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Measurement of ^{137}Cs in soils of Tehran province

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Background: An amount of artificial radionuclide has been released into the environment as fallout, resulting from atmospheric nuclear weapon tests, nuclear accidents such as Chernobyl and together with air currents have polluted the world. *Materials and Methods:* 37 surface soil samples of Tehran province were collected in the period between June and September 2008, by implementing methods and standard instruments. The concentration of the artificial radionuclides (^{137}Cs) in the soils of Tehran province were determined by gamma spectroscopy (HPGe), and the data were analyzed both quantitatively and qualitatively. The results have been compared with other radioactivity measurements. *Results:* The concentration of ^{137}Cs found in top soils (0-5 cm), in the depth of (12.5-17.5 cm) and in the depth of (27.5- 32.5 cm), ranged from 0.29-28.82 Bq.kg^{-1}, 0.3-19.81 Bq.kg^{-1}, 0.8-7.43 Bq.kg^{-1}, respectively. The total average of ^{137}Cs activity, in the above depths was, 11.30, 4.87 and 1.8 Bq.kg^{-1}, respectively. *Conclusion:* Considering the obtained results from high average values of ^{137}Cs in Europe and its relation to Chernobyl accident, and the higher average concentration of ^{137}Cs in Tehran province, can also be attributed to Chernobyl accident due to the proximity of Iran to the place of the accident's occurrence. **Iran. J. Radiat. Res., 2009; 7 (3): 141-149**

Keywords: *Cs-137, soil sample, gamma spectroscopy, HPGe, Tehran province.*

INTRODUCTION

Due to destructive interference of human being in his environment, artificial and natural radionuclides are found in the nature. An amount of artificial radionuclides have been released into the environment as fallout resulting from atmospheric nuclear weapon tests, nuclear accidents such as Chernobyl, and together with air currents have polluted the world (1).

Among the various radionuclides released to the environment, we have focused on the distribution of ^{137}Cs, because of its long half life (about 30.17 year), which will remain in the environment with all its destructive effects (2).

Deposition of radioactive fallout including ^{137}Cs at any site is related to factors such as, latitude, precipitation and local topography. ^{137}Cs is strongly absorbed and retained by soil particles and it can enter into the diet of human beings, and other leaving creatures. Maintaining ^{137}Cs in surface layers of clay soil is considerable (3, 4). Therefore, the access to distribution of ^{137}Cs in Tehran province soils has been the main objective of this research.

In this study, points of sampling were chosen by VSP (Visual Sample Plan) software, GPS (Global Positioning System) and considering of Tehran province dominant wind current. The chosen points were marked by a digital map and their coordinates were entered in to GPS system. The points on the Tehran province map, as shown in figure 1 were marked and used while collecting soils. Tehran province is approximately located between 35°:43′ N latitude and 51°:25′ E longitude. Table 1 shows the geographical coordinates of the sampling point and the labels of different samples of different townships.

MATERIALS AND METHODS

Sampling procedure

Thirty-seven soil samples were collected from several regions all over Tehran province. The samples were collected from the depths of (0-5 cm), (12.5- 17.5 cm) and (27.5- 2.5 cm), using Template method (5).

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Table 1. Sample identification.

Sample code	Site	GPS coordinates	Alt(m)
S001	Lashgarak (I)	51.70150-35.86832	2800
S002	Lashgarak (II)	51.53354-35.96699	2800
S003	Rineh	52.07669-35.85727	3000
S004	Roodehen	51.75907-35.73762	1866
S005	Sarbandan	52.32778-35.64694	2665
S006	Arjmand (I)	52.62531-35.74773	2110
S007	Arjmand (II)	52.55092-35.75814	2100
S008	Pirdeh	52.81778-35.68754	2530
S009	Shangoldeh	52.42197-35.78739	2400
S010	Sefidargoleh	53.09712-35.79046	2945
S011	Yam	51.78658-35.36978	1000
S012	Javad Abad	51.69475-35.19797	836
S013	Varamin	51.58461-35.45075	977
S014	Arad	51.76667-35.31525	857
S015	Asara	51.11824-36.09546	3500
S016	Gajereh	51.31842-36.05314	2765
S017	Mahdasht (I)	50.90134-35.52739	1228
S018	Mahdasht (II)	50.96441-35.73711	1228
S019	Sharghe Tehran	51.67856-35.70783	1600
S020	Lavasan Bozorg	51.90361-35.77233	2400
S021	Shahryar	51.16330-35.64164	1100
S022	Robat karim	51.09011-35.46894	1100
S023	Tehran	51.42628-35.62172	1200
S024	Eshtehard	50.45989-35.73117	1630
S025	Gomrokan	50.69038-35.61284	1227
S026	Karaj (Part 2) (I)	50.77378-35.80309	1257
S027	Karaj (Part 2) (II)	50.86556-35.99667	1675
S028	Hashtgerd	50.74352-35.97528	2500
S029	Abyek	50.64517-36.11414	2560
S030	Fashand	50.94339-36.21442	2500
S031	Karaj (Part 1) (I)	51.07237-35.93467	2100
S032	Ghale boland	51.81147-35.14908	797
S033	Istgah Kavir	52.15878-35.17394	1000
S034	Tajrish	51.28223-35.78699	1700
S035	Karaj (Part 2) (II)	51.24222-35.86058	2632
S036	Gharpooz Abad	50.29572-35.76375	1260
S037	Gazorkhan	50.50469-36.41678	1645

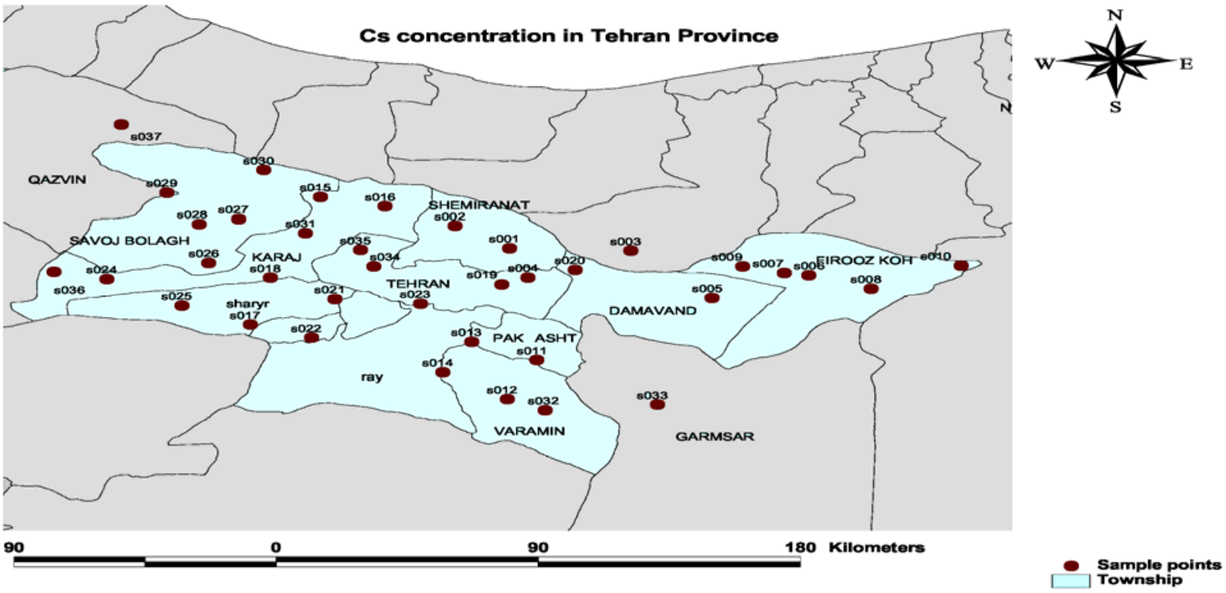

Figure 1. The map of a part of the Tehran province and the location of the sampling sites.

Sample preparation

The samples were dried in an oven at the temperature of 200°C for about 24h. Then the dried soils were grounded by jaw and planet mill, and passed through a 50 mesh sieve (with 0.2 mm aperture diameter). Then, 950 gr of the homogenized samples were placed in the Marinelli Beaker for spectroscopy and analysis $^{(6)}$.

Spectroscopy and analysis

The samples were measured by using two p-type coaxial High Purity Germanium (HPGe) (EG&ORTEC) gamma spectrometers with relative efficiency (38.5%) and (55%).The resolution of these detectors at 1.33 MeV of ^{60}Co were 1.98 keV and 1.8 keV, respectively. Both detectors were connected to standard electronics and the spectra were accumulated in 4K MCA (multi channel analyzer) Made by IAP (Institute of Applied Physics)).The detectors were surrounded by a 10-cm thick lead shield to reduce the background from the surrounding material and cosmic rays. The detectors were calibrated by using certified gamma-ray standard sources. The counting time was prolonged as necessary to ensure at least 95% of statistical significance. The background spectra was measured frequently under the same conditions of sample measurements and used to correct the calculated sample activities. The characteristic gamma peak for the determination of ^{137}Cs was 661.66 keV.

After electronic instruments adjustment, the energy calibration in the region of 60–3000 KeV was done. The background rate for the mentioned detectors was 2.5 and 2.9 count/second, respectively. Analysis and collecting data for both detectors were fulfilled with OMINGAM Ortec software.

Determining the efficiency of HPGe detectors is the main factor for using of these detectors to specify quantity values of active samples. The use of convenient standard samples is a reliable method to determine the efficiency of the specified regions of energy. Science determining the efficiency of HPGe detectors is confined to the production of standard ^{137}Cs samples, to ensure the validity of determining efficiency, the standard samples of ^{152}Eu, ^{241}Am, ^{137}Cs and ^{133}Ba, in the same configuration of the analyzed samples were prepared $^{(7)}$, and after making sure of the accuracy of the production of the standard samples, the efficiency of 661.66 keV peak of ^{137}Cs was used to determine quantity efficiency. The preparation of these standard samples was accomplished by spiking 50 gr of Al_2O_3(3), by a suitable volume of standard solutions and adding this dried spiked Al_2O_3 to the 900 gr of sieved soil (50-mesh), as a complete homogenized compound. After collecting the spectrums of the standard samples, they were processed by the mentioned software. In calculating the efficiency of photo peaks, equation (1) was applied.

$$\varepsilon(\%) = \frac{NetArea}{(Act._{(Bq)})(B.R_{(\%)})(t_{(Sec.)})} \times 100 \qquad (1)$$

In this equation, e stands for the efficiency of detector, *Act* is the activity of the standard isotope at $Bq.kg^{-1}$, *B.R* is the branching ratio related to concerned energy at percent, *t* is the time of collecting spectrum of samples at second, *Net Area* is the net area under the concerned peaks calculated by software. After fitting convenient functions on efficiency data through software, equations (2) and (3) are for efficiency functions of detectors (38.5%) and (55%), respectively.

Efficiency value at energy (661.66 keV) of ^{137}Cs, in HPGe (38.5%) and (55%) has been 1.41 and 2.03, respectively. The spectrums were collected between 30000-60000s. The peak (661.66 keV), indicated the presence of 137Cs in samples were the analysis of this isotope could be done.

RESULTS

Determination of radionuclide concentration

Equation (4) was applied for calculating the activities of ^{137}Cs in soil samples of Tehran province.

.Where, *w* is the weight of samples.

Table 2, shows the concentration of ^{137}Cs in soil samples of Tehran province. The first column is the sample code and the second column is the depth of collecting samples (0-5), (12.5-17.5) and (32.8-37.5) cm, and the last column is the ^{137}Cs concentration in the mentioned depths. For all 37 samples, in the 3 depths, the information were given and for almost all samples the depth profile distribution of ^{137}Cs showed a tendency to decrease toward deeper layers. The variations of ^{137}Cs concentration in the depths of (0-5), (12.5-17.5) and (32.8-37.5) cm is shown in figure 2, and the shape of frequency distribution of ^{137}Cs activity concentration are plotted in figure 3, X and Y axises are ^{137}Cs concentration ($Bq.kg^{-1}$) and Frequency, respectively.

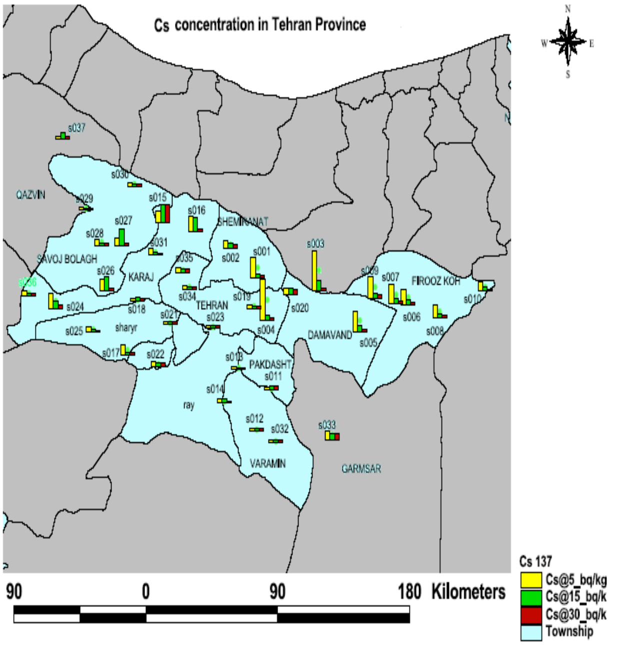

Figure 2. The variations of ^{137}Cs concentration in the depths of (0-5), (12.5-17.5) and (32.8-37.5) cm.

$$\varepsilon(\%) = a + b \times Ln(E) + \frac{C}{Ln(E)} + d \times (Ln(E))^2 + \frac{e}{(Ln(E))^2} + f \times (Ln(E))3 \qquad (2)$$

$$\varepsilon(\%) = \frac{a + c \times (E)^{0.5} + e \times E + g \times (E)^{1.5} + i \times (E)^2}{1 + b \times (E)^{0.5} + d \times E + f \times (E)^{1.5} + h \times (E)^2} \qquad (3)$$

$$Act._{(Bq/kg)} = \frac{NetArea}{\varepsilon(\%)(B.R_{(\%)})(t_{(\sec)})(W)} \times 100 \qquad (4)$$

Table 2. ^{137}Cs concentration in Tehran province soil samples by HPGe (38.5%) and (55%).

Code sample	Depth(cm)	^{137}Cs(Bq.kg^{-1})
S001	0-5	25.75±0.68
	12.5-17.5	2.48±0.19
	27.5-32.5	0.36±0.16
S002	0-5	11.76±0.91
	12.5-17.5	5.48±0.4
	27.5-32.5	4.13±0.36
	42.5-47.5	<MDA*[i]
S003	0-5	20.47±1.11
	12.5-17.5	14.36±0.39
	27.5-32.5	0.63±0.18
S004	0-5	22.35±1.23
	12.5-17.5	4.01±0.27
	27.5-32.5	0.19±0.09
S005	0-5	26.42±0.75
	12.5-17.5	8.12±0.27
	27.5-32.5	0.19±0.84
S006	0-5	24.79±0.55
	12.5-17.5	3.35±0.38
	27.5-32.5	0.21±0.08
S007	0-5	24.08±0.8
	12.5-17.5	5.72±0.36
	27.5-32.5	0.36±0.12
S008	0-5	20.03±0.50
	12.5-17.5	3.27±0.3
	27.5-32.5	0.71±0.09
S009	0-5	28.82±0.79
	12.5-17.5	6.48±0.34
	27.5-32.5	1.73±0.06
S010	0-5	14.01±1.96
	12.5-17.5	3.2±0.2
	27.5-32.5	<MDA
S011	0-5	1.80±0.24
	12.5-17.5	4.82±0.17
	27.5-32.5	2.98±0.14
S012	0-5	1.77±0.03
	12.5-17.5	1.16±0.03
	27.5-32.5	1.90±0.11
S013	0-5	0.76±0.01
	12.5-17.5	<MDA
	27.5-32.5	<MDA
S014	0-5	3.04±0.22
	12.5-17.5	3.78±0.12
	27.5-32.5	<MDA
S015	0-5	19.49±0.57
	12.5-17.5	10.75±0.61
	27.5-32.5	12.82±0.62
S016	0-5	27.47±0.74
	12.5-17.5	12.95±0.53
	27.5-32.5	1.01±0.15
S017	0-5	15.27±0.42
	12.5-17.5	<MDA
	27.5-32.5	<MDA
S018	0-5	0.64±0.14
	12.5-17.5	3.17±0.21
	27.5-32.5	2.92±0.17

Table 2 (Continue). ^{137}Cs concentration in Tehran province soil samples by HPGe (38.5%) and (55%).

S019	0-5	1.62±0.35
	12.5-17.5	<MDA
	27.5-32.5	0.08±0.18
S020	0-5	7.55±0.37
	12.5-17.5	6.38±0.21
	27.5-32.5	4.93±0.18
S021	0-5	1.03±0.13
	12.5-17.5	1.32±0.12
	27.5-32.5	1.4±0.15
S022	0-5	4.51±0.41
	12.5-17.5	3.47±0.29
	27.5-32.5	2.37±0.22
S023	0-5	<MDA
	12.5-17.5	<MDA
	27.5-32.5	<MDA
S024	0-5	25.36±0.47
	12.5-17.5	10.65±0.54
	27.5-32.5	1.77±0.3
S025	0-5	6.92±0.29
	12.5-17.5	1.7±0.13
	27.5-32.5	<MDA
S026	0-5	18.55±0.48
	12.5-17.5	13.41±0.49
	27.5-32.5	0.73±0.06
S027	0-5	11.64±0.58
	12.5-17.5	19.81±0.61
	27.5-32.5	1.41±0.18
S028	0-5	6.79±0.23
	12.5-17.5	0.44±0.11
	27.5-32.5	0.32±0.13
S029	0-5	1.21±0.28
	12.5-17.5	<MDA
	27.5-32.5	<MDA
S030	0-5	1.27±0.17
	12.5-17.5	0.95±0.13
	27.5-32.5	<MDA
S031	0-5	8.03±0.41
	12.5-17.5	1.36±0.29
	27.5-32.5	<MDA
S032	0-5	1.91±0.45
	12.5-17.5	0.44±0.08
	27.5-32.5	<MDA
S033	0-5	11.86±0.23
	12.5-17.5	6.78±0.15
	27.5-32.5	7.43±0.28
S034	0-5	1.77±0.23
	12.5-17.5	0.82±0.14
	27.5-32.5	0.8±0.13
S035	0-5	5.41±0.27
	12.5-17.5	1.48±0.24
	27.5-32.5	1.97±0.1
S036	0-5	5.96±0.28
	12.5-17.5	0.3±0.09
	27.5-32.5	<MDA
S037	0-5	0.29±0.07
	12.5-17.5	6.92±0.19
	27.5-32.5	<MDA

* MDA:0.09±0.02
Minimum Detectable Activity (MDA)

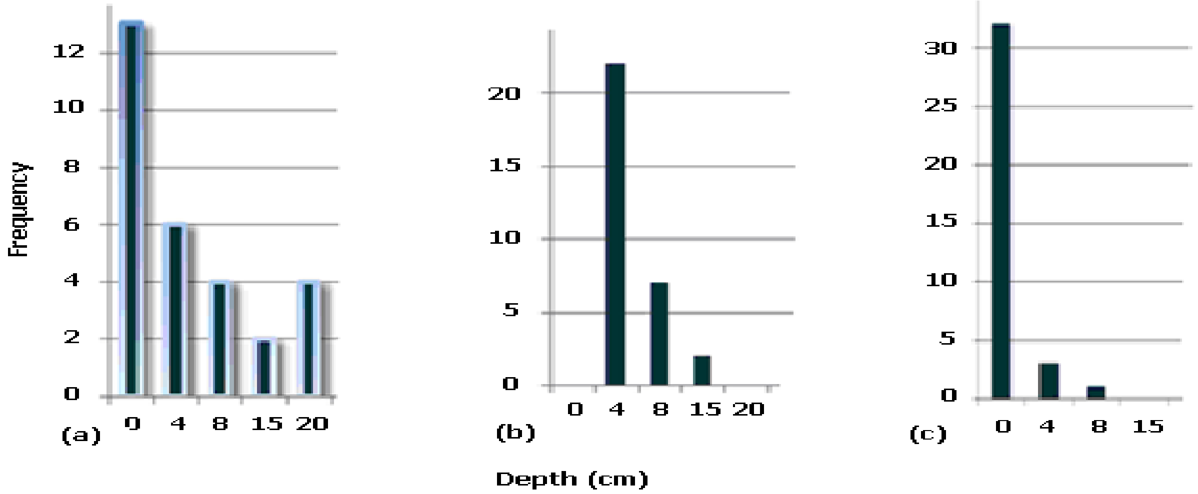

Figure 3. The shape of frequency distribution of ^{137}C activity concentration in the depths: a. (0-5), b. (12.5-17.5) and c. (32.8-37.5) cm.

DISCUSSION

High-resolution gamma-ray spectrometry was used to determine the concentration of ^{137}Cs in soil samples collected in the period between June to September 2008 in Tehran province.

The relatively high contamination of ^{137}Cs in Tehran, in comparison with other countries, has been of significant importance to the present study.

The main reason for the accumulation of ^{137}Cs in some regions was due to atmospheric fallouts. It seemed that air currents, in their course of movements, accumulate heavy particles, such as ^{137}Cs covered with dust in higher altitudes (height of Alborz Mountains). The heights of North East of Tehran were strongly contaminated with ^{137}Cs which was at the end of the route of the dominant air currents during the year (with the direction of west to east).

Considering the obtained results from high average values of ^{137}Cs in Europe and its relation to Chernobyl accident, and the higher average concentration of ^{137}Cs in Tehran province, can also be attributed to Chernobyl accident due to the proximity of Iran to the place of the accident's occurrence, as shown in figure 4 and 5 (15). Neighboring countries which were in the same heights and geography with Iran could have the same average concentration of ^{137}Cs as Iran presumably, and it was obvious by moving farther from the place of occurrence (Chernobyl accident) to lower height, where the accumulation of ^{137}Cs decreased.

The depth profile distribution of ^{137}Cs in most of the Tehran province soil samples showed a tendency of decrease toward deeper layers (as figure 4 shows). To confirm the assumption, it was necessary to make a survey of ^{137}Cs concentration in different depths (with regard to annual accumulation of soils). To do so the time of the beginning of increasing ^{137}Cs concentration was estimated and proved to be related to Chernobyl accident. In addition, it seemed necessary to make a more accurate survey of the course of air currents in the regions behind the Alborz Mountains (Northern provinces).

The range of ^{137}Cs concentration in surface soils, was observed to vary in the range 0.29-77.35 (Bq.kg^{-1}), and the average ^{137}Cs activity was about 15.09 (Bq.kg^{-1}), which was more than the reported values in countries such as Egypt (3), China (1), Nigeria (8), Alkharje city (9), Kuwait (6), western areas of Pakistan (10), Faisalabad in Pakistan (11), Dhaka city (4); and also provinces in Iran, such as Booshehr,

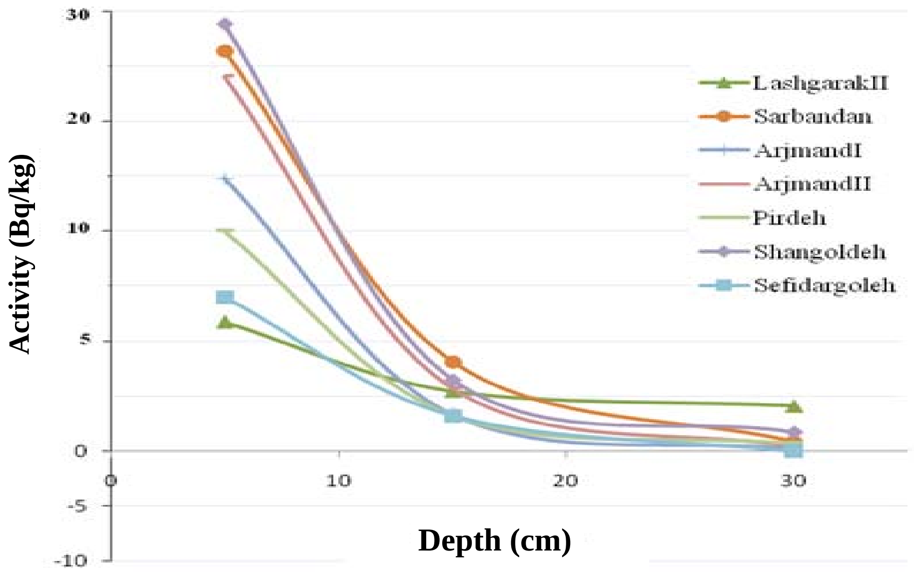

Figure 4. ^{137}Cs activity versus of depths.

Khoosestan and Hormozgan (12), and it was less than the reported values in countries such as, Coniferous forest (2), Jordan (13), Firtina Valley (Rize, Turkey) (14). The limit of detection was mainly governed by the counting statistics. ^{137}Cs in some samples was found to be lower than the minimum detectable activity of the gamma counting systems (<MDA).

CONCLUSION

The results of the measurements are presented in table 2. The range of ^{137}Cs concentration in surface soils, was observed to vary in the range 0.29-28.82 (Bq.kg^{-1}), and the average ^{137}Cs activity was about 11.3 (Bq.kg^{-1}). The highest concentrations 28.82 (Bq.kg^{-1}) was observed in Shangoldeh and the lower concentrations 0.29 (Bq.kg^{-1}) in Gazorkhan. The depth profile distribution of ^{137}Cs in most of the Tehran province soil samples showed a tendency of decrease toward deeper layers.

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