consumers (target hazard quotient, hazard index, and hazard quotient < 1), except the hazard index in the downstream areas (1.04 - 1.14). In contrast, rice was considered a threat in terms of carcinogenic risks (CR). In this study, CR values of Cd and Cr in rice were > 1×10^{-4}, while this value was in the safe range for Pb (<1×10^{-4}), however TCR of all HMs had carcinogenic risk (> 1×10^{-4}). According to the results, the continuous monitoring of rice samples is essential to mitigate exposure to toxic metals through rice ingestion in the region.

Keywords: Health risk; Heavy metals; Kor River; Rice

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1. Introduction

Heavy metals (HMs) are one of the main soil pollutants that are a threat to healthy crop production. After entering the human food cycle, HMs can cause neurological diseases and cancer (Genchi et al., 2020). For example, heavy elements such as Cd, As, and Pb are unnecessary elements for plants in the soil, which cause plant poisoning and disease in humans (Rai et al., 2019). Accumulation of HMs in crops is different (Zhang et al., 2019; Zhou et al., 2019) and the bioaccumulation ability of HMs is related to the concentration of HMs (Mehrab et al., 2021); however, contamination of rice is easier than in other crops (Williams et al., 2007).

As an important source of energy, amino acids, and minerals (Zeng et al. 2009), rice plays an important role in the nutrition of the world's people. The searches have shown that more than 50% of the world's people consume rice (Fakhri et al., 2018; Sharafi et al., 2019). Moreover, almost half of the daily calories of the people of the world are supplied from rice (Abbas et al. 2011; Pishgar-Komleh et al. 2011). Wailes et al. (2005) reported that people's caloric intake from rice globally, in low-income countries, and in Asian countries are 20.5%, 29.2%, and 31.6%, respectively. In Asian countries (including Iran, Malaysia, Thailand, India, etc.), rice is the most consumed food item. In Iran, more than 65% of rice consumed is domestic (Sharafi et al., 2019), so studying the health of cultivated rice is of great importance.

The results of previous studies conducted in Iran showed that the concentration of Cd and Pb in the investigated rice samples exceeded the standard limit of these metals (Rezaiyan and Hesari, 2014; Naseri et al., 2015), while some studies showed that Iranian rice samples were not contaminated with Cd and Pb (Hojjati et al., 2022; Tavakoli et al., 2016; Mosayebi and Mirzaee, 2014). These different results depend on the contamination or non-contamination of the soil and water used in rice cultivation. Hemati Farsani et al. (2014) studied rice grown in the north of Iran and reported that rice grown in Giulan

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Province had Hg, Ni, Cd, and As toxicity, while rice grown in Mazandaran Province had Pd toxicity. Also, similar reports have been given in other parts of the world. For example, studies conducted by Wang et al. (2005) showed the concentration of Cd, Pb, and Cr (0.003-0.02, 0.001-0.15, and 0.02-0.5 μg g^{-1}, respectively) in rice cultivated in four regions of Tianjin, China.

The presence of HMs in irrigation water is one of the main concerns of rice cultivation. Kor river is the main source of water for rice fields in Kamfiruz, Marvdasht city in Fars Province. It is reported that Kor is a river that contains agricultural pollutants (chemical fertilizers and poisons) even upstream and before and after the Darudzen dam. Studies have shown that urbanization and industrial and agricultural activities in the proximity of the Kor river have led to the pollution of the river water with HMs including Cd, Pb, and Cr (Sheykhi and Moore 2012; Mokarram et al., 2020; Mokarram et al., 2022). Therefore, there is a possibility of soil and rice contamination. Although Kamfiruz rice is tasty and easy to cook, sometimes news about the presence of poison in food, especially rice, creates a sense of worry among people, so it seems necessary to study the health of rice in this region. In the present study, we have tried to answer the following questions; (i) Determining the amount of HMs (Pb, Cd, and Cr) in Kamfiruz rice samples and comparing them with standards (ii) investigating the changes in the amount of HMs (Pb, Cd, and Cr) in rice samples from the upstream and downstream of Kor river, and (iii) investigating the risk of toxicity of rice cultivated in Kor river basin in Kamfiruz District.

2. Material and Methods

The methodology of the current research was based on the following steps (Figure 1): (i) determination of sampling locations from rice fields on the banks of the Kor river, (ii) collecting rice samples from determined points, (iii) digestion of rice samples using the dry digestion method, (iv) measurement of the contamination of HMs (Cd, Pb, and Cr) in rice, (v) evaluation of risk assessment of rice using indicators for adults and children (target hazard quotient (THQ), hazard index (HI), Carcinogenic risk (CR), etc.).

2.1. Study area

The present study was conducted in Fars province in the fields along the Kor river. Five regions including Palengri, Allah-Moradkhani, Chamriz, Darehhamune, and Jamalbaig were studied. The locations of the areas are shown in Figure 2.

2.2. Collection of samples and laboratory analysis

Rice samples were randomly collected from the upstream and downstream of the Kor river. In each region, nine points were randomly sampled. The present study was conducted on hulled grains of rice.

The rice samples (hulled and polished rice) were dried in the oven at 105°C for one hour and then kept at 72°C until the weight of the samples was fixed. After grinding, the rice samples were passed through a 149 mm mesh and placed in an electric furnace for 2 hours for ashing of samples. Ashed samples (1 gr rice samples) were digested with 10 cc of HNO_3 and HCl (3:1), then were made up to 25 cc with deionized water (USEPA, 2011). Finally, the concentration of Cd, Pb, and Cr was measured using Atomic Absorption Spectroscopy (ContrAA 300, Company; Analytic Jena).

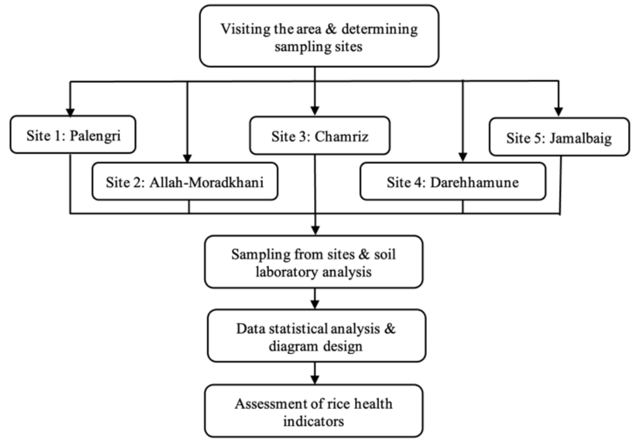

Fig. 1. Methodology flowchart of the present study.

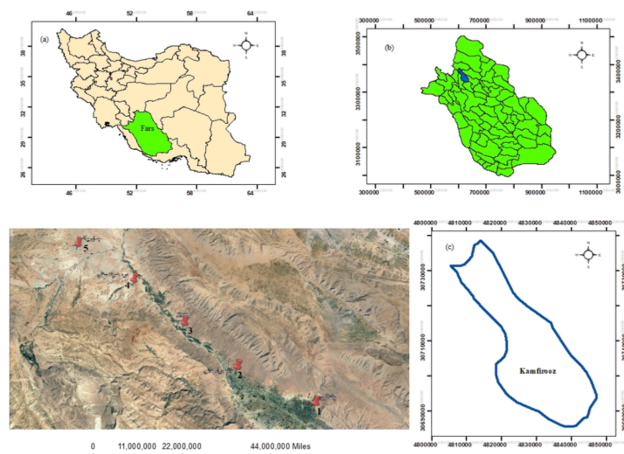

Fig. 2. Maps of studied areas. Iran, Fars province, and Kamfiruz District; (1) Palengri, (2) Allah-Moradkhani, (3) Chamriz, (4) Darehhamune, (5) Jamalbaig.

2.3. Health risk assessment

Non-carcinogenic risk assessment

The synergistic effect of HMs, which are considered non-carcinogenic risk factors, can be calculated by using risk indices. The health risk of rice contaminated with HMs was evaluated by THQ. This factor was proposed by the United States Environmental Protection Agency (USEPA) (1989) to determine the health evaluation of rice. THQ is calculated from the ratio of the average dietary intake (ADI) to the reference oral dose (RFD) as a standard (Zeng et al., 2019) and it is assumed that the absorbed dose of the contamination is equal to the consumed dose. Also, using the HI, it is finally possible to calculate the non-carcinogenic risk of rice consumption. THQ and HI were calculated according to the Equations 1, 2 and 3 (Zheng et al., 2007):

$$ADI = \frac{(C \times IR \times EF \times ED)}{(BW \times AT)} \quad (1)$$

$$THQ = \frac{ADI}{RFD} \quad (2)$$

$$HI = \sum_{i=1}^{n} THQ_i \quad (3)$$

where ADI is the average dietary intake (mg $kg^{-1}day^{-1}$), C is the heavy metal concentration (mg kg^{-1}), IR is rice intake (children: 0.240, adults: 0.337 kg day^{-1}), BW is average body weight (children: 24.9, adults: 59.1 kg) (Zhao et al., 2014; Duan, 2016), EF is the exposure frequency (365 d^{-1}), ED is the duration of exposure (children: 9, adults: 77) and AT is the average exposure time (ED × 365 d^{-1}) and THQ represents target hazard quotient.

The RfD represents the oral reference dose (mg kg^{-1} d^{-1}), with Cd, Hg, As, Pb, Cr, Ni, Cu, and Zn being 0.001, 0.0007, 0.0003, 0.0037, 1.5, 0.02, 0.04 and 0.3 mg kg^{-1} d^{-1}, respectively (WHO, 1997; USEPA, 2006). HI is the hazard index. If THQ and HI values exceed 1.0, humans may suffer potential toxic effects (Du et al., 2019).

To calculate chronic daily intake (CDI) and non-carcinogenic risk of HMS in humans based on the daily consumption of rice by every Iranian adult weighing 70 kg, 110 gr of rice is used per day, which is calculated through the Equation 4:

$$CDI = C \times \frac{DI}{BW} \quad (4)$$

Also, according to the Equation 5, the hazard quantity (HQ) of HMs was determined by chronic daily intake (CDI) and the reference oral dose (RFD):

$$HQ = \frac{CDI}{RFD} \quad (5)$$

CR indicates the lifetime probability that an individual will develop cancer which can be estimated by the strength and level of exposure to a carcinogen (USEPA, 1989). In addition, total carcinogenic risk (TCR) can be used to assess the carcinogenic risk of mixed pollutants (Halder, 2020). CR and TCR were calculated according to the Equations 6 and 7 (Zhang, 2019):

$$CR = ADI \times SF \quad (6)$$

$$TCR = TCR_{Cd} + TCR_{Pb} + TCR_{Cr} \quad (7)$$

where CR is the carcinogenic risk, ADI is the average dietary intake (mg kg^{-1} d^{-1}), SF is the carcinogenicity slope factor, while Cd, As, Cr, and Ni were 6.1, 1.5, 0.5, and 0.84, respectively (WHO, 1990; USEPA, 2006). TCR represents the total carcinogenic risk. The values of CR and TCR above 1×10^{-4} are viewed as a high probability of carcinogenic, while those below 1×10^{-6} are acceptable (USEPA, 2006).

2.4. Statistical analysis

The SPSS (Statistical Package for the Social Sciences—version 16) was used for statistical analysis. Means were compared using Duncan's Multiple Range Test (DMRT) at the 5% probability level. Also, the maps were produced using ArcMap 10.2 and Excel software to carry out the figures.

3. Results and Discussion

3.1. Distribution of heavy metals in rice

The average concentrations of Cd, Pb, and Cr in rice were 0.034, 0.129, and 0.354 mg kg^{-1}, respectively, in Palengri (upstream of Kor river), 0.062, 0.169, and 0.393 mg kg^{-1}, respectively, in Darehhamune, and 0.069, 0.186, and 0.426 mg kg^{-1}, respectively, in Jamalbaig (downstream of Kor river) (Table 1). Compared with the limit indicators of the Standards and Industrial Research of Iran (ISIRI, 2010), the average concentrations of Pb were 13% (in the Darehhamune) and 24% (in the Jamalbaig) more than the value of the Iranian standard value, respectively. However, the Cd concentration of the rice in the downstream of Kor river (Darehhamune and Jamalbaig) was at the permissible limit of concentration (0.062-0.069 mg kg^{-1}). In addition, compared with the values from permissible limits of HMs in Soil and Plants (WHO, 1996) the concentrations of HMs studied in rice (Cd, Pd, and Cr) were within the concentrations in international standards.

Moreover, in all the studied areas, Pb concentration was more than Cd concentration, which is consistent with the results of previous studies (Tinggi et al, 2018, Mu et al, 2019). These results can be attributed to the higher Pb concentration in the soil and water used for rice cultivation, pesticides that contain Pb, and the plant's ability to transport Pb from the soil (Atamaleki et al, 2019). Other studies mentioned that rice plant roots absorb Pb through irrigation water and soil (Sharafi et al, 2019; Rezaei et al, 2021). In addition, expanding factories near rice fields is another important factor in increasing the pollution of HMs (Latare et al., 2014). However, it should be noted that Pb is generally present in the superficial layers of rice seeds, so it is expected that most of the Pb be removed by repeated washing of rice in the cooking methods (Mihucz et al., 2010).

The coefficients of variation (CV) values of Cd, Pb, and Cr, in rice were 1.85%, 1.91%, and 1.03%, respectively (Table 1). They showed low variability (0.1 ≤ CV) until moderate variability (0.1 ≤ CV < 1.0). These results show that there was not much data dispersion in the sampling points.

3.2. Risk of heavy metals on people's health

3.2.1. Average dietary intake of rice

According to Table 2, the ADI values of HM in adults were 50% to 75% higher than in children. In the downstream of Kor river (Jamalbaig), the ADI values of Cd, Pb, and Cr in adults compared to children were increased by 75%, 64%, and 71%, respectively, when in the upstream of Kor river (Palengri), values were 50%, 72%, and 70%, respectively. According to the reports of JECFA (2019), the provisional tolerable daily intake (PTDI) of Cd, Pb, and Cr was 0.001, 0.003 and 1.5, respectively. Compared to PTDI (JECFA, 2019), the ADI of Cd, Pb, and Cr in Jamalbaig was 1.66, 2.53, and 454.54 times lower, while the ADI of Cd, Pb, and Cr in Palengri, was 4.00, 3.70, and 555.55 times lower, respectively. So, the ADI HMs were within their tolerable range.

3.2.2. Non-carcinogenic risks

THQ values for children and adults were ranked Cd > Pb > Cr, respectively (Table 3). For all HMs, THQ was significantly higher

Table 1. Statistical analysis for heavy metals in rice of studied areas (mg kg^{-1}).

Metal	Palengri	Allah-Moradkhani	Chamriz	Darehhamune	Jamalbaig	CV%	Iranian standard[a]	International standard[b]
Cd	0.034	0.046	0.059	0.062	0.069	1.851	0.06	0.40
Pb	0.129	0.144	0.157	0.169	0.186	1.910	0.15	0.20
Cr	0.354	0.368	0.384	0.393	0.426	1.03	Null*	1.30

a The values from Institute of Standards and Industrial Research of Iran (ISIRI, 2010).
b The values from Permissible Limits of Heavy Metals in Soil and Plants (WHO, 1996).
* "Null" stands for no relevant standard value was found.

Table 2. Average Dietary Intake (ADI) of Cd, Pb and Cr (mg kg^{-1}day^{-1}) in samples of rice grown in Kamfiruz District, Fars Province by adults and children.

Sampling area	Cd		Pb		Cr	
	Adults	Children	Adults	Children	Adults	Children
Palengri	0.0002	0.0003	0.0007	0.0012	0.0020	0.0034
Allah-Moradkhani	0.0003	0.0004	0.0008	0.0014	0.0021	0.0035
Chamriz	0.0003	0.0006	0.0009	0.0015	0.0022	0.0037
Darehhamune	0.0004	0.0006	0.0010	0.0016	0.0022	0.0038
Jamalbaig	0.0004	0.0007	0.0011	0.0018	0.0024	0.0041

Table 3. Target Hazard Quotient (THQ) of Cd, Pb and Cr (mg kg^{-1}day^{-1}) in samples of rice grown in Kamfiruz District, Fars Province by adults and children.

Sampling area	Cd		Pb		Cr	
	Adults	Children	Adults	Children	Adults	Children
Palengri	0.1932	0.3266	0.1986	0.3358	0.0013	0.0023
Allah-Moradkhani	0.2642	0.4466	0.2226	0.3763	0.0014	0.0024
Chamriz	0.3390	0.5730	0.2414	0.4081	0.0015	0.0025
Darehhamune	0.3535	0.5976	0.2603	0.4400	0.0015	0.0025
Jamalbaig	0.3909	0.6608	0.2860	0.4834	0.0016	0.0027

compared to adults ($p<0.01$). In general, the THQ in none of the investigated HMs exceeded 1.0 even in the downstream.

Also, HI and HQ were used to measure the non-carcinogenic risks of HMs in rice. According to the results (Figure 3, Table 4), HI in adults reached ≥ 1 in the river's downstream areas. In the downstream areas, HI was 1.04 and 1.14 in Darehhamune and Jamalbaig, respectively, while HI in adults was ≤ 1 in the river's upstream areas. Also, the value of HI in children was < 0.7. Moreover, HQ increased from upstream to downstream of the river, so that in Jamalbaig, Cd, Pb, and Cr reached in order 0.3909, 0.2860, and 0.0016 in adults, and 0.6608, 0.4834, and 0.0027 in children, respectively. However, HQ didn't reach more than 1 in any of the sampling sites. Therefore, there is no specific non-carcinogenic risk. The HI and HQ in adults were lower than in children.

In general, residents of Kamfiruz District, Fars province are not at a considerable non-carcinogenic risk due to the consumption of rice containing Cd, Pb, and Cr, however, Darehhamune and Jamalbaig are on the border of a non-carcinogenic risk and should be given special attention.

In different studies, inconsistent results have been reported regarding the non-carcinogenic risk of HMs in rice. The study by Zheng et al. (2020) in the Pearl River Delta in China showed that the THQ of Cd and Pb were 1.03 and 0.46, respectively, and they reported that Cd and Pb were the two main non-carcinogenic pollutants in rice that affected the health of the people. Lu et al. (2021) also studied the risk assessment of HMs in rice in Fujian province, China. They stated that HI values of Cd showed that rice is a non-carcinogenic threat. Furthermore, in a study conducted by Fang et al. (2014), HQ < 1 was reported for Pb in rice in China. Similarly, Wang et al (2005) conducted a study in Tianjin, China and stated that the HQ for Cd and Pb was 0.3 and 0.2, respectively. Also, Li et al (2010), by studying varieties of rice grown in China, reported that HQ related to Cd ranged from 0.6 to 2.

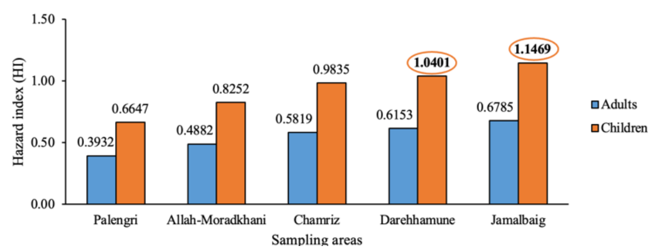

Fig. 3. Hazard Index (HI) of Cd, Pb and Cr in samples of rice grown in Kamfiruz District, Fars Province by adults and children.

In the studies conducted in Iran, Sharafi et al (2019) investigated HMs in Iranian, Pakistani, and Indian rice. They stated that the THQ of Cd, Pb, and As was 1> (THQ = 0.61-0.62) in Iran and Pakistan and 1< (THQ = 1.28) in India. Rezaei et al. (2021) assessed the health risk through rice consumption in Hormozgan province, Iran. They reported that the total target hazard ratio (THQ) for Cd, Pb, and As indicated a negligible non-carcinogenic risk through rice consumption (THQ < 1). Also, Ghoochani et al. (2019) studied the carcinogenic and non-carcinogenic risk of Pb and As in rice samples imported to Iran and reported that HI in the rice sample was within the safe range. Vatanpour et al. (2020) on the assessment of the risks of HM in rice cultivated from the Tajen river basin, Iran, showed that the THQ for HMs was more than 1 (THQ values of Pb = 13.8, Fe = 7.7, Cr = 5.5, and Cd = 1.5).

Table 4. Hazard Quotient (HQ) of Cd, Pb and Cr (mg $kg^{-1}day^{-1}$) in samples of rice grown in Kamfiruz District, Fars Province by adults and children.

Sampling area	Cd		Pb		Cr	
	Adults	Children	Adults	Children	Adults	Children
Palengri	0.1932	0.3266	0.1986	0.3358	0.0013	0.0023
Allah-Moradkhani	0.2642	0.4466	0.2226	0.3763	0.0014	0.0024
Chamriz	0.3390	0.5730	0.2414	0.4081	0.0015	0.0025
Darehhamune	0.3535	0.5976	0.2603	0.4400	0.0015	0.0025
Jamalbaig	0.3909	0.6608	0.2860	0.4834	0.0016	0.0027

Table 5. Carcinogenic Risk (CR) of Cd, Pb and Cr (mg kg-1day-1) in samples of rice grown in Kamfiruz District, Fars Province by adults and children.

Sampling area	Cd		Pb		Cr	
	Adults	Children	Adults	Children	Adults	Children
Palengri	0.0029	0.0049	0.0000	0.0000	0.0010	0.0017
Allah-Moradkhani	0.0040	0.0067	0.0000	0.0000	0.0010	0.0018
Chamriz	0.0051	0.0086	0.0000	0.0000	0.0011	0.0019
Darehhamune	0.0053	0.0090	0.0000	0.0000	0.0011	0.0019
Jamalbaig	0.0059	0.0099	0.0000	0.0000	0.0012	0.0021

They also reported that the HI was high (HI = 29.2), indicating that the exposure concentration of people compared to the effective threshold was high. Niknejad et al (2024) studied Iranian rice produced in Amol and Mahmoudabad in Mazandaran Province and reported that the average HI in rice samples was more than 1 (2.42 and 1.91 in Amol and Mahmoudabad, respectively). They also showed that HQ for Pb was 1.86 and 1.22 for Amol and Mahmoudabad households, respectively. According to their results, rice consumers have a high potential risk. In addition, Mousavi Khaneghah et al. (2023) studied rice samples collected from Tehran, Iran, and reported that the HI for adults and children were 1.05 and 4.34, respectively, indicating a potential non-carcinogenic risk associated with multiple PTE exposures. Nozari et al. (2023) studied the rice of Mazandaran Province and indicated that the target hazard quotient (THQ) did not have a significant non-carcinogenic risk for children and adults, while the total target hazard quotient (TTHQ) showed a non-carcinogenic risk, which indicates the cumulative effect of HM risk on rice.

It seems that the amount of THQ is affected by the type of HMs and the concentration of HMs, the duration of exposure to these pollutants, etc. (Abtahi et al, 2017; Fakhri et al, 2018; Yousefi et al 2018). Previous studies showed that the aleurone layer and endosperm of rice accumulate a high concentration of HMs (Xu et al., 2006; Meharg et al., 2008). In this regard, Liu et al., (2007) stated that Cd concentration in straw and polished rice was 5 times lower than that of the cortex (embryo). According to these studies, brown rice can endanger people's health more than polished rice, so polishing rice can reduce the concentration of heavy metals in rice. The current study has been conducted on polished rice, and this has led to a reduction in the concentration of HMs in rice and the risk of disease.

3.2.3. Carcinogenic risks

According to WHO studies on carcinogenic substances, CR more than 1×10^{-4} has carcinogenic risk (USEPA, 2006). In this study, CR values of Cd and Cr in rice were > 1×10^{-4}, while this value was in the safe range for Pb (<1×10^{-4}) (Table 5). CR of adults was significantly lower than that of children ($p<0.01$). CR of Cd and Cr were at their highest values in the downstream of Kor river (Jamalbaig) i.e. 59×10^{-4} and 12×10^{-4} for adults and 99×10^{-4} and 21×10^{-4} for children, respectively.

Moreover, it was at its lowest level in the order of 29×10^{-4} and 1×10^{-3} for adults and 49×10^{-4} and 17×10^{-4} for children in the upstream of Kor river (Palengri).

The range of TCR values of HMs in rice in adults was 39×10^{-4} to 71×10^{-4}, while in children these values were 1.7 times that of adults (66×10^{-4} to 12×10^{-3}) (Figure 4). So, According to WHO studies on carcinogenic substances (USEPA, 2006), TCR of HMs has carcinogenic risk. Also, TCR was in the highest value in the downstream of Kor river (Jamalbaig) and in the lowest value in the upstream of Kor river (Palengri). Moreover, the participation percentage of the HMs to TCR were Cd (80.70%) > Pb (0.13%) > Cr (19.17%) (Figure 5).

Studies showed that children who were exposed to HMs during their life, especially Cd and As, had a high potential for cancer (Ma et al., 2016; Halder et al., 2020; Sun et al., 2020). In this regard, the studies of Mao et al (2019) also showed that the CR of Cd in children and adults using paddy rice in China was higher than the upper limit of human tolerance (1×10^{-4}).

In the present study, although the TCR was significant in the exposed population, the calculated risks are likely lower than the true cancer risk. That can be attributed to digestive processes in the body, which may reduce the absorption of heavy metals in the body (Praveena and Omar, 2017). In addition, washing rice before cooking can reduce the toxicity of contaminated rice (Behrouzi et al, 2018; Liu et al, 2018). According to the studies of Ghoochani et al. (2019), after cooking rice, the lead of rice decreased from 0.3417 to 0.2219.

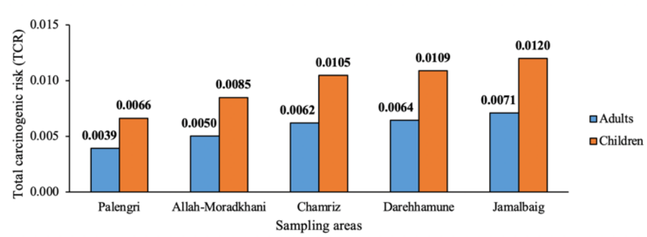

Fig. 4. Total Carcinogenic Risk (TCR) of Cd, Pb, and Cr in samples of rice grown in Kamfiruz District, Fars Province by adults and children.

In this regard, Niknejad et al (2024) evaluated the health risk of HMs in rice in Mazandaran province, Iran and stated that the average lifetime cancer risk (LTCR) values of the HMs in rice of Amol (Cd (3.46×10^{-4}) > As (8.60×10^{-5}) > Cr (5.71×10^{-5})) and

Mahmoudabad (Cd (3.97×10^{-4}) > As (1.04×10^{-4}) > Cr (4.75×10^{-5}) was within the acceptable range (10^{-6} to 10^{-4}). Also, Mousavi Khaneghah et al. (2023) reported that the values of lifetime cancer risk (ILCR) resulting from exposure to HMs (Cr, Ni, As, and Cd) exceeded the threshold value in Iranian rice, showing a carcinogenic risk from exposure to PTEs. Moreover, Nozari et al (2023) in a study assessed the risk of heavy metal and pesticide contamination on people's health in Mazandaran Province, Iran. They stated that the TCR value indicated carcinogenicity for carcinogenic HMs in the area.

Based on the results of the previous studies, the values of HI and TCR in children are higher than in adults (Hang et al., 2009; Minh et al., 2012; Hu et al., 2020; Sun et al., 2020). It seems that although the amount of heavy metals received by adults is more than that of children, due to the lower body weight of children, the amount of ADI in children is higher than that of adults (Table 2). These results were consistent with the study conducted by Chen et al. (2018). In addition, Kukusamude et al. (2020) showed that children's bodies have less tolerance to heavy metals.

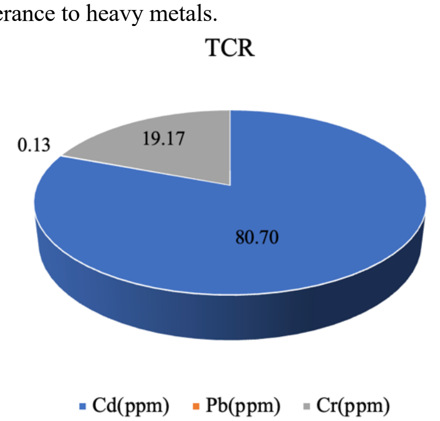

Fig. 5. Participation percentage of Cd, Pb and Cr to Total Carcinogenic Risk (TCR) in samples of rice grown in Kamfiruz District, Fars Province by adults and children.

4. Conclusion

Rice in five paddy fields around the Kor river was examined for the risks of HMs (Cd, Pb, and Cr). The concentration of HMs not was higher than the standard concentration of these metals in the world, however, due to stricter standards in Iran, the concentration of HMs in studied rice was higher than the standard set in Iran.

According to the results, the consumption of Kamfiruz local rice didn't have a specific non-carcinogenic risk for consumers, however, it is considered a threat in terms of carcinogenic risks. It should be noted that the amount of HM risks in human health has been determined in the most value because the concentration of HMs decreases during washing and cooking rice, so it is recommended that rice be soaked for several hours and then cooked. However, based on these results and due to the high consumption of rice in Iran, it is recommended a deep and detailed investigation and continuous monitoring of the soil, water and agricultural products, including rice, in the assessed region.

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Conflict of interest

The authors declare that there is no conflict of interest.

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