



# Measurement of $^{226}\text{Ra}$ , $^{232}\text{Th}$ , $^{137}\text{Cs}$ and $^{40}\text{K}$ activities of Wheat and Corn Products in Ilam Province – Iran and Resultant Annual Ingestion Radiation Dose

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## Abstract

**Background:** Natural background radiation is the main source of human exposure to radioactive material. Soils naturally have radioactive mineral contents. The aim of this study is to determine natural ( $^{238}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ ) and artificial ( $^{137}\text{Cs}$ ) radioactivity levels in wheat and corn fields of Eilam province.

**Methods:** HPGe detector was used to measure the concentration activity of  $^{238}\text{U}$  and  $^{232}\text{Th}$  series,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  in wheat and corn samples taken from different regions of Eilam province, in Iran.

**Results:** In wheat and corn samples, the average activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  were found to be 1.67, 0.5, 91.73, 0.01 and 0.81, 0.85, 101.52, 0.07 Bq/kg (dry weight), respectively.  $H_{\text{ex}}$  and  $H_{\text{in}}$  in the present work are lower than 1. The average value of  $H_{\text{ex}}$  was found to be 0.02 and average value of  $H_{\text{in}}$  to be found 0.025 and 0.027 in wheat fields samples and corn samples in Eilam provinces, respectively. The obtained values of AGDE are 30.49 mSv/yr for wheat filed samples and 37.89 mSv/yr for corn samples; the AEDE rate values are 5.28 mSv/yr in wheat filed samples and this average value was found to be 6.13 mSv/yr in corn samples in Eilam. Transfer factors (TFs) of long lived radionuclide such as  $^{137}\text{Cs}$ ,  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  from soils to corn and wheat plants have been studied by radiotracer experiments.

**Conclusion:** The natural radioactivity levels in Eilam province are not at the range of high risk of morbidity and are under international standards.

**Keywords:** HPGe detector, Gamma spectrometry, Environmental radioactivity, 40K, 137Cs, 226Ra, 232Th

## Introduction

Humans and other organisms in their environment are under continuous radiation of natural radioactive material found in earth's crust and cosmic rays. In addition, they receive the radiation of medical and industrial sources. The most important natural radionuclides are  $^{226}\text{Ra}$ ,  $^{40}\text{K}$ ,  $^{232}\text{Th}$  which with the different physical and chemical

properties enter into the physical and biological environments (1).  $^{226}\text{Ra}$  with half-life 1620 (y) belong to  $^{238}\text{U}$  chain is one of the main pollutants in the natural radiation environment and there is widely in different ecosystems. Higher solubility of this element than uranium causes this element be washed by underground water and brought to

the surface. This element is chemically similar to calcium and absorbed by plants through the soil and then through the food chain enters human's body. Almost 70% of  $^{226}\text{Ra}$  is accumulated in the bones and the rest spread to soft tissues of the body. This radionuclide is a bone-oriented element and due to its long half-life remains in bones. However because of alpha radiation serious dangers such as bone marrow cancer can threaten human health. Average annual absorption of  $^{226}\text{Ra}$  through the food and drink is about 19 Bq in global level that causes effective dose equivalent approximately 3.8  $\mu\text{Sv}$  in a year (2).

The main stages of infection entering the human food chains are:

1 – To be uptaken radionuclide by plants through leaves or roots and transferring it to fruit or in cereal and legumes to grains.

2 - Radionuclide transport from plants, fodder animals and animal products.

3- Finally human in biological cycle, both through the polluted plants and animal products can be affected.

Therefore it is necessary to pay attention to radioactivity pollution and their mechanism absorption. Amount of radioactive pollution in various food and plants according to their absorption capacity is different. Consumed diet, consumed dosage, preparation site, and ways of preparing food, whether vegetable or animal influence on the effects that plant pollution can put on people. Considering that the main objective of the study of radioactive contamination in plant sources is the impact on humans, makes necessary to do this type of studies (3-5). Also, the use of phosphate fertilizers in agricultural land makes multiplier radionuclide levels in soil and eventually plant contamination (6, 7).

Many worldwide studies show that food can absorb radioactive materials (2). Wheat and corn are of important grains which are grown in different regions of the world. Ilam Province in Iran is including areas that these grains as their main products are planted. People of Ilam consume wheat for their food and corn for their domestic animals. Wheat grows in any soil, but the soil quality can increase the exact product per unit area. So that

the silt clay and silt soils that composed of fluvial sediments give the best product. Soils with silt clay loam texture, silt loam, silt clay (with the requirement of having cubic structure) and the loam are suitable for wheat (8).

Other aim in this study was to measure  $^{137}\text{Cs}$  as an artificial gamma-ray emitter element with half-life of 30 years (9). This radionuclide could be produced as the results of nuclear tests, normal function of nuclear power plants or reactor accidents that are important ways to do soil contaminations. As a matter of fact  $^{137}\text{Cs}$  could be found in superficial layers of soil and be absorbed by plant roots conducting that to the human food chain (10). Determination of radionuclide concentrations in wheat and corn and to determine the effective dose from radionuclide according to the annual consumption of wheat and corn in different areas of the province has a special place. Since it is possible that radionuclide values existed in wheat and corn to be excessive and endanger safety of people living in the area it was decided to do a study on this issue so the amount and type of radionuclide were determined in Ilam Province. In addition to determine the concentration of natural and artificial radioactive materials, the amount of transferring them from soil to plant was determined and compared. In Iran because of natural resources, study of natural radioactive particularly radium is very important. It is a long time that some researches on evaluation of  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  in the human body, food, plants and water have been started. In Tehran (Iran) Hosseini et al. measured concentrations in samples of eggs, lentils and wheat with gamma spectroscopy system. The results showed that concentration in samples of wheat was about 2.15  $\text{mSv.y}^{-1}$  (11). Hosseini et al. conducted studies on water, soil and food, including wheat, in Zahedan City. They showed that these nutrients and soil considering radioactivity and the creation of disease have no threat to the people of region (12). The concentration of radioactive materials in cereal were measured in some other parts of world too such as in France and Brazil (13-14).

In Iraq due to increased intake of wheat, (TF) transfer factor from soil to plant in different portions of wheat, for example, the leaves and roots was evaluated in 2008. The results showed that this transitional factor in roots is more than leaves for  $^{137}\text{Cs}$  (15).

The aim of this study is to determine natural ( $^{238}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ ) and artificial ( $^{137}\text{Cs}$ ) radioactivity levels in wheat and corn fields of Ilam Province.

## Material and Methods

### Collecting samples

After obtaining topographical map and measuring wind speed, samples were collected according to harvest wheat and corn. Using a GPS device geographical coordinates of sampling area were recorded. Figures 1 and 2 show sampling locations of wheat and corn. One kg wheat and 1kg corn were collected from each location. After packing the samples in plastic bags and weighed, tags specifying the sampling locations pasted on the plastic bags and eventually worksheet of samples were filled. 32 samples (23 samples of wheat in May, 2010 and 9 corn samples in November, 2009 studied.

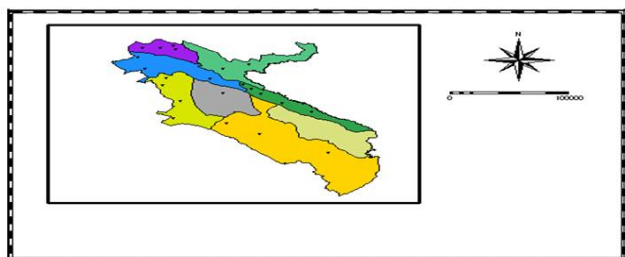


Fig. 1: Sampling locations of wheat on the map in Ilam Province

### Preparation of samples

For samples soil particles, corn leaves, stems of wheat and their skins were removed carefully. Wet sample's weight (not dried) was measured by the balance. Samples were dried against the sun for 2 days. However because of saving more water corn samples needed to be kept in open air for a week. Then to ensure adequate drying of corn samples,

they were placed about 48 hours in oven at temperature of 128 °C.

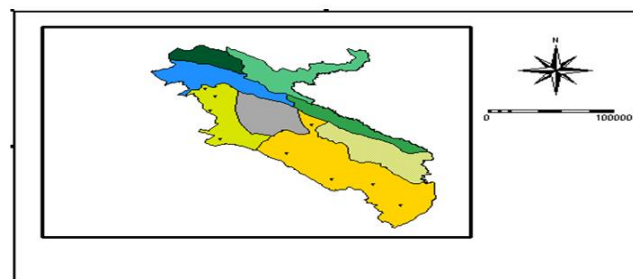


Fig. 2: Sampling locations of corn on the map in Ilam Province

Then the samples were ground by the conventional grinding mill, and finally passed through a 1 mm mesh to get homogeneous samples to be entered within Marineli. Samples from 10 different places of 6 cities including Saleh Abad, Dehloran, Mehran, Dareshahr, Chalsra, Chavar using disposable gloves and shovel with the dimensions 40 \*40 cm and 30 cm depth were collected in plastic bags. Soils were screened to be taken large rocks, roots and stems of plants out. Then they were dried against sunlight by the action of natural aeration for 4 to 5 days. For complete drying samples were placed in the oven for 48 hours at a temperature of 200 ° C. To get homogeneity in Marineli container the samples weight was selected of about  $950 \pm 0.01$  gr. Marineli containers were sealed for 30 days to prevent releasing radon gas out of the sample and the longstanding balance creation between  $^{226}\text{Ra}$  and  $^{222}\text{Ra}$  and its decay products in the  $^{238}\text{U}$  series and also between  $^{228}\text{Ra}$  and its products in the  $^{232}\text{Th}$ .

### Spectroscopy and analysis of samples

To determine the activity and concentration of natural and artificial radionuclides each sample was placed in gamma radiation spectrometer system (HPGe) with efficiency of 38.5% and energy resolution of 920 ev at energy of 122keV. Concentration of radioactive substances in samples was compared with the international standards.

Following calibration of detection system performance and determining the minimum detectable

activity of system, quantitative analysis of prepared samples was performed. Photo peak efficiency for each of the peaks with the mentioned energy can be calculated using the following equation:

$$\varepsilon(\%) = \frac{\text{NetArea}}{(\text{Act.}_{(Bq)}) * (\text{B.R}_{(\%)}) * (t_{(Sec.)})} * 100$$

In this equation,  $\varepsilon$  is the detector efficiency, Act. Is a radionuclide activity existed in standard sample in terms of Bq, B.R shows breakaway energy related to desired energy in terms of percentage,  $t$  reveals the spectroscopy time duration of the sample and Net Area is area under the requested peaks.

To determine the average concentration of  $^{226}\text{Ra}$ , the activity of  $^{214}\text{Pb}$  with peaks at energies of 295.22 (keV) and 351.93 (keV) and  $^{214}\text{Bi}$  with peak at energy of 609.31 (keV) were used. Also for

$^{228}\text{Ra}$ ,  $^{228}\text{Ac}$  with peaks at energies of 911.2 (keV), 968.97 (keV) and 338.32 (keV) was taken.

In this study AKAWIN software was used for spectrometry. The activity of samples was collected in the ranges of 40000-80000 sec and 20000-40000 sec to get reasonable statistics for wheat-corn and soil respectively.

## Results

Tables 1 and 2 show average concentrations of natural and artificial radioactive materials in terms of  $\text{Bq.kg}^{-1}$  for 23 samples of wheat and 9 samples of corn. In Table 1 the highest concentration of  $^{226}\text{Ra}$  is related to Dehloran in samples of c4. In Table 2 the highest concentrations of natural and artificial radionuclides are in the samples of W17, W5, W23 related to Bartesh -Dehloran, Darre-shahr, and Zarne -ivan.

**Table 1:** Average concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{137}\text{Cs}$  and  $^{40}\text{K}$  in corn samples

	Ra226( $\text{Bq.kg}^{-1}$ )	Th232( $\text{Bq.kg}^{-1}$ )	Cs137( $\text{Bq.kg}^{-1}$ )	K40 ( $\text{Bq.kg}^{-1}$ )
C1	0.16±0.03	0.33±0.26	0.05±0.08	31.45±0.57
C2	0.72±0.20	1±0.43	<MDA	92.35±1.66
C3	0.61±0.25	1.14±0.48	0.34±0.13	157.66±2.77
C4	3.93±0.31	0.98±0.35	0.05±0.03	78.61±0.98
C5	0.08±0.04	<MDA	0.03±0.01	91.46±2.48
C6	0.72±0.43	1.02±0.41	<MDA	107.21±1.07
C7	0.17±0.11	1.08±0.3	<MDA	114.48±1.90
C8	0.39±0.2	1.12±0.26	<MDA	94.65±1.59
C9	0.58±0.23	1.06	0.16±0.23	126.73±2.3

Activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ , and  $^{137}\text{Cs}$  in samples of corn were equal to 0.81 (0.08-3.93), 0.85 (0.33-1.14), 101.52 (50.75-157.66) and 0.07 (0.03-0.34) (dry weight) respectively in term of  $\text{Bq.kg}^{-1}$  and for wheat samples these values were equal to 1.67 (0.05-1.4), 0.5 (0.08-1.36), 91.73 (50.57-143.26) and 0.01 (0-0.18) (dry weight) respectively in term of  $\text{Bq.kg}^{-1}$ .

Global average concentrations presented for above natural radionuclides respectively are 40, 40 and 580  $\text{Bq.kg}^{-1}$  (17). Since  $^{137}\text{Cs}$  is a synthetic man made element, the mean value was not provided, and in total, the calculated value in all regions must be equal to zero and values above zero indicate contamination in the area and can have many different reasons.

Table 2: Average concentrations of Ra-226, Ra-228 137-Cs and k-40 in wheat samples

Sample Cod	Ra-226(Bq/Kg)	Th232(Bq/Kg)	Cs-137(Bq/Kg)	K-40(Bq/Kg)
	0.46±0.16	1.2±0.3	<MDA	106.69±1.83
W2	<MDA	0.44±	<MDA	89.98±2.48
W3	0.45±0.3	1.17±0.5	0.18±0.6	125.52±1.97
W4	0.3±0.11	<MDA	<MDA	66.65±2.04
W5	1.4±0.39	1.16±0.2	<MDA	143.26±1.97
W6	0.29±0.11	0.55±0.25	<MDA	47.11±1.5
W7	0.09±0.03	0.16±0.09	<MDA	42.99±1.04
W8	0.80±0.03	<MDA	<MDA	114.04±2.74
W9	0.31±0.11	0.85±0.34	<MDA	61.75±2.99
W10	0.08±0.02	<MDA	<MDA	94.56±2.29
W11	0.35±0.08	0.56±0.32	□□□ <MDA	99.38±2.41
W12	0.05±0.02	0.11±0.06	<MDA	62.43±1.69
W13	0.51±0.2	<MDA	<MDA	108.43±2.7
W14	0.42±0.12	<MDA	<MDA	81.48±1.6
W15	0.49±0.12	0.08±0.03	<MDA	26.65±2.7
W16	0.58±0.11	0.15±0.05	<MDA	114.08±1.89
W17	0.61±0.17	1.36±0.05	<MDA	126.28±1.86
W18	0.62±0.08	<MDA	<MDA	31.00±2.48
W19	<MDA	0.15±0.09	<MDA	102.51±2.45
W20	0.49±0.23	0.7±0.34	<MDA	102.13±2.48
W21	0.31±0.13	0.98±0.31	<MDA	101.38±2.39
W22	0.07±0.06	0.16±0.08	<MDA	98.83±2.4
W23	0.54±0.15	0.98±0.4	<MDA	120.09±2.00

Tables 3 and 4, show radiometric results indicating related data to the air absorbed dose rate  $D$  (nGy / h), the Internal Hazard Index ( $H_{in}$ ) and the External Hazard Index ( $H_{ex}$ ), the Annual Gonadal Dose Equivalent (AGDE) ( $\mu\text{Sv.y}^{-1}$ ), the Annual Effective Dose Equivalent (AEDE) ( $\mu\text{Sv.y}^{-1}$ ), the Average Radium Equivalent Activity ( $Ra_{eq}$ ). Tables 5-8 reveal comparison of mean concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  in wheat and corn samples among some studies in world including present work.

#### Absorbed dose rate in air ( $D$ )

Natural radionuclide decay in the soil is one of the major sources of human radiation exposure. This radiation level is different depending on the content of minerals and radioactive elements of each region. Gamma radiation dose due to natural radioactive contents of the soil is important to population of the area that they live in. Absorbed dose

rate in air for radionuclide were calculated based on provided guidance as follows (17).

$$D \text{ (nGy/h)} = (0.462A_{Ra} + 0.604A_{Th} + 0.0417AK)$$

In which  $A_{Ra}$ ,  $A_{K}$ , and  $A_{Th}$  respectively are the average activity concentrations of  $^{226}\text{Ra}$ ,  $^{40}\text{K}$ ,  $^{232}\text{Th}$  in terms of Bq/kg. The highest values of  $D$  (nGy / h) for wheat samples in Dare- shahr, Zarne and Bartesh- Dehloran cities respectively were about 7.82, 6.38, 6.34 and amounts of these three regions were calculated higher than the other parts of the province. The highest value of  $D$  (nGy / h) for corn samples obtained in Dehloran city close to Geysers was about 7.53 Gy / h. But the lowest  $D$  value of 3.85 Gy / h was related to Mohsen- Ab.

#### External and internal hazard index

To access the equivalent average of annual effective dose imposed on the residents of each area, external hazard index for wheat and corn samples were calculated.

**Table 3:** Radiometric results obtained for wheat samples

Sample Cod	D(nGy/h)	H <sub>in</sub>	H <sub>ex</sub>	AEDE(μSv.y <sup>-1</sup> )	AGDE(μSv.y <sup>-1</sup> )	Ra <sub>eq</sub>
W1	5.38	0.028	0.027	6.60	39.93	10.39
W2	4.01	0.019	0.019	5	30.08	7.56
W3	6.148	0.032	0.025	7.5	45.69	11.78
W4	2.91	0.014	0.013	3.6	21.84	5.43
W5	7.32	0.040	0.031	9	54.14	14.08
W6	2.43	0.012	0.012	3	17.97	4.70
W7	1.93	0.009	0.008	2.4	14.42	3.62
W8	5.12	0.027	0.025	6.3	38.88	9.58
W9	3.23	0.016	0.016	4	23.88	6.28
W10	3.98	0.020	0.019	4.48	30.00	7.36
W11	4.64	0.023	0.022	5.7	34.62	8.80
W12	2.68	0.012	0.013	3.3	20.20	5.01
W13	4.75	0.024	0.023	5.8	35.61	8.56
W14	3.59	0.018	0.017	4.40	26.87	6.69
W15	2.38	0.012	0.011	3	17.71	4.50
W16	5.11	0.026	0.025	6.27	38.23	9.58
W17	6.36	0.034	0.032	7.80	47.21	12.28
W18	2.79	0.014	0.014	3.33	20.11	5.35
W19	4.36	0.021	0.021	5.35	32.8	8.11
W20	4.90	0.024	0.024	6.01	36.57	9.37
W21	5	0.024	0.024	6.08	36.87	9.52
W22	4.25	0.020	0.021	5.21	32	7.91
W23	5.84	0.030	0.029	7.16	43.43	11.16

**Table 4:** Radiometric results obtained for corn samples

	D(nGy/h)	H <sub>in</sub>	H <sub>ex</sub>	AEDE(μSv.y <sup>-1</sup> )	AGDE(μSv.y <sup>-1</sup> )	Ra <sub>eq</sub>
C1	2.36	0.012	0.011	2.89	45.8	4.53
C2	4.78	0.025	0.023	5.87	35.3	9.26
C3	7.53	0.039	0.036	9.24	56.16	14.38
C4	6.66	0.037	0.03	8.20	40.9	11.38
C5	3.85	0.023	0.02	4.71	28.9	7.12
C6	5.41	0.029	0.026	6.63	40	10.43
C7	5.49	0.028	0.027	6.73	40.9	10.53
C8	4.79	0.025	0.024	5.87	35.5	9.43
C9	6.16	0.032	0.031	7.55	17.64	11.80

**Table 5:** Comparison of mean concentrations of  $^{226}\text{Ra}$  in wheat and corn samples among some studies

Country	Sample	Ra-226(Bq/kg)	References
France	Wheat	0.570±0.057	16
Kazakhstan	Wheat	1.100±0.176	16
USA	Corn	0.210±0.057	16
USA	Corn	0.147±0.025	16
Total wheat samples	wheat	1.67±0.12	Present work
Total corn samples	corn	0.81±0.03	Present work

**Table 6:** Comparison of mean concentrations of  $^{232}\text{Th}$  in wheat and corn samples among some studies

Country	Sample	(Bq/kg) $\text{Th}^{232}$	References
France	Wheat	<0.035	16
Kazakhstan	Wheat	<0.035	16
USA	Corn	0.195±0.055	16
USA	Corn	<0.035	16
Brazil	Corn	-	14
Total wheat samples	wheat	0.50	Present work
Total wheat samples	corn	0.85±0.03	Present work

**Table 7:** Comparison of mean concentrations of  $^{40}\text{K}$  in wheat and corn samples among some studies

Country	Sample	$^{40}\text{K}$ (Bq/kg)	References
France	Wheat	146.3±7.3	16
Kazakhstan	Wheat	99.4±2.0	16
USA	Corn	87.0±2.6	16
USA	Corn	9.3±0.5	16
Brazil	Corn	-	14
Total wheat samples	Wheat	91.73±0.45	Present work
Total corn samples	Corn	101.52±1.29	Present work

**Table 8:** Comparison of mean concentrations of  $^{137}\text{Cs}$  in wheat and corn samples among some studies

Country	Sample	Ave. $^{137}\text{Cs}$ (Bq/kg)	References
France	Wheat	<0.014	16
Kazakhstan	Wheat	<0.014	16
USA	Corn	0.075±0.013	16
USA	Corn	<0.013	16
Total wheat samples	Wheat	0.01	Present work
Total corn samples	Corn	0.07	Present work

This symbol is supposed to review samples in a completely closed environment with thick walls without windows considering the following formula. Radiation dose limits for permissible dose equivalent is less than 1 mSv/y and if the number is multiplied by 100, it shows the percentage of people at risk in the area (17).

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \leq 1$$

In which  $A_{Ra}$ ,  $A_K$ , and  $A_{Th}$  respectively are the average activity concentrations of  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  and  $^{232}\text{Th}$  in term of Bq/kg.

It's important to know if the average size of  $H_{ex}$  is greater than 0.3, it will increase the risk up to

30%. Therefore people, who are living in that area, must comply with safety principles.

The internal hazard index is to locate within the exposure of radon and the descendants with a short half-life and it shows a similar formula with slightly different with external hazard index.

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \leq 1$$

In which  $A_{Ra}$ ,  $A_K$ , and  $A_{Th}$  are respectively the average activity concentrations of  $^{226}\text{Ra}$ ,  $^{40}\text{K}$ ,  $^{232}\text{Th}$  in terms of Bq/kg. The external hazard index value in wheat samples obtained for the Dareshahr, Zarne and Brtesh- Dehloran cities respectively about 0.031, 0.032, and 0.029. The values were reported higher than the other areas of the prov-

ince. The lower external risk was related to Chalsara of 0.008.

The external hazard index value for corn samples in Dehloran City was estimated around 0.036. The lower external risk value was associated with Mohsen – Ab of 0.011.

The internal hazard index value in wheat samples was obtained for the Dareshahr, Zarne, and Brtresh-Dehloran cities respectively about 0.04, 0.03, 0.029. These values were reported higher than the other areas of the province. The lower internal risk value was related to Chalsara of 0.009. The higher internal risk value for the corn samples was about 0.039 related to Dehloran city and near Geysers and the lowest was related to Mohsen – Ab of 0.012. The average value of  $H_{ex}$  and  $H_{in}$  for corn samples was estimated about 0.02.

$H_{in}$  and  $H_{ex}$  should be lower than 1. The results of  $H_{in}$  for the wheat samples were in a range of 0.16 - 0.34 with mean value of 0.21 mean and no sample was found to be higher than unit. To be subunit of this symbol indicates minimal risk creation effects of radon and progeny morbidity resulting from the soil samples of these areas in the respiratory organs.

#### Annual Gonadal Dose Equivalent, AGDE ( $\mu\text{Sv.y}^{-1}$ )

Reportedly by UNSCEAR (2000) effect of radioactivity on the bone marrow and its surface cells is interesting. For this reason annual dose equivalent applied on endocrine according to the concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  is calculated in each sample (17).

$$AGDE (\mu\text{Sv.y}^{-1}) = 3.09 A_{\text{Ra}} + 4.18 A_{\text{Th}} + 0.314 A_{\text{K}}$$

In which  $A_{\text{Ra}}$ ,  $A_{\text{K}}$ , and  $A_{\text{Th}}$  are respectively the average activity concentrations of  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  and  $^{232}\text{Th}$  in term of Bq/kg.

The highest annual gonadal dose equivalent for wheat samples for the Dareshahr, Zarne and Brtresh-Dehloran cities respectively was obtained about 54.14, 47.21, 43.43  $\mu\text{Sv.y}^{-1}$ . The lowest Annual dose equivalent on endocrine was related to Chalsara and about 14.42  $\mu\text{Sv.y}^{-1}$ .

The highest annual gonadal dose equivalent for corn samples is related to Dehloran and about 56.16  $\mu\text{Sv.y}^{-1}$  and the lowest value is for Mohsen - Ab with 17.64  $\mu\text{Sv.y}^{-1}$ .

#### The annual effective dose equivalent, AEDE ( $\mu\text{Sv.y}^{-1}$ )

In order to measure the annual effective dose equivalent, conversion coefficients associated with the absorbed dose coefficients in the air are used. The amount of 0.7 Gy / Sv is used to convert modified coefficients of absorbed dose in air to effective dose received annually by adults and 0.2 is used as external occupation factor (17).

$$AEDE (\mu\text{Sv.y}^{-1}) = D (n\text{Gyh}^{-1}) \cdot 8766(\text{h/year}) \cdot 0.2 \cdot 0.7 (\text{sv/Gy}) \cdot 10^{-3}$$

The highest value of the annual effective dose equivalent for wheat samples for Dareshahr, Zarne, and Brtresh –Dehloran cities were respectively obtained about 9, 9, 8 and 9, 9  $\mu\text{Sv.y}^{-1}$  and the lowest value of the annual effective dose equivalent was related to Chalsara of 2.4  $\mu\text{Sv.y}^{-1}$ . The highest value of the annual effective dose equivalent for corn samples was of 9.24  $\mu\text{Sv.y}^{-1}$  for Dehloran City and the lowest value was of 2.89  $\mu\text{Sv.y}^{-1}$  for Mohsen -Ab.

#### Equivalent activity of $Ra_{eq}$

The results of this study offer the value of risk creation with an average of Ra radiation equivalent activity  $Ra_{eq}$ . Natural Radionuclides including  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  in soil and plants have a non uniform distribution and this feature causes each area to have specific level of background radiation and be different from other sites. In order to compare the specific activities of these materials with different amounts of this Radionuclide, equivalent activity of  $Ra_{eq}$  is defined as follows (17).

$$Ra_{eq} = A_{\text{Ra}} + 1.43A_{\text{Th}} + 0.077A_{\text{K}}$$

In which  $A_{\text{Ra}}$ ,  $A_{\text{K}}$ , and  $A_{\text{Th}}$  are respectively the average activity concentrations of  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  and  $^{232}\text{Th}$  in term of Bq/kg.

$^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  with  $Ra_{eq}$  of 370, 259 and 4810 Bq/kg respectively cause the production of similar gamma dose rates. Specific average of corn and



wheat samples were estimated 9.87 Bq / kg and 8.15 Bq /kg respectively. This amount is less than the permitted amount, which are 370 Bq / kg. It shows all the samples of corn and wheat in Ilam province have no biological hazards.

**Transition factor**

Transfer of radioactive elements from soil to plant is determined by transition factor (TF). This factor include radionuclide concentration per gram of plant (dry or wet plant weight) (Bq/g) at harvest divided by radionuclide concentration per gram of soil (Bq /g).TF is dependent on the factors such as, radionuclide type, product type, soil type, EC, pH and bicarbonate content of the soil. Using TF we can find if plants receive contamination from soil or root. Finally, the absorbed doses of these elements can be estimated in humans. In this study transfer rate of <sup>137</sup>Cs according to the following transfer factor equation in the samples of corn and wheat based on strategic role of products has been calculated.

**Table 9:** Transition rate of <sup>40</sup>K from soil to plant for wheat and corn samples

	Cp	Cs	TF=Cp/Cs (K40)
SA	94.56	190.05	0.49
SB	50.57	219.50	0.23
SC	92.35	188.13	0.49
SD	114.47	187.13	0.61
SE	91.46	153.23	0.59
SF	157.66	261.46	0.60
SG	78.61	267.46	0.29
SH	42.99	71.66	0.59
SI	114.04	108.52	1.05
SJ	47.99	192.16	0.24
SK	107.21	195.20	0.54
SL	126.78	318.13	0.39

**TF = Radionuclide concentration in plant (dry weight) (Bq / g) / Radionuclide concentrations in soil (Bq / g) (dry weight)**

Transfer factor for the <sup>137</sup>Cs in most samples of wheat and corn was zero. Since the <sup>137</sup>Cs is a synthetic element, its presence in plants can be dangerous. <sup>137</sup>Cs sticks tightly to clay mineral soil that

is available for plant. Its root uptake is low, but the leaf absorption, especially when the nuclear loss is ongoing would be important. Cesium and potassium are double. Cesium absorption rate is inversely proportional to soil's potassium. Experience has shown that cesium transport through root uptake is low enough to be ignored. The main method of reducing pollution is washing plants, peeling fruits and seeds like wheat.

**Table 10:** Transition rate of <sup>226</sup>Ra from soil to plant for wheat and corn samples

	Cp	Cs	TF=Cp/Cs (Ra226)
SA	0.08	46.77	0.001
SB	0.16	29.53	0.005
SC	0.72	17.95	0.04
SD	0.17	17.89	0.009
SE	0.08	27.67	0.002
SF	0.61	25.39	0.02
SG	3.93	25.40	0.15
SH	0.09	16.55	0.005
SI	0.80	20.36	0.03
SJ	0.29	26.08	0.011
SK	0.72	25.67	0.02
SL	0.53	30.09	0.017

**Table 11:** Transition rate of <sup>232</sup>Th from soil to plant for wheat and corn samples

	Cp	Cs	TF=Cp/Cs ( <sup>232</sup> Th)
SA	0	15.78	0
SB	0.33	16.75	0.01
SC	1	12.64	0.07
SD	1.08	12.67	0.08
SE	0	12.3	0
SF	1.14	17.26	0.06
SG	0.98	17.78	0.05
SH	0.16	13.40	0.01
SI	0	7.65	0
SJ	0.55	15.14	0.03
SK	1.02	16.78	0.06
SL	1.06	12.76	0.08

<sup>137</sup>Cs accumulation in plants that grow in top mountain areas, such as mosses and lichens, is more than that of those grow in the protected are-

as. Cesium move and spread more easily within the plant so that the direct absorption of the surface led to widespread contamination in other parts. Move and transfer coefficients for major agricultural seeds are in the range of 3- 29 that according to the type of seed, this difference could appear to be 45 times (18) Tables 9-12 reveal transition rate of  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{137}\text{Cs}$  from soil to plant for wheat and corn samples.

**Table 12:** Transition rate of  $^{137}\text{Cs}$  from soil to plant for wheat and corn samples

	Cp	Cs	TF=Cp/Cs (cs137)
SA	0	17.63	0
SB	0.05	1.96	0.02
SC	0	2.10	0
SD	0	2.4	0
SE	0.03	2.12	0.01
SF	0.34	1.68	0.20
SG	0.05	1.60	0.03
SH	0	2.10	0
SI	0	5.01	0
SJ	0	4.24	0
SK	0	4.35	0
SL	0.16	9.49	0.01

## Discussion

Natural radioactivity levels in samples of wheat and corn were evaluated in Ilam Province (Iran). Natural radioactivity in the areas of Ilam was found very low and almost in the level of global standards. Tables 5-8 reveal comparison of mean concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  in wheat and corn samples among some studies in world including present work. According to these tables  $^{226}\text{Ra}$  and  $^{232}\text{Th}$  level for wheat in Ilam Province is greater than those in France and Kazakhstan and for corn greater than those in the USA.  $^{40}\text{K}$  level for wheat in Ilam Province was lower than that in France and Kazakhstan. This level for corn was greater than that in the USA. Concentration  $^{137}\text{Cs}$  for wheat in this study was the same as that in France and Kazakhstan. Importance of pollution varies with the growing season, so area before harvest, during harvest, or

under active grazing by domestic animals (such as animals that produce milk) would be at more risk. Wheat's cluster structure makes easy to attract and capture radionuclides. As in winter the products are not on the ground, risk is kept at the lowest level. Of course, it is possible that natural radionuclides to be saved on the ground in permanent pastures in winter and to be absorbed by the growing plants next spring. This recording and maintenance for plants that their body parts such as old stems or surface roots are exposed will be more. Generally, direct contamination is to be considered less than contamination by soil, because the determining factors of it have more diversity. Soils used for wheat cultivation is clay loam soil. This soil is porous and causes the conquer of  $^{137}\text{Cs}$  and prevents that from transferring into the plant. However, in some instances cesium was observed. In this study the concentration of all natural elements for samples of wheat and corn in Ilam province were measured and also for these products radium equivalent activities ( $Ra_{eq}$ ), absorbed dose rate in air (D), symbol of external and internal risk creation, the equivalent annual dose of endocrine, and also equivalent annual effective dose and their mean values were calculated, and compared with recommended international values. Allowable global values for  $^{226}\text{Ra}$  released by UNSCEAR; 1988, 93 is between  $8 \text{ Bq.kg}^{-1}$  to  $160 \text{ Bq.kg}^{-1}$  with mean of  $40 \text{ Bq.kg}^{-1}$  and in UNSCEAR; 2000 this value is  $35 \text{ Bq.kg}^{-1}$ . In this study, for wheat samples the average concentration of  $^{226}\text{Ra}$  was obtained  $1.67 \pm 0.72 \text{ Bq.kg}^{-1}$  and in corn samples was obtained  $0.81 \pm 0.56 \text{ Bq.kg}^{-1}$  that were lower than UNSCEAR; 1988,93  $\text{Bq.kg}^{-1}$ . Allowable average concentration of  $^{232}\text{Th}$  (17) is  $40 \text{ Bq.kg}^{-1}$  with the range of  $8\text{-}130 \text{ Bq.kg}^{-1}$ . This study showed that mean values of  $^{232}\text{Th}$  concentrations for samples of wheat and corn were of  $0.5 \pm 0.2 \text{ Bq.kg}^{-1}$  and  $0.85 \pm 0.45 \text{ Bq.kg}^{-1}$  respectively that none of them were higher than the permitted global range. Allowed global average value of  $^{40}\text{K}$  was announced  $580 \text{ Bq.kg}^{-1}$  by

UNSCEAR; 1988, 93 and 400Bq / kg by UNSCEAR; 2000 (17). For wheat samples, average activity concentration of  $^{40}\text{K}$  was equal to  $91.73 \pm 1.89 \text{ Bq.kg}^{-1}$  and for corn samples was to be  $101.52 \pm 2.3 \text{ Bq.kg}^{-1}$  Ilam province. The mean activity concentration of  $^{40}\text{K}$  in corn samples was more than that of wheat samples; however for both samples those values were less than the permitted global range.

The main cause of high amounts of absorbed dose rate in air, creating the risk of internal and external annual effective dose of the endocrine, the annual effective dose in the cities of Darreh shahr, Zarne and Bartesh- Dehloran for wheat samples is being located in the Zagros Mountains Series. People who are living in that area, they must comply with safety principles.

Observing  $^{137}\text{Cs}$  in some samples could be done by the Chernobyl accident. Due to the existence of the Zagros Mountains, it was possible to have been gathering large amounts of elements from the incident in this area. Puffing Wind from the North to West can be the main cause of existing concentrations of cesium in the samples.

The Average Radium Equivalent Activity ( $\text{Re}_{eq}$ ), The Absorbed Dose Rate in air (D), The External Hazard Index ( $H_{ex}$ ) and the Internal Hazard Index ( $H_{in}$ ), The Annual Gonadal Dose equivalent (AGDE), the Annual Effective Dose Equivalent (AEDE) were calculated and their average values respectively in Wheat samples obtained:  $8.15 \text{ Bq.kg}^{-1}$ ,  $4.3 \text{ nGy / h}$ ,  $0.020$ ,  $0.025$ ,  $30.49 \text{ } \mu\text{Sv.y}^{-1}$  and  $5.28 \text{ } \mu\text{Sv.y}^{-1}$  and for corn samples, respectively obtained:  $11.45 \text{ Bq.kg}^{-1}$ ,  $5.92 \text{ nGy / h}$ ,  $0.025$ ,  $0.027$ ,  $33.89 \text{ } \mu\text{Sv.y}^{-1}$  and  $6.41 \text{ } \mu\text{Sv.y}^{-1}$ . The results were compared to Recommended International values. This study revealed mean value of  $\text{Re}_{eq}$  for wheat and corn samples were lower than that of standard values of  $370 \text{ Bq.kg}^{-1}$  (17). Also this study revealed absorbed dose in air (D) for wheat and corn samples were to be lower than the global average value of  $55 \text{ nGy / h}$ . It was found annual effective dose limit (AEDE) for wheat and corn samples were to

be lower than that of standard value of  $70 \text{ } \mu\text{Sv / y}$  (UNSCEAR, 2000).

All of the results of this study were compared fully with the international values and those of the other studies in other countries in the world totally. It was found the natural radioactivity levels in Ilam province are not at the range of high risk of morbidity and are under international standards. The radium concentrations for wheat and corn samples were under allowable levels and therefore there's no the risk of ionizing radiation effects on humans. It is necessary to consider that allowable level of radium-226, according to the international standard values is defined as  $110 \text{ m Bq/ liter}$  (19).

One of the reasons for increasing radionuclides in vegetables can be use of fertilizers such as phosphate fertilizer. However, the amount of radioactive elements for wheat and corn in Ilam province was so low that consumer health is not to be threatened. Radionuclides are being absorbed through the roots and leaves of plants. The values in the tables 9, 10, 11, 12 show that radioactive substances were being absorbed by plants through roots of wheat and corn. However absorption of radioactive material in grain area of crop was less than the others (root, stem). This study showed the transfer of radioactive materials into plant's seed area was to be very low. The use of ammonium sulfate and nitrate fertilizers for foliar application on corn samples were caused higher transmission rate of  $^{137}\text{Cs}$  into the plant. The relationship between the amount of potassium in the soil and amount of  $^{137}\text{Cs}$  absorption by plants was studied. Values in Tables 9 and 12 showed that there's a contrast between potassium in the soil and the value of transferring  $^{137}\text{Cs}$  into the plant.

## Conclusion

It was found the natural radioactivity levels in Ilam Province are not at the range of high risk of morbidity and are under international standards.

## Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or fal-

sification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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