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Assessment of anthropogenic Cesium-137 in soil of Islamabad capital territory and its suburbs, Pakistan

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► ***Original article***

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ABSTRACT

Background: Cesium-137 is one of those man-made radioactive nuclides that results from human activities including open air nuclear weapons testing, nuclear accidents, operation of nuclear reactors and has a relative long half-life, higher water solubility, high fission yield, relatively high volatility and a close physic-chemical similarity to potassium that makes it a dangerous radioactive element in the human environment and is a hazardous byproduct of nuclear fission. Cesium-137 being a γ-emitter is also a potential carcinogen. ***Materials and Methods:*** A total of 100 soil samples were collected from various sites in Islamabad and its suburbs for the assessment of the presence of Cesium-137 in the environment. Spectroscopy of the collected samples for determination of aforementioned radionuclide was performed using a computer based High Purity Germanium (HPGe) detector. ***Results:*** The highest value of Cesium-137 was found to be 57.0±4.2 Bq/kg in samples collected from Nilore, a suburb of Islamabad. ***Conclusion:*** The presence of Cesium-137 in all samples is clear evidence that the studied area is contaminated either due to past fallout or ongoing nuclear activities in this area. Cesium-137 was found in higher concentration for this area than the reported values in literature for the rest of country, but not to an alarming level. However, local concerned authorities must pay attention to avoid the development of possible future health hazards to the residents of this area.

Keywords: *Radioactivity, cesium-137, gamma spectroscopy, Islamabad capital territory.*

INTRODUCTION

The global environment has been and continues to be subjected to exposure to ionizing radiation. This implies that almost all living organisms including human beings are exposed to and accumulate dose from varying amounts of radiation from both natural and anthropogenic sources. These exposures induce various biological effects by altering the structure of cells and lead to damage of DNA (deoxyribonucleic acid). DNA damage results in potential mutation of genes, chromosomal abnormality and malfunction or death of the cells [1]. Long term exposure of humans to ionizing radiation may also result in chronic lung disease, cataract, anemia, necrosis of the mouth, acute leucopoenia, lung cancer and leukemia [2-5]. Cancer is still one of the deleterious effects caused by radiation from primordial as well as anthropogenic sources.

Anthropogenic radioactivity emerges purely from human activities on this planet, which includes testing of nuclear weapons, operation of nuclear power reactors and nuclear medicine [6]. The assessment of artificial radioactivity has drawn much global attention from researchers especially following the well-publicized nuclear reactor incidents in Japan (Fukushima, 2011) and Ukraine (Chernobyl, 1986) [7].

Strontium-90 and Cesium-137 are considered foremost among all of the fall out radioactive constituent due to their high toxicity, long half-lives, and higher uptake by bio systems [8]. Cesium-137 is perhaps the most significant fission by-product due to volatility, with a half-life of more than thirty years (30.17 years). It has since been distributed throughout the Earth's atmosphere due to global

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atmospheric weather patterns. Its water solubility is another measurable factor, which plays an important role in defining its concentration in the environment [9]. Historical atmospheric nuclear weapons testing and other detonations constitutes a significant source of Cesium-137 is of these 60% of the collective effective dose equivalent from external radiation resulted from ground based testing [10]. It also gets into our environment via routine operation of nuclear reactors for power generation and military purposes, radioactive fuel reprocessing plants, and sites for nuclear waste disposal [8]. Therefore, analyzing the concentration of Cesium-137 in soil is essential valuable indicator of the environmental effect of radioactivity level, as soil is one of the most important materials which are used for many purposes in modern society [11].

Cesium-137 can enter the food chain either by direct accumulation on exposed plants or by its solubility in water through the uptake of the plant's roots system. Cesium isotopes are very similar in chemical and physical properties to Potassium and are therefore easily accumulated in plant and animal tissues. Therefore, soil composition (chemistry), as well as retention of the isotope in the top surface soil structure, plays an important role [12]. A large number of global monitoring bodies, researchers and scientists have expressed concern for the level of radioactivity from non-natural sources, especially the anthropogenic fission by-product (Cs-137) [13]. The potential environmental impacts of the Fukushima (2011) and Chernobyl (1986) nuclear reactor incidents are reviewed in reference [14].

Environmental samples including soil, air, water and, vegetation have been assessed for natural as well as artificial radioactivity by various researchers from across the world [15, 16, 25–34, 17–24]. The present work constitutes one of these ongoing investigations and is centered on Pakistan.. The mountainous region of Islamabad in Pakistan is a potential geographical region with higher concentrations of anthropogenic radio-active fall-out and therefore, it is desirable to perform a gamma survey of this area. This is the first time that such a survey has been undertaken. This article mainly deals with the quantitative assessment of radioactivity concentration of Cs-137 in clay samples obtained from various sectors of Islamabad and its suburb particularly Nilore.

The results obtained are compared with the data available in the literature for the Islamic Republic of Pakistan as well as other countries around the globe. Radioactivity assessment of Cesium-137 in soil of residential as well as cultivated suburbs of Islamabad is important as it is one of the major sources of radionuclide entrainment into the food chain. The main aim of this study is to undertake a survey for the existence of cesium-137 radioactive nuclides in the soil and to establish a reference line for further and future work on radioactivity concentration in this locality.

MATERIALS AND METHODS

Description of study sites

Islamabad is Pakistan's federal capital city envisaged in 1960 as the new capital of the country, situated geographically (33.49^0 N, 72.24^0 E) at the edge of the Pothohar Plateau at the foot of the Margalla Hills in the northeast of the country with varying altitude ranging from 457 to 610 m. Its climate is subtropical humid. This kind of climate is characterized by hot summers with a monsoon followed by cold winters. The average annual rainfall is about 41inches with over fifty percent (50%) precipitation taking place due to the monsoon system. The location of Islamabad makes it a gateway to both Punjab and Khyber Pakhtunkhwa, as it falls at the intersection of the two provinces of Islamic Republic of Pakistan. This well planned city of the country occupies an area of 906.50 Km^2 with a population greater than 2.0 million according to the 2017 census conducted by the Pakistan Bureau of statistics. For administrative purposes, the city is divided into sectors, which can be identified by an English alphabet with a number shown in f igure1 and each sector covers an area of approximately 2 km × 2 km.

Sample collection

A total of 100 soil samples (IS-1 to NS-100) from Islamabad various sectors of capital territory and its suburbs were collected as shown in figure1. The adopted strategy for sampling was according to the standard method outlined in IAEA (International Atomic Energy Agency) report No. 295 [35]. An area of approximately 1m × 1m of undisturbed, open and relatively level ground was marked for collection of each sample by removing the surface layer contain gravels, stone pieces, grass and its roots. The samples were taken to a depth

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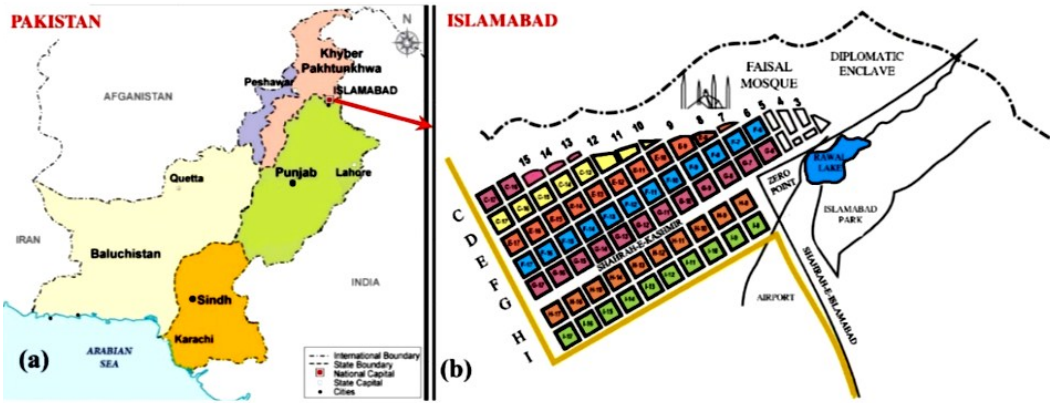

Figure 1. (a) Islamabad location on Pakistan's map and **(b)** Sectorial map of Islamabad.

of 5-15 centimeters from each corner and one from center of the marked area of 1m^2 using a standard coring tool. A minimum distance of two kilometers was maintained between any two sampling sites. The collected soil was then mixed well to obtain a representative sample of the specified location each of weight 2.0 Kg. The geographical location (Latitude, Longitude) of each sample was recorded using a Garmin eTrex 309x GPS (Global Positioning System) unit. The samples were placed in previously unused properly polyethylene bags labeled with the site codes and were subsequently transported to a laboratory of Radiation Surveillance Center (RSC), Islamabad for further processing.

Sample preparation

The collected soil samples were initially spread on a plastic mat and allowed to dry at room temperature for a period of one week to avoid any loss of radioactive content. Constant weight was achieved as each sample was further dried overnight in an electric furnace at a temperature of 110±5 ^{0}C. After that the dried samples were then ground, pulverized and powdered by some mechanical treatment and passed through a sieve having mesh of size 0.2 centimeters. These prepared samples each weighing 0.5 Kg were then sealed in air-tight Marinelli beakers keeping its geometrical dimension exactly identical to the International Atomic Energy Agency (IAEA) provided reference soil-375. The samples geometrical dimensions were identical to the calibration requirement [36].

Spectroscopy for gamma activity

A high resolution activity measuring system comprising a low energy high-purity germanium semiconductor (HPGe) detector (Model: GC-3020 Canberra, USA) was used for radiometric assessment of the collected samples. The detector has a relative efficiency of 30% with an active volume 180 mm^3 .The detector was housed in a lead shielding of well-type (thickness 5–15 cm) with a fixed bottom and removable cover for the reduction of background radiation from its surrounding environment. Calibration of this measuring system was performed using a reference material (Soil-375) obtained from the International Atomic Energy Agency (IAEA, Vienna, Austria) in order to determine the activity of the Cesium-137 γ-ray in the collected soil samples [36]. The detector is subjected to a high operating voltage of 3 KV via a preamplifier, which was then coupled to a PC based multichannel analyzer (Accuspec-A, Canberra) having 8192 channels through an analogue to digital converter (ADC) for the acquisition of the processed data. The activities concentrations and corresponding uncertainties were estimated according to statistical uncertainty of peak areas given by commercially available (Genie-2000 Canberra, USA) software along with Excel (Microsoft Corporation, Redmond, WA). The detector was continuously cooled using liquid nitrogen in order to minimize the detector thermal noise. The system energy resolution at 1332.5 keV from ^{60}Co is 2 KeV FWHM. The spectrum for each of 0.5 kg dried soil sample

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was acquired continuously for about 18 hours to achieve adequate counts at the anticipated peaks. The lower Limits of Detection (LLD) for Cesium-137 was obtained as 1.24 Bq/kg with a 95% confidence level. The activities of Cesium-137 were determined from the gamma ray lines of energy 661.7 KeV present in the acquired spectrum of energies for the analyzed soil samples. Signals from the surrounding environment of the laboratory were also continuously recorded and were subtracted from each measurement. The activity mass concentration in Bq/kg of Cs-137 was calculated using equation 1 as follows [20, 21].

$$A_s = \frac{C_S - C_B}{E_\gamma \times P_\gamma \times T \times M} \quad (1)$$

Where,
A_s = activity mass concentration
C_s = Counts/second for sample
C_B = Counts/second for background
E_γ = Detector efficiency for gamma ray
P_γ = Probability of gamma emission
T = Counting time
M = Mass of sample

RESULTS AND DISCUSSION

The assessment of radioactivity concentration of anthropogenic Cesium-137 in soil samples collected from various sectors of Islamabad capital territory and its suburbs was conducted using a direct γ-ray spectrometry technique. The resulting values are reported in Becquerel per kilogram (Bq/kg) for collected samples on a dry weight basis. Activity concentration with plus minus counting uncertainty was found to be in the range of 8.8±2.8 (Bq/kg) to 57.0±4.2 (Bq/kg) as shown in table 1.

Results indicate the variation of Cesium-137 activity concentration from sample to sample. This variation may be caused by various factors including variations in local soil characteristics of the sampling site and metrological conditions. The latter is dominated by the amount of rainfall in the preceding few days, which plays a significant role in the deposition of the radio-nucleotide in the soil. Area topography is another factor affecting its accumulation. However this variation in activity concentration of radiocesium is considered as insignificant keeping in view the large geographic and geological diversification. The pre-mentioned factors may be accountable for the variation in activity level of Cesium-137 in the soil of this territory.

The results of the present work were compared to the available data in the literature for various parts of the country as well as some other countries around the globe as shown in table 2. It is evident from table 2 that the maximum value of radioactivity concentration of Cesium-137 in soil of Islamabad capital territory is comparatively higher than the maximum value reported for Kohistan [37], Jhangar Valley [38], Peshawar and Nowshera [39], Murree [40], Jhelum , Attock and, Chakwal [41], Southern Punjab [42] and Mirpur, Azad Kashmir, Pakistan [43] and some other environs of the world including Tehran (Iran) [44], Tongliao & Bayanwula (China) [45, 46], İkizdere Valley (Turkey) [47]. The elevated concentrations of Cesium-137 in soil samples collected from suburbs of Islamabad i.e. Nilore may either be due to the operation of a nearby nuclear research reactor under the control of Pakistan Atomic Energy Commission (PAEC) without any interruption for the last few decades or the area may have experienced high past fallout. The data of this investigation is in close agreement with the maximum values reported for Louisiana (USA) [39] and Vojvodina (Serbia) [48] but significantly less than data available for Syria [49] as well as the Leningrad Region (Russia) [50], where Cesium-137 is deposited with higher concentration in surrounding environment after the occurrence of the Chernobyl nuclear reactor incident near Russia.

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Table 1. Activity concentration (± counting uncertainty) of anthropogenic Cesium-137 in soil samples collected from Islamabad and its suburbs.

Sectors	Sample ID	Coordinates	Activity (Bq/kg)	Sectors	Sample ID	Coordinates	Activity (Bq/kg)
C	IS-1	33°42'44.43"N, 72°55'11.42"E	13.1±3.1	H	IS-51	33°38'46.92"N, 72°59'53.18"E	26.8±3.1
	IS-2	33°42'20.92"N, 72°55'30.90"E	16.2±3.4		IS-52	33°38'41.02"N, 72°58'32.91"E	26.1±3.3
	IS-3	33°42'31.97"N, 72°56'8.70"E	18.3±2.9		IS-53	33°37'35.77"N, 72°58'15.76"E	33.3±2.9
	IS-4	33°43'0.39"N, 72°56'20.38"E	20.4±3.7		IS-54	33°38'56.61"N,72°59'37.49"E	30.0±3.7
	IS-5	33°42'34.45"N,33°42'34.45"N	24.6±3.5		IS-55	33°37'47.86"N, 72°58'42.43"E	32.5±2.8
D	IS-6	33°42'29.95"N,72°57'11.76"E	12.3±2.9		IS-56	33°37'56.05"N, 72°58'12.15"E	33.4±3.6
	IS-7	33°42'3.52"N, 72°57'13.91"E	15.7±3.5	I	IS-57	33°40'2.19"N, 73° 4'20.99"E	11.5±3.0
	IS-8	33°41'53.32"N, 72°56'35.86"E	19.7±3.1		IS-58	33°39'12.36"N, 73° 3'30.02"E	14.7±2.9
	IS-9	33°42'9.81"N, 72°56'26.03"E	22.8±3.6		IS-59	33°38'56.57"N, 73° 2'29.99"E	16.6±3.1
	IS-10	33°42'24.67"N, 72°56'50.17"E	25.6±3.2		IS-60	33°38'14.47"N, 73° 1'14.94"E	19.3±2.8
	IS-11	33°42'4.02"N, 72°57'33.26"E	26.9±3.4		IS-61	33°35'51.95"N, 73°13'0.64"E	23.7±3.2
	IS-12	33°42'15.48"N, 72°57'9.91"E	28.1±2.9		IS-62	33°37'33.01"N, 72°59'46.69"E	26.8±3.4
E	IS-13	33°43'38.54"N, 73° 3'5.17"E	12.5±3.5		IS-63	33°36'28.87"N, 72°58'0.52"E	28.6±3.1
	IS-14	33°43'22.52"N, 73° 1'57.18"E	14.0±3.0		IS-64	33°35'57.02"N, 73°12'58.67"E	30.7±2.8
	IS-15	33°42'54.61"N, 73° 1'14.88"E	16.8±2.9		IS-65	33°35'50.68"N, 72°56'10.89"E	31.0±3.2
	IS-16	33°42'44.25"N, 73° 0'48.92"E	19.3±3.6		IS-66	33°35'36.12"N, 73°12'46.80"E	33.5±2.9
	IS-17	33°42'25.33"N, 73° 0'19.75"E	23.1±2.8	Nilore	NS-67	33°39'8.22"N, 73°14'6.01"E	41.8±4.1
	IS-18	33°42'20.99"N, 72°59'26.15"E	22.4±3.2		NS-68	33°39'10.47"N, 73°14'29.03"E	50.4±3.8
	IS-19	33°42'4.69"N, 72°58'55.49"E	27.2±3.7		NS-69	33°39'0.64"N, 73°14'48.49"E	57.0±4.2
	IS-20	33°41'52.08"N, 72°58'33.78"E	29.2±3.8		NS-70	33°38'47.50"N, 73°15'22.54"E	44.8±2.8
	IS-21	33°39'29.38"N, 72°53'18.88"E	30.9±3.9		NS-71	33°38'51.39"N, 73°15'31.29"E	55.1±3.7
	IS-22	33°39'11.10"N, 72°52'38.32"E	29.4±3.5		NS-72	33°38'54.62"N, 73°15'45.18"E	51.6±3.2
	IS-23	33°38'0.68"N, 72°51'6.15"E	31.3±2.9		NS-73	33°39'7.66"N, 73°15'58.83"E	49.3±3.9
F	IS-24	33°43'31.56"N, 73° 4'43.14"E	11.3±3.6		NS-74	33°39'0.80"N, 73°16'7.99"E	45.7±3.0
	IS-25	33°43'50.76"N, 73° 3'54.14"E	12.0±2.8		NS-75	33°38'53.44"N, 73°16'53.76"E	48.6±3.2
	IS-26	33°42'48.47"N, 73° 1'56.54"E	16.6±3.7		NS-76	33°39'1.84"N, 73°17'1.29"E	56.3±3.8
	IS-27	33°42'12.70"N, 73° 2'15.14"E	18.5±2.9		NS-77	33°39'6.53"N,73°16'52.99"E	50.4±3.0
	IS-28	33°42'15.04"N, 73° 1'40.82"E	19.6±3.2		NS-78	33°39'13.65"N, 73°16'43.43"E	43.8±2.9
	IS-29	33°42'2.68"N, 73° 0'29.41"E	22.8±3.0		NS-79	33°39'20.14"N, 73°16'43.01"E	44.5±3.6
	IS-30	33°40'32.86"N, 72°59'8.19"E	21.7±3.6		NS-80	33°39'23.32"N, 73°16'42.66"E	49.5±3.4
	IS-31	33°41'4.30"N, 72°58'47.71"E	22.5±3.1		NS-81	33°39'27.13"N, 73°16'34.94"E	53.1±3.2
	IS-32	33°37'52.66"N, 72°52'25.43"E	26.3±2.9		NS-82	33°39'29.09"N, 73°16'29.47"E	42.9±3.4
	IS-33	33°38'19.36"N, 72°53'15.40"E	30.4±3.3		NS-83	33°39'31.52"N, 73°16'24.18"E	46.7±3.5
	IS-34	33°37'26.12"N, 72°52'35.69"E	34.1±3.2		NS-84	33°39'32.47"N, 73°16'17.07"E	41.1±2.8
G	IS-35	33°43'12.71"N, 73° 5'57.21"E	8.8±2.8		NS-85	33°39'37.89"N, 73°16'10.18"E	40.9±3.0
	IS-36	33°42'48.75"N, 73° 5'20.64"E	12.0±3.1		NS-86	33°39'40.79"N, 73°16'4.41"E	56.4±3.1
	IS-37	33°42'32.07"N, 73° 4'24.41"E	16.7±3.6		NS-87	33°39'39.16"N, 73°15'54.52"E	55.9±3.9
	IS-38	33°42'2.95"N, 73° 3'23.76"E	20.2±2.9		NS-88	33°39'39.28"N, 73°15'12.91"E	50.1±3.0
	IS-39	33°41'8.96"N, 73° 2'0.68"E	26.3±3.2		NS-89	33°39'39.06"N, 73°15'4.85"E	54.5±3.7
	IS-40	33°40'31.83"N, 73° 1'18.71"E	29.7±3.4		NS-90	33°39'35.81"N, 73°15'0.71"E	53.4±3.1
	IS-41	33°40'2.53"N, 73° 0'18.62"E	19.3±3.7		NS-91	33°39'30.65"N, 73°14'59.01"E	50.7±3.2
	IS-42	33°39'0.44"N, 72°57'57.24"E	21.0±2.9		NS-92	33°39'24.63"N, 73°14'56.93"E	49.8±2.9
	IS-43	33°38'43.11"N, 72°58'7.96"E	30.2±3.6		NS-93	33°39'18.72"N, 73°14'53.66"E	44.9±3.4
	IS-44	33°38'35.81"N, 72°57'5.25"E	31.4±3.0		NS-94	33°39'14.38"N, 73°14'46.22"E	56.5±2.9
	IS-45	33°38'5.66"N, 72°55'34.30"E	30.1±3.7		NS-95	33°39'13.10"N, 73°14'38.74"E	51.9±3.6
	IS-46	33°37'26.86"N, 72°55'27.00"E	29.1±3.1		NS-96	33°39'12.69"N, 73°14'35.32"E	50.1±3.4
	IS-47	33°40'55.42"N, 73° 3'26.07"E	21.8±2.9		NS-97	33°39'11.00"N, 73°14'37.25"E	49.3±2.8
	IS-48	33°40'15.33"N, 73° 2'58.74"E	19.7±3.1		NS-98	33°39'3.30"N, 73°14'30.80"E	47.6±3.9
	IS-49	33°39'37.31"N, 73° 1'28.87"E	16.7±2.9		NS-99	33°38'53.20"N, 73°14'33.00"E	55.8±2.7
	IS-50	33°38'49.31"N, 73° 0'30.13"E	23.6±3.0		NS-100	33°38'51.59"N, 73°14'32.62"E	53.7±3.0

IS = Soil Samples collected from Islamabad capital territory

NS = Soil samples collected from Nilore

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Table 2. Comparison of present work with reported values of Cesium-137 in literature for various parts of Pakistan and some other countries around the globe.

Location	Minimum Activity (Bq/kg)	Maximum Activity (Bk/kg)	Mean values (Bq/kg)	References
Kohistan, Pakistan	7.06	14.9	9.5	(35)
Jhangar Valley, Pakistan	1.3	46.8	13.39	(38)
Peshawar and Nowshera, Pakistan	4.6	44.1	--	(39)
Murree, Pakistan	1.3	54.1	13.6±11.8	(40)
Jhelum, Pakistan	0.5	4.5	2.3±0.2	(41)
Attock, Pakistan	0.4	6.7	2.4±0.2	(41)
Chakwal, Pakistan	0.8	3.7	1.7±0.2	(41)
Mirpur, Azad Kashmir, Pakistan	0.076	2.94	1.39	(43)
Southern Punjab, Pakistan	0.25	3.8	1.6+1.1	(42)
Tehran (Iran)	0.29	28.82	11.30	(44)
Tongliao (China)	0.10±0.01	21.33±2.13	4.23±4.76	(46)
Bayanwula (China)	0.2	15.6±1.6	5.64±0.6	(45)
Syria	1.2	143	37.17	(49)
İkizdere Valley, Turkey	3.83	6.45	5.25	(47)
Louisiana (USA)	5	58	--	(39)
Vojvodina (Serbia)	5.7	55	--	(48)
Leningrad Region (Russia)	29	5320	467	(50)
Present study	8.8±2.8	57.0±4.2	--	

CONCLUSION

The results of this investigation showed a detectable quantity of Cesium-137 in all collected samples of soil from the Islamabad area.

The highest value for activity concentration of aforementioned nuclide in soil samples collected from a suburb of Islamabad (Nilore) was found to be 57.0±4.2 Bq/kg, which is higher than the reported values in the literature for other parts of the country.

The existence of Cesium-137 proved that the studied area is contaminated probably due to fallout from a past nuclear incident that occurred in Ukraine (Chernobyl, 1986) and Japan (Fukushima, 2011) or due to ongoing nuclear activities in this territory.

The detectable level of Cesium-137 in the studied region is insignificant and poses no health risk to the dwellers of this locality; however, concerned local authorities are advised to pay attention to avoid any possible future health hazards occurring to the state population and environment.

This work may also be helpful for providing guidance for further future work regarding evaluation of radioactivity level in the case of the occurrence of any unexpected radiological emergency.

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***Conflicts of interest*:** *Declared none.*

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