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Nitrate Content in Potato (*Solanum tuberosum* L.) and Onion (*Allium cepa* L.) and Its Human Health Risk Assessment in the Fields with the Highest Cultivated Area in Kermanshah Province, Iran

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ABSTRACT

The major portion of daily dietary nitrate that enters the human body is derived from vegetable consumption. High concentration of nitrate in edible parts of vegetables causes a variety of poisonings, anemia in children and production of carcinogen nitrosamine in adults. To investigate the concentration of nitrate in potatoes and onions grown in Kermanshah province, sampling was carried out from the fields located in different counties at the time of harvest in the summer and autumn of 2019. After washing, drying, grinding, and extracting the samples, the nitrate concentrations were determined with a spectrophotometry method. The results showed that the mean nitrate concentration in potato and onion samples (94.56 and 74.62 mg kg^{-1} FW, respectively) of all regions was significantly lower than the World Health Organization standard limit (250 and 1000 mg kg^{-1} FW, respectively). The highest concentration of nitrate in potato (153.70 mg kg^{-1} FW) and onion (98.02 mg kg^{-1} FW) was observed in samples from the Qasr-e-Shirin and Kermanshah, respectively. The non-cancer hazard quotient (HQ) of nitrate via potato and onion consumption was below 1 for all age receptor groups. Although, it does not seem to be a particular problem with consuming these vegetables; however, the evaluation of nitrate concentration in potato and onion samples is recommended at regular time intervals.

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1. Introduction

Nitrate (NO_3^-) is one of the non-protein forms of nitrogen. When the plant grows under unusual conditions, the activity of the nitrate reductase (NR) enzyme decreases and, as a result, NO_3^-accumulates in the plant and is not converted to protein. The most important sources of NO_3^- in the diet are drinking water and vegetables (Jalali *et al.*, 2020). Vegetables are usually consumed daily by humans and account for about 72-94 % of the total daily NO_3^- intake (Haftbaradaran *et al.*, 2018a). Vegetables are an important part of the Iranian families' diet, accounting for 20% of the country's food basket. High concentrations of NO_3^- in vegetables cause a variety of poisonings, anemia in children, and the production of nitrosamine carcinogen in adults (Karwowska and Kononiuk, 2020). According to clinical and epidemiological studies, gastric cancer is caused by high concentrations of NO_3^- and nitrite in the diet (Seyyedsalehi *et al.*, 2023). One of the main ways to have a healthy food basket is to produce a healthy product (Koocheki *et al.*, 2017).

Numerous factors affect NO_3^- accumulation in plants, including environmental and genetic factors. The type and variety of plants can greatly affect their ability to produce the NR enzyme (Tabandeh and Safarzadeh Shirazi, 2018). Another main reason for the presence of excess NO_3^- in vegetables is the excessive and unbalanced use of urea and other nitrogen fertilizers (Haftbaradaran *et al.*, 2018a; Taghipour *et al.*, 2019). According to the available information, about 2.4 million tons of different chemical fertilizers are applied to agricultural soils in Iran, about 60% of which are nitrogen fertilizers (Malakouti *et al.*, 2013).

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Onion (*Allium cepa* L.) belongs to the Amaryllidaceae family. Based on the Food and Agriculture Organization (FAO), Iran was the seventh-largest producer of onions in the world (FAO, 2020). In Iran, onion consumption per capita is about 22 kg yr^{-1}, which is 20 times greater than the global average consumption (1.1 kg yr^{-1}). This information shows the importance of this vegetable in the country's food basket (Mousavi Moayed *et al.*, 2017). Potato (*Solanum tuberosum* L.), with a global production of 376 million tons, is one of the most important agricultural products in the world after corn, wheat, and rice (FAO, 2021). Potato production in Iran is 4.5 million tons and ranks 19th among the producing countries in 2020 (Vejdani, 2020). The potato consumption per capita in the country is 45.6 kg yr^{-1} and 66 kg yr^{-1} in the world in 2020 (FAO, 2020).

In general, the maximum amount of NO_3^- that enters the human body should be less than the acceptable daily intake (ADI) of 3.65 mg kg^{-1} body weight per day (Jalali *et al*., 2020). This means that for example, a 70-kg person should not consume more than 255 mg NO_3^- per day. Therefore, the concentrations of NO_3^- should be reduced to a minimum level, especially for people who eat a lot of vegetables in their diet (Li *et al.*, 2022). Vegetables whose roots, stems, and leaves, are usually used, have higher NO_3^- accumulation than products which their fruits are consumed (Liu and Huang, 2021).

Pirsaheb et al. (2012) determined NO_3^- concentrations in edible parts of potatoes in Kermanshah city. Their results showed that the average NO_3^- concentrations of 347.7 mg kg^{-1}FWwas more than the standard amount of 250 mg kg^{-1} FW recommended by the World Health Organization (WHO) for potatoes. Pirsaheb et al. (2013) also reported that the average NO_3^- concentrations in onions (20.70 mg kg^{-1} FW) in different plains of Kermanshah province was less than the standard amount of 1000 mg kg^{-1} FW recommended by the WHO for onion. In their study, Ardakani et al. (2005) reported the mean NO_3^- concentrations in onion bulbs and potato tubers of 450 and 203 mg kg^{-1} FW in different counties of Isfahan province, respectively. These reported amounts were less than the WHO standard limit. Haftbaradaran et al. (2018a) showed that the mean NO_3^- concentrations of potatoes (59 mg kg^{-1} FW) were lower than the WHO standard limit in all counties of Isfahan province. Tabandeh and Zarei (2018) reported that the mean NO_3^- concentrations in potatoes and onions grown in two consecutive years in Zanjan province were 30 and 69 mg kg^{-1} FW, respectively.

The areas which are under cultivation of potatoes and onions in Kermanshah province are about 6735 and 2637 hectares, respectively. Moreover, about 303075 and 141537 tons of potatoes and onions are harvested annually from these areas, respectively (Ahmadi, 2019). There is public concern about the high concentrations of NO_3^- in crops such as potatoes and onions. Also, chemical fertilizers containing nitrogen are applied by local farmers more than the optimal recommendations. Moreover, the regular determination of NO_3^- in products is a necessity. The current study was conducted to 1) determine the status of NO_3^- in potatoes and onions grown in Kermanshah province, and 2) evaluate the human health risks of their consumption.

2. Materials and methods

2.1. Description of the study area

Kermanshah province is located between the longitude of 46° 67ʹE and latitude of 34° 45ʹ N in the west of Iran and covers an area of 24.640 km^2. The Minimum and maximum elevations are 372 and 1700 m above sea level, respectively. The average annual temperature and precipitation are 15.8 °C and 693.1 mm, respectively (Kermanshah Department of Meteorology, 2023).

Kermanshah, with an area of more than 2.3 million hectares, plays a significant role in the production of agricultural products in the country due to its diverse climatic conditions. The total area under cultivation of agricultural products in the province is 900 thousand hectares, of which 670 and 230 thousand hectares are rain-fed and irrigated lands, respectively. The main agricultural products of this province belong to cereals, oilseeds, fodder plants, legumes, and industrial plants (Allahyari *et al.*, 2015).

2.2. Plant, soil, and water sampling

According to the data collected from the Agriculture Jihad Organization of Kermanshah province, the counties with the highest cultivation areas of potato and onion were selected for sampling. Qasr-e-Shirin, Ravansar, and Sonqor counties had the highest areas under potato cultivation. Also, Kermanshah, Ravansar, and Bisotun counties had the highest areas under onion cultivation. Depending on the harvest time (summer and autumn), potato tubers and onion bulbs were sampled in 2019. In each county, sampling was carried out on the large farms, which were somewhat advanced and provided most of the province's agricultural products. After determining the desired fields, samples were randomly collected from each field, then all the samples were combined and a composite sample of at least 3 kg was prepared from that field. To prepare the representative samples for each region, different fields were collected depending on the area under cultivation and the variety of grown cultivars.

Information about farm management such as the type and amount of applied chemical and organic fertilizers, irrigation time, date of cultivation, and harvest time were recorded simultaneously. The collected samples were transferred to the laboratory in a portable refrigerator. It should be noted that due to heavy rains in the autumn of 2018 in Kermanshah County, farmers did not succeed to plant potatoes, so it was not sampled in this region in the summer of 2019. The composite samples of soil and irrigation water (wells or rivers) were also taken from each field. The number of soil and irrigation water samples was similar to potato and onion samples. The water samples were stored in the refrigerator until analysis. Soil samples were collected from a depth of 0-30 cm and passed through a 2 mm sieve after air drying.

2.3. Plant and soil preparation and NO_3^- extraction

Plant samples were first washed with tap water and then with distilled water. The samples were oven dried at 70 °C for 48 h after cutting them into smaller pieces. Then they were ground and kept at -18 °C until analysis. The plant samples moisture content was measured as the difference between fresh and dry weight, divided by dry weight. To extract NO_3^- from plant samples, 0.4 g dried, ground sample + 0.5 g active coal (for decolorization) were shaken in 40 mL of 0.025 M aluminum sulfate solution in a tube for 30 min at 200 rpm. The extracts were filtered through Whatman filter paper No. 42 (Jones, 2001).

To extract soil NO_3^-, 50 mL of 2M KCl solution was added to a 10 g soil sample. Then, the sample was shaken for 15 min at 180 rpm. The supernatant was then filtered through the Whatman filter paper (Jones, 2001). All extractions were made in 3 replications.

2.4. NO_3^- analysis

For the determination of NO_3^- concentrations in plant and soil extracts and water samples, 0.8 mL of 5% sulfosalicylic acid was added to 0.2 mL of sample extract. At this stage, the temperature of the samples increased. After cooling the samples (20 min), 19 mL of 2M NaOH was added. Finally, after the formation of the yellow complex, the absorbance of samples and standards was recorded using a spectrophotometer at 410 nm (Cataldo *et al*., 1975).

2.5. Exposure evaluation

By using the United State Environmental Protection Agency (USEPA) equation (Equation 1), average daily intake rates of NO_3^- for ingestion of potato tuber and onion bulb were calculated (USEPA, 1989):

$$\text{(1)} \qquad \text{Intake (mg kg}^{-1}\text{ d}^{-1}) = \frac{CF \times IR \times FI \times EF \times ED}{BW \times AT}$$

where CF= NO_3^- concentration in food (mg g^{-1}), IR= ingestion rate (g d^{-1}) or (g L^{-1}), FI= fraction ingested from contaminated source (unit less), EF= exposure frequency (d yr^{-1}), ED= exposure duration (yr), BW= body weight (kg), and AT= averaging time that is the period over which exposure is averaged and calculated (d) by AT= 365 (d yr^{-1}) × ED (yr).

The mean FI amount is 0.25, and its "worst-case" amount is 0.4 (Haftbaradaran *et al*., 2018b). The amount of 0.4, representing the upper 95th percentile, was used in this study. The parameters used in risk assessment are presented in Table 1.

2.6. Risk assessment

By using the following USPEA equation (Equation 2) (Mousavi Moayed *et al*., 2017), the non–cancer hazard quotient was calculated by dividing the daily intake by the reference dose (RfD):

$$\text{(2)} \qquad HQ = \text{Intake}/\text{RfD}$$

where HQ = non-cancer hazard quotient, RfD = chronic reference dose for contaminant (mg kg^{-1} d^{-1}), which is 3.65 mg kg^{-1} d^{-1} (Yeganeh and Bazargan, 2016). Table 1 shows the amount of factors used in the above equations for different age receptor groups and regions.

Table 1. Range of parameters used to assess the risk.

Factors	ED (yr)	EF (d/yr)	Body weight (kg)	IR (g/d)	
				Potato	Onion
Girls less than 6	4	365	17.5	19.4	2.9
Boys less than 6	4	365	18.8	19.4	2.9
Girls 7 to 14	7	365	39	68	19.2
Boys 7 to 14	7	365	35	68	19.2
Girls 14 to 18	4	365	56	68	19.2
Boys 14 to 18	4	365	59.1	68	19.2
Women 18 to 54	27	365	61	68	19.2
Men 18 to 54	27	365	76.4	68	19.2
Women more than 55	15	365	60.6	68	19.2
Men more than 55	15	365	65.1	68	19.2
References	(Aghili *et al.*, 2009)	(WHO, 1978)	(Prasad and Chetty, 2008)	(MHME, 2013)	(Chavoshi *et al.*, 2011)

2.7. Statistical analysis of data

Statistical analysis of data was conducted using SPSS (16). At first, the normality of data was checked and then Duncan's test was used for mean comparison between NO_3^- concentrations in potatoes or onions of different counties. The comparison between NO_3^- concentration in potato or onion and WHO standard limit and Iranian National Standardization Organization (INSO) was done by a one-sample T-test. NO_3^- standard limits of 250 and 1000 mg kg^{-1} FW are recommended by WHO for potatoes and onions, respectively (WHO, 1978). Iranian standard limits for potato and onion were 170 and 90 mg kg^{-1}FW, respectively (INSO, 2013).

3. Results

3.1. NO_3^- content in potato and onion

Descriptive statistics of NO_3^- concentration in plant samples collected from different counties are presented in Table 2.

Table 2. Statistics of NO_3^- concentration (mg kg^{-1} FW) in potato and onion samples of the studied areas.

Crop	County	Number of sampling points	Minimum	Maximum	Mean±SD	Median	Skewness	Kurtosis
Potato	Kermanshah	10	23.58	159.34	80.36±37.96	74.31	0.42	1.12
	Qasr-e-Shirin	5	111.18	194.95	153.70±23.45	148.29	0.19	-0.43
	Ravansar	13	25.40	130.65	72.76±31.19	61.06	0.56	-0.89
	Sonqor	11	12.02	166.56	71.42±37.99	69.42	0.45	-0.40
Onion	Kermanshah	5	86.51	142.32	98.02±19.91	89.71	0.44	-1.65
	Ravansar	5	51.72	77.61	65.16±9.46	66.24	-0.19	-1.88
	Bisotun	5	28.46	91.39	60.69±17.84	63.97	-0.24	-0.56

Results of the Kolmogorov-Smirnov test showed that NO_3^- concentrations of potatoes and onions were normally distributed. Duncan's test revealed that the mean concentrations of NO_3^- in the Kermanshah, Sonqor, and Ravansar counties were not different ($P>0.05$).

The highest and lowest mean concentrations of NO_3^- were observed in potato samples of Qasr-e-Shirin (153.7 mg kg^{-1} FW) and Sonqor (71.42 mg kg^{-1} FW), respectively (Fig. 1). The mean NO_3^- concentrations in onions of Bisotun and Ravansar didn't show a significant difference at the 5% level. The highest and lowest mean NO_3^- concentrations in onions were in Kermanshah (98.02 mg kg^{-1} FW) and Bisotun (60.69 mg kg^{-1} FW), respectively (Fig. 2). The T-test results showed that the mean NO_3^- concentrations in potatoes and onions of all counties were significantly lower than WHO and INSO of 250 and 170 mg kg^{-1} FW, respectively ($P<0.001$). NO_3^- concentration in onions was lower than the WHO standard limit (1000 mg kg^{-1} FW) in all counties ($P<0.001$). According to ISNO (90 mg kg^{-1}) onion NO_3^- concentration in Kermanshah was a little higher but not significant.

3.2. NO_3^- concentration in soil and water samples

ANOVA results showed significant differences between soil NO_3^- concentrations in different counties ($P<0.001$) (data not shown). The mean NO_3^- concentrations in the studied soils of different counties are shown in Fig. 3. The mean NO_3^- concentrations in the soils ranged from 19.4 to 48.6 mg/kg. NO_3^- concentrations in the soils of Kermanshah, Sonqor, and Bisotun were significantly higher than those of Ravansar and Qasr-e-Shirin. Soil NO_3^- standard limit has been reported from 20 to 22 mg kg $^{-1}$ in different studies (Mehrabi *et al.*, 2017). Based on one sample T-test, the mean soil NO_3^- concentrations in Kermanshah, Sonqor, and Bisotun were significantly higher than the NO_3^- standard limit of 22 mg kg^{-1}.

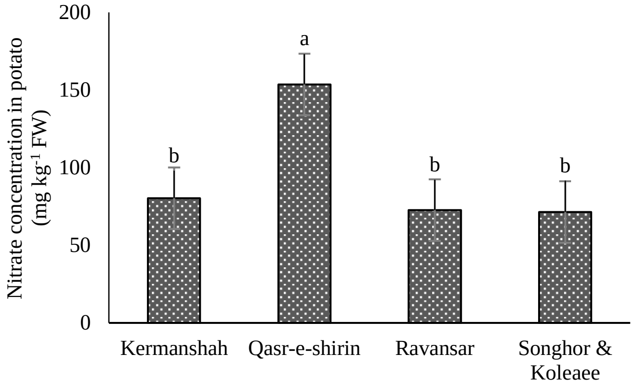

Figure 1. Mean NO_3^- concentrations in potato samples of the different studied counties. Columns with different letters are significantly different at P<0.05. The bars on each column show standard deviation.

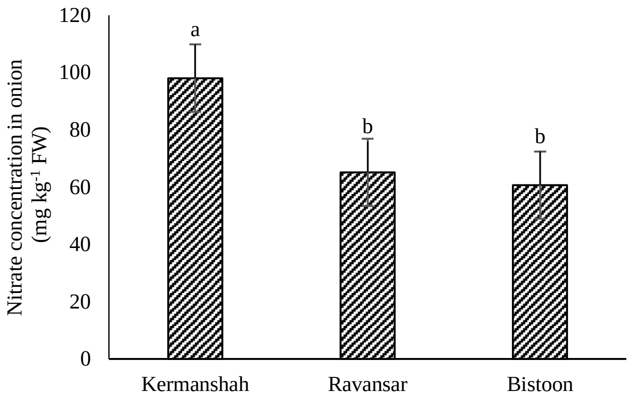

Figure 2. Mean NO_3^- concentrations in samples of the different studied counties. Columns with different letters are significantly different at P<0.05. The bars on each column show the standard deviation.

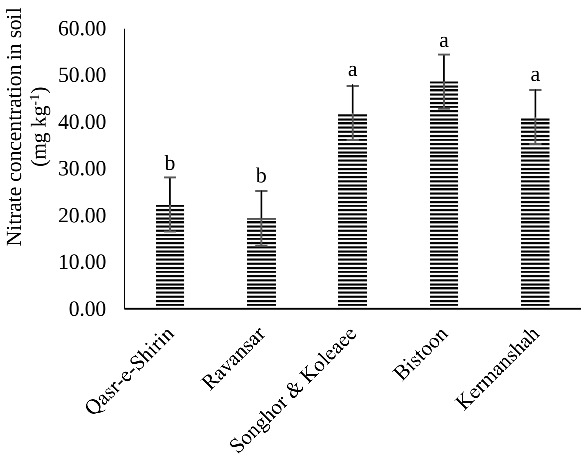

Figure 3. Mean soil NO_3^- concentrations of the different studied counties. Columns with different letters are significantly different at P<0.05. The bars on each column show standard deviation.

ANOVA results did not show a significant difference between NO_3^- concentration in irrigation water in different counties (P>0.05) (data not shown). Mean NO_3^- concentrations in water samples of different counties ranged from 2.6 to 25.5 mg L^{-1} (Fig. 4). The NO_3^- concentrations in water samples of Kermanshah and Sonqor were significantly higher than samples of Ravansar, Qasr-e-Shirin and Bisotun. The NO_3^- standard limit in irrigation water is 44.2 mg L^{-1} (USEPA, 2001). The result of the T-test showed that the mean NO_3^- concentrations of water samples were significantly lower than the permissible limit of irrigation water NO_3^- ($P<0.001$) (44.2 mg L^{-1}).

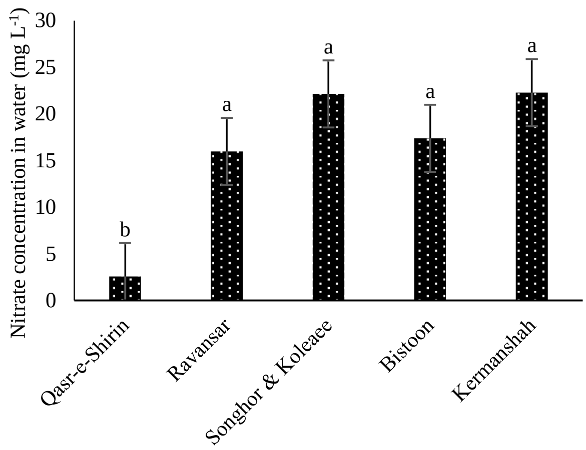

Figure 4. Mean water NO_3^- concentrations of the different studied counties. Columns with different letters are significantly different at P<0.05. The bars on each column show the standard deviation.

3.3. Non-cancer risk assessment

Table 3 shows the results of non-cancer risk assessment in different age receptor groups. The HQ factor was less than 1 for potatoes and onions in all age receptor groups. The mean HQ for potatoes in all counties was highest in girls and boys between 7 and 14 years old. The highest HQ (0.12) was found for 7-14-year-old boys in Qasr-e-Shirin, while the lowest HQ (0.025) was obtained for 18-54-year-old men in Sonqor, which the latter was about 5 times lower than the former (Table 3). The mean HQ of onion in all counties was higher for 7-14-year-old boys and girls than for other age receptor groups. The highest amount of HQ of onion (0.021) was obtained for boys and 7-14-year-old girls in Kermanshah county, while the lowest HQ (0.0037) was observed for boys and girls who were < 6 years old in Bisotun county, which the latter was about 6 times lower than the former (Table 3).

Table 3. Non-cancer hazard quotient (HQ) from potato and onion consumption for different age receptor groups and counties.

Crops	County	Girls<6	Boys<6	Girls 7-14	Boys 7-14	Girls 14-18	Boys 14-18	Women 18-54	Men 18-54	Women>55	Men>55
Potato	Kermanshah	0.035	0.033	0.056	0.062	0.039	0.037	0.035	0.028	0.036	0.033
	Qasr-e- Shirin	0.068	0.063	0.110	0.120	0.074	0.070	0.068	0.054	0.069	0.064
	Ravansar	0.032	0.030	0.050	0.056	0.035	0.033	0.032	0.026	0.032	0.030
	Sonqor	0.031	0.029	0.049	0.055	0.034	0.032	0.031	0.025	0.031	0.029
Onion	Kermanshah	0.006	0.006	0.019	0.021	0.013	0.012	0.012	0.010	0.012	0.011
	Ravansar	0.004	0.004	0.012	0.014	0.009	0.008	0.008	0.006	0.008	0.007
	Bisotun	0.004	0.003	0.011	0.013	0.008	0.007	0.007	0.006	0.007	0.007

4. Discussion

4.1. NO_3^- content in potato and onion

According to the results, NO_3^- concentrations in potatoes and onions were less than the WHO standard levels of 250 and 1000 mg kg^{-1} FW for potatoes and onion, respectively. However, based on ISNO limits for potato (170 mg kg $^{-1}$ FW) and onion (90 mg kg^{-1} FW) only onion NO_3^- concentration in Kermanshah was a little higher than the standard limit. Qasr-e-Shirin had the highest NO_3^- concentrations in potatoes, whereas Kermanshah had the highest NO_3^-concentration in onions compared to the other counties. According to the farmers' survey during the sampling, a combination of chemical nitrogen and organic fertilizers was used almost in all studied areas. It seems that the increase in the price of nitrogen fertilizers during the last 5-6 years has changed the management operation of farmers in the production of potatoes and onions in the field. The decrease in the application rate of nitrogen fertilizer has been compensated by the application of organic fertilizers. This approach could be one of the reasons for the low concentrations of NO_3^-in the studied vegetables. The analysis of NO_3^- concentrations in soil and water samples also confirmed that the rate of chemical (mainly urea) and organic fertilizers used by farmers was appropriate and based on the expert recommendation.

In addition to the application rate of fertilizer, the cultivar of crops is an important factor in the NO_3^- accumulation. Therefore, the differences in NO_3^- concentration in potatoes or onions of different regions can be related to their different cultivars. The high concentration of NO_3^- in potatoes of Qasr-e- Shirin and onions of Kermanshah can be ascribed to more urea use in these areas based on the information obtained from the farmers. Also, among the different counties, Qasr-e-Shirin had the lowest NO_3^- concentration in the soil and irrigation water. This result shows that most of the soil NO_3^- in this area was probably absorbed and accumulated in potatoes and is not left in the soil or leached.

Haftbaradaran et al. (2018a) reported that the time and method of nitrogen fertilizers application has a greater effect on the accumulation of NO_3^- in food products compared to the amount of fertilizer applied. The time and method of fertilizer application in each region depend on climate and geological factors. Furthermore, planting management has particular importance in the accumulation of NO_3^- in crops (Haftbaradaran *et al.*, 2018b). The concentration of NO_3^-in potato and onion crops in different parts of Iran has been measured in various studies. The results of the present study were consistent with some studies (Haftbaradaran *et al.*, 2018b; Tabandeh and Zarei, 2018) and in contrast with some others (Mousavi Moayed *et al.*, 2017). It should be noted that different standard limits have been used to interpret the NO_3^- concentration in these studies.

4.2. NO_3^- concentration in soil and water samples

Based on the results of the present study, soil NO_3^- concentration after crop harvest in Kermanshah, Sonqor, and Bisotun was about twice the permissible limit of 20 -22 mgkg^{-1}. The results of various studies show that NO_3^- concentration in soil is very variable and depends on the time of fertilization, type and use rate of fertilizer, irrigation time and the amount of NO_3^- uptake by the plant (Mehrabi *et al.*, 2017). Mehrabi et al. (2017) found that in three cultivars of potato, nitrogen chemical fertilizer uses and irrigation water decreased soil NO_3^- concentration but organic fertilizer application increased it.

The NO_3^- concentration in water samples is affected by different factors such as the type of water source (surface or well), soil type, type and amount of applied nitrogen fertilizers, and field water management. According to the results of this study, the mean concentrations of NO_3^- in the irrigation water of all regions were less than the permissible limit (44.2 mg L^{-1}). It seems that the most important factor that increases the concentration of NO_3^- in water, especially groundwater sources, is NO_3^- leaching from agricultural soils. Therefore, the management of applied nitrogen fertilizers can be very effective in reducing this problem.

4.3. Non-cancer risk assessment

The HQ values appeared to be a better indicator than a traditional single-based critical concentration (Haftbaradaran *et al.*, 2018a). Based on the results, in all age receptor groups and regions and for both crops, the calculated HQ values were less than 1, suggesting a non-significant risk level from the consumption of these vegetables. These results were consistent with the results of Haftbaradaran et al. (2018a) and Yeganeh and Bazargan (2016). This indicates that the potential for non-cancer hazards due to daily NO_3^- intake through the consumption of potatoes and onions is acceptable. A hazard quotient value less than 1 for non-carcinogen diseases indicates that there is no significant detrimental effect on human health due to NO_3^- uptake from potato and onion consumption during the lifetime of a person. HQ factor in potatoes was higher than in onions. This is due to the higher IR values in potatoes than in onions (more daily consumption rate of potatoes than onions). The highest amount of HQ for potato consumption in 7-14-year-old boys in Qasr-e-Shirin (0.12) and for onion consumption in 7-14-year-old boys in Kermanshah (0.021) were due to the higher per capita ratio of consumptions in this age group. In other words, the amount of NO_3^- received per unit of their body weight was higher than in the other groups. While NO_3^- concentrations in potatoes and onions were less than the critical levels, it is necessary to use risk assessment studies for completing the pollution studies and decision-making about the pollution of different elements and compounds in foodstuffs or in the environment (Hussain *et al.*, 2019).

5. Conclusion

According to the results, the mean concentrations of NO_3^- in potato samples of the studied counties were less than the WHO and ISNO limits. Also, the NO_3^- concentration in onion samples in all counties was less than the WHO standard limit but in Kermanshah it was a little higher than the Iranian standard limit. The nitrate HQ for potato and onion in all age receptor groups and regions was less than one. Therefore, it does not seem to be a particular problem with consuming these products.

Since large cultivated areas of these crops are leased to non-native farmers for several years, more monitoring and workshops should be done on the application of nitrogen fertilizer and environment-friendly substitutes in the future. Also, because of the large changes in NO_3^- concentration in different seasons and to ensure the health of the crops, it is recommended to determine the NO_3^- concentration in potatoes and onions at regular time intervals.

Abbreviations

ED= exposure duration, EF= exposure frequency, IR= ingestion rate, MHME=Ministry of Health and Medical Education

Conflict of interests

We wish to confirm that there are no known conflicts of interest associated with this publication.

Ethics approval and consent to participate

This study was not required to include a statement of ethics approval because no living organisms participated in it.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

The authors embedded all data in the manuscript.

Authors' contributions

All authors have participated in designing the idea, doing, analyzing and writing the article.

Informed consent

The authors declare not to use any patients in this research.

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