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Short Communication

Primordial radionuclides contamination level in fertilized farms soils of Faisalabad-Pakistan

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Abstract

Primordial radioactivity in soil depends upon the type, origin and the amount of phosphate fertilizers applied to it. Certain selected cultivated soils of the third largest city of Pakistan, Faisalabad were probed for the values of radioactivity contamination because of the use of phosphate fertilizers. The soils selected for this study were the farms of Nuclear Institute for Agriculture and Biology (NIAB) (about 80 hectares), 120 hectares of University of Agriculture, Faisalabad (UAF) farm and Ayub Agriculture Research Institute (AARI) (about 100 hectares). These all soils were situated in the urban area of Faisalabad. The technique exercised in order for the natural radioactivity estimation was gamma ray spectrometry, which revealed that the existence of radioactivity in soils of these farms result the presence of Potassium (^{40}K), Cesium (^{137}Cs), and Uranium (^{238}U). The average amount of radioactivity due to the presence of ^{40}K in the NIAB, AARI, and UAF were 650.50, 642.6 and 659.50 Bq kg^{-1}, respectively. For ^{232}Th contamination, the averaged values found were 57.52, 55.80 and 63.0 Bq kg^{-1} for AARI, NIAB and UAF farms, respectively. For ^{238}U, the average values were 36.51, 30.60 and 39.8 Bq kg^{-1} for all the above farms, respectively. For ^{137}Cs (nuclear fall) the averaged value in all the investigated farms was 2.50, 2.43 and 2.60 Bq kg^{-1}, respectively. The existence of ^{137}Cs in the soil samples of the investigated farms shows that these farms might have received the nuclear fall from man made sources. Its absorbed dose in air for NIAB, AARI and UAF farms amounted to 49.52, 47.55 and 52.99 nGy kg^{-1}, respectively. The values of Radium equivalent activity were 159.74, 145.01 and 163.67 Bqkg^{-1}, respectively. The calculated annual effective doses for the selected agricultural farms were 0.96, 0.95 and 0.98 mSvy^{-1}, respectively. External and Internal radioactive radiation hazard index for all the investigated farms were also calculated, which were less than one. This result leads to the information that the existing radiation contamination in the soils of the investigated farms is not an immediate hazard to the labourers/general public who are in contact with these farms. However, if the cultivation of these farms with the use of artificial fertilizers goes on then with time, in future the soils of these farms may pose a risk for the general public.

Keywords: Primordial radionuclides, agricultural farms, HPGe detector, Gamma spectrometry, environmental radioactivity, ^{40}K, ^{137}Cs, ^{238}U, ^{232}Th

Excessive contamination of agricultural land (Hussain *et al.*, 2008a) can lead to the transfer of radioactivity from soil to food grown (Hussain *et al.,* 2008b). Typical soil contains the radionuclides, radioactive potassium (^{40}K), uranium (^{238}U) and thorium (^{232}Th) and a nuclear fall cesium (^{137}Cs) (Nasim-Akhtar, 2006). These radionuclides are taken up by crops grown and transferred to foods obtained. Investigations and estimation of radiation dose rates in natural environments are important for community general health, as well as for radiation protection matters. Exposure dose rates from gamma ray emitted by these natural radionuclides have been investigated in several countries, and it is found that the exposure rates in 42 countries, were three-fifths of the world population, lie in the range of 24 -160 nGyh^{-1} (United Nations Scientific Committee on Effects of Atomic Radiations UNSCEAR, 2000). Most of the dose rate of natural radioactivity (85%) is due to the effect of primordial radionuclides, which also includes the contribution of cosmic radiation and cosmogenic radionuclides. In fact, only about 15% of the total effective dose equivalent keeps its share from the exposure of cosmic radiation, and about 0.6% is attributed to the cosmogenic radionuclides.

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The reported study was carried out in order to measure the amount of radioactivity to which the local population is exposed and annual effective dose hazard indices, due to the use of phosphate fertilizer in the agricultural farms of Faisalabad. The study also investigated the effects on the environmental gamma radiation doses to the population from agricultural farms of Faisalabad. The purpose of this investigation was to update the available data on exposures to external sources of natural radiation in the agricultural farms of the Faisalabad.

Area under investigation

The area under investigation consisted of 300 hectares of cultivated soil in the famous city of Faisalabad in the Punjab province of Pakistan. The location of the area is 31.2^o / N and 73.05^o /E, respectively. In this area, Agriculture Research farm of Nuclear Institute for Agriculture and Biology (NIAB) was established in 1970. The second farm, Ayub Agriculture Research Institute (AARI) was established in 1962. The third Postgraduate Agriculture Research Station, University of Agriculture, Faisalabad (UAF) is the oldest one; it was established in 1906. All the three farms are cultivated with fertilizers and are irrigated with canal water. During the shortage of canal water, these research farms are irrigated by the tube wells. The entire three farms have very fertile soil.

Geology of the Area

The areas under investigation consisted of fertile cultivated soils a Faisalabad. The area is a part of natural unit known as the Indus Plains, which represent a vast geosynclines lying between the Himalayan foothills and center core of the Indian Subcontinent. This depression which once may well have as offshoot of the sea, has been filled with tremendous quantities of sediments brought down by rivers from the Himalayas, and has consequently turned into an alluvial plain. In a few places, this alluvium has been estimated to be several thousand feet thick. The rocks underlying the alluvium are at great depth, have no bearing on the soils. Although the entire area is an alluvial plain, different parts of the plain were deposited in different ways and at different times ranging from late Pleistocene to Recent, as indicated by the degree of development of soils and elevation of land surface. The soil of Faisalabad is silt loam and very fine sandy loam having a weak subsoil structure with common kankers within five feet. It is the fertile soil with saline patches (WASID, 1968).

Experimental methods

Sample collection

Soil sampling was carried out in the month of May–June in 2003. Sampling from the saline patches was done using the soil sampling pattern recommended by the various agricultural agencies such that the selected research areas were divided into 25 sites for each farm. The distance between every point was about 15–17 meters. Five samples were taken from each point at a step of 5 cm depth covering 25 cm depth. In this way, twenty five points (sites) were covered and the total number of samples from one farm was 125. The samples were properly marked, catalogued and brought to Health Physics Laboratory at NIAB, Faisalabad, Pakistan for processing before analysis.

Sample preparation

For radiometric analysis, the soil samples were first dried in the sun for seven days. The samples were then crushed to small pieces and dried in a temperature controlled oven set at 100 °C until the moisture of the soil samples was removed completely. The dried samples were ground, powdered and sieved through a mesh of 200 μm in size. Plastic containers were used for filling and packing of the soil samples (IAEA, 1989). The container material was chemically resistant for the elements and compounds of soil. The containers were thick enough for permeation of radon (Lee *et al.,* 2001). Empty containers were weighed and filled with soil from the samples and weighed again. The net weight of the soil samples was recorded. The containers were closed by screw caps and plastic tapes over the caps. Same procedure was applied for the reference material, soil–6 obtained from IAEA.

Sample analysis

The soil sample analysis was carried out by using gamma rays spectrometer in order to investigate activity concentration of natural radionuclide of uranium and thorium series ^{40}K and fission product ^{137}Cs. The gamma–ray system (Canberra coaxial hyper pure germanium detector) has a photo peak efficiency of 30% and energy resolution of 1.8 keV full–width at half maximum (FWHM) for the 1332 keV gamma-ray line of ^{60}Co. A model 747 Canberra lead shield was used with the detector and had a 0.040 inch tin and 0.62 inch copper graded liner to prevent interference by lead X-rays. Along with the HPGe it consisted of an MCA card (both purchased from ORTEC, USA) with 8096 channels with in-built power supply and amplifier. The card was installed in a PC (personal computer). The standard and the sample were measured with a uniform geometry container. An empty bottle with the same geometry was measured for subtracting the background. The quality assurance of the measurements was carried out by a daily efficiency and energy calibration and repeating with each sample measurement. Soil–6 of IAEA was used as a reference material for the calibration of the spectrometer. A secular equilibrium was reached between ^{232}Th and ^{238}U and their decay products during storage of samples. The concentration of ^{232}Th was determined from the average concentrations of ^{212}Pb and ^{228}Ac in the samples, and that of ^{238}U was determined from the average concentrations of the ^{214}Pb and ^{214}Bi in their decay products (Shirley, 1986). The analysis of ^{40}K concentrations was based on single peak in the spectra (Table 1).

Table 1: Gamma ray energies used for calibration of spectrometer and for measurement of activity of the radionuclides of interest (Shirley, 1986)

Parent Nuclide	Daughter Nuclide	γ-ray energy (keV)	Abundance (%)
^{226}Ra	^{214}Pb	241.98	7.12
	^{214}Pb	395.21	19.20
	^{214}Pb	351.92	35.10
	^{214}Bi	609.32	44.60
	^{214}Bi	768.30	4.76
	^{214}Bi	1120.28	14.70
	^{214}Bi	1238.11	5.78
	^{214}Bi	1764.52	15.10
^{228}Th	^{228}Ac	202.39	3.81
	^{212}Pb	238.63	43.50
	^{228}Ac	338.42	11.26
	^{228}Ac	463.10	4.50
	^{208}Tl	583.19	30.58
	^{212}Bi	727.33	6.64
	^{208}Tl	860.56	4.50
	^{228}Ac	911.16	26.60
	^{228}Ac	964.64	5.05
	^{228}Ac	968.97	16.23
	^{208}Te	2641.60	35.80
^{40}K		1460.80	10.67
^{137}Cs		661.60	87.50

The detection efficiency on the system 'η' was plotted as a function of γ-ray energy (E) on the log–log graph paper, and a polynomial of degree two was fitted on the experimental data, according to the following equation:

$$\log \eta = 9.002 - 1.923 (\log E) + 6.448\times10^{-2} (\log E)^2 \quad \textbf{(1)}$$

Every sample was measured for 65,000 second; therefore, only one sample result could be collected in a day. The lowest limits of detection (LLD) for ^{40}K, ^{137}Cs, ^{232}Th and ^{226}Ra were determined and are given in Table 2. Spectrum analysis was carried out with the help of the computer software "Gene 2000" and activity concentration and related parameters for ^{40}K, ^{137}Cs, ^{238}U and ^{232}Th were determined, which are given in Table 3 and Table 4.

Table 2: The lowest limit of detection (LLD) for the radionuclides for ^{40}K, ^{137}Cs, ^{232}Th and ^{238}U (UNSCEAR, 2000)

Nuclide	Conversion Factors (Bqh(nGykg)$^{-1}$)	Lowest detection limit (Bq kg^{-1})
^{40}K	0.0417	59
^{137}Cs	0.1243	1.3
^{238}U	0.662	3.3
^{232}Th	0.604	3.3

By using gamma ray spectrometer, activity concentrations of the natural radionuclides of the uranium and thorium series, ^{40}K and fission product ^{137}Cs were investigated in the soil samples collected from agriculture research farms of Faisalabad in the Punjab province of Pakistan. The three most important primordial radionuclides investigated in the areas of interest were ^{40}K, ^{238}U and ^{232}Th and the man made ^{137}Cs. The average values of specific gamma ray activities along with maximum and minimum values due to ^{40}K, ^{137}Cs, ^{232}Th and ^{238}U are given in Table 3.

Natural potassium (K), also a part of nitrogen phosphate fertilizers (NPK) has 3 isotopes; ^{39}K, ^{40}K and ^{41}K. Among them only ^{40}K ($T_{1/2}$ = 1.3×10^{9} y) possesses natural gamma radioactivity and its abundance in nature is 0.012 % of all potassium (Knoll, 2000). During decay, ^{40}K produces two daughter isotopes; ^{40}Ca and ^{40}Ar, with the emission of beta and gamma radiation. The use of fertilizers in large extent have affected radionuclides concentration, specially potassium containing fertilizers (NPK) are one of the main cause of the presence of high activity of ^{40}K in soil (Tufail *et al.,* 2006a). The Phosphate fertilizer, NPK contains the K isotope along with Phosphate. By the continuous use of fertilizer, the amount of ^{40}K increases in the Agricultural farms. Concentration range of ^{40}K in NIAB, AARI, and UAF Farms were 650.50, 642.6 and 659.50 Bq kg^{-1}, respectively, which is in order of magnitude higher than that of ^{238}U and ^{232}Th as given in the Table 3. In addition to ^{40}K, the other naturally occurring radionuclides measured, were ^{238}U and ^{232}Th. Radium-226 (a member of ^{238}U series) is considered as the highly radiotoxic natural radionuclide. The emanation of radon (^{222}Rn) is associated with the presence of radium and its ultimate precursor uranium in the ground. The range of measured activity of ^{238}U for Faisalabad cultivated farms ARRI, NIAB and UAF were 36.51, 30.6 and 39.8 Bqkg^{-1}, respectively. The measured specific activity of ^{232}Th ($T_{1/2}$ = 1.4 × 10^{10} y) in the Faisalabad Farms: ARRI, NIAB and UAF were 57.52, 55.80 and 63.00 Bq kg^{-1}, respectively. Phosphate rocks contain substantial concentration of uranium, thorium, radium and radium decay products (Tufail *et al.,* 2006a).

Since phosphate rock is an important raw material used for manufacturing different types of phosphate fertilizers. Therefore, when this rock is processed in to phosphate fertilizers, most of the uranium and some of the radium accompanies the fertilizers (Hussain, 1994). It has also been estimated earlier that phosphate fertilizers applied to the fields in recommended amounts could raise radioactivity level in soils (Tufail *et al.,* 2006b). The Major sources are: 1) origin of soil and 2) the use of phosphate fertilizers used in the soils. There is no use of radioisotopic material in the NIAB or NIBGE fields. So, there is no effect on neighborly farms. The amount of the radioactive materials in other farms is greater than NIAB/NIBGE. We have analyzed different phosphate and other fertilizers, which show that radioactivity in phosphate fertilizers is much more than the other fertilizers. This is due to the bonding of phosphate with uranium (Tufail *et al.,* 2006a).

Table 3: Activity of naturally occurring radioisotopes in the soil samples from saline agricultural farms of Faisalabad

Name of the Farm Sample	No. of Sample	Activity concentration (Bq kg^{-1})			
		^{40}K	^{232}Th	^{238}U	^{137}Cs
		Average (Min-Max)	Average (Min-Max)	Average (Min-Max)	Average (Min-Max
AARI Farm	125	650.50 (590.68-670.00)	57.52 (41.51-49.53)	36.51 (34.6-39.5)	2.55 (0-4.53)
NIAB Farm	125	642.6 (646-696)	55.80 (50-55.61)	30.6 (32-37)	2.60 (0-5.04)
UAF Farm	125	659.50 (610.5-709)	63 (45-55)	39.8 (30-50)	2.43 (0- 4.02)
UNSCEAR Farm	125	140-850	11-64	17-60	0-35

In addition to these radionuclides, the soil samples also revealed the presence of a fission product, ^{137}Cs. The amount of radioactivity due to this fission fragment in Faisalabad farms: ARRI, NIAB and UAF were 2.55, 2.60 and 2.34 Bqkg^{-1}, respectively. The reasons of less existence of ^{137}Cs, indicates that the study area might have received some nuclear fall out from Chernobyl accident or any other sources, like open air explosions. It is clear from the results that the deposition of ^{137}Cs is not uniform and varies from site to site. Variation in diffusion of radionuclides in different soils, complexing processes, plant uptake, and plant or animal originated mechanical changes may result in the formation of the site specific distribution since the water patches also affect the leaching of ^{137}Cs. Fixation of soil is dependent on clay content of the soil, which is affected by ploughing (Vukašinović *et al*., 2010).

The variations in the activity levels have been observed to be lying within the activity values measured all over the world (IAEA, 1989). The comparison of activity levels with that of the world level can be observed from Table 4.

The decay of naturally occurring radionuclides in the soil produces a gamma–beta radiation fields in soil that also crosses the soil–air interface to produce exposures to humans (Nasim-Akhtar, 2006). External exposure outdoors arise from terrestrial radionuclides present at trace levels in all soils. The external gamma dose rate in air is calculated from the measurement of concentration of the relevant radionuclide in soil. In the UNSCEAR 2000 report, coefficients for conversion of activity concentration to the absorbed dose rate in air are given in Table 5. The external gamma dose rate in air is calculated from the measurement of concentration of the relevant radionuclide in soil. An important parameter related with the activity concentration is the radiation dose rate, D, at one meter above the ground surface which is measured in units of nGyh^{-1} can be calculated by the following formula:

$$\dot{D} = A \times C_f \qquad \textbf{(2)}$$

Where A is the activity concentration measured in Bqkg^{-1}, and C_f is the dose conversion factors in units of nGyh^{-1}/Bqkg^{-1} (absorbed dose rate in air per unit of activity concentration). The coefficients for conversion of activity concentration to absorbed dose rate in air as given in the UNSCEAR 2000 report. The absorbed dose was calculated by applying the dose coefficients relating soil concentration to absorbed dose rate in air from the activity concentration values and the results are also given in Table 4. The calculated values of absorbed dose in air for Faisalabad cultivated farms were 49.52, 47.55 and 52.99 nGyh^{-1} respectively. These values lie between the dose rate range of 18– 93 nGyh^{-1} given for the world in UNSCEAR report 2000. The values of dose from all farms of Faisalabad are less than the World average which is 55.50 nGyh^{-1}.

A quantity related to the absorbed dose in air is the annual mean effective dose. In order to assess the annual mean effective dose 'H' in $mSvy^{-1}$ to general public from out door terrestrial gamma radiation the conversion factor and the dose calculation model given in UNSCEAR 2000 report was used as follows:

$$H = (1 \times 10^{-6}) \times \dot{D} \times f \times T \times O \quad \textbf{(3)}$$

where $\dot{D}$ stands for dose rate in air ($nGyh^{-1}$), 'f' for dose to equivalent dose conversion factor (0.7 $SvGy^{-1}$), 'T' for time (8760 hy^{-1}), and 'O' for outdoor occupancy factor, the factor 1×10^{-6} comes from conversion of nano to milli.

Table 4: Radiation Absorbed Dose, Radium Equivalent Activity and Hazard Indices from various locations in the Indo- Pak subcontinent source (Nasim-Akhtar, 2006)

Country/Area	Radiation Absorbed Dose ($nGy\ h^{-1}$)	Radium Equivalent Activity ($Bq\ kg^{-1}$)	Internal Hazards Index (H_{int})	External Hazard Index (H_{ext})
BANGLADESH				
Dhaka	73	153	0.41	0.61
Kurigram	205	435	1.17	1.39
Rangpur	112	332	0.89	1.10
INDIA				
Amritsir	96	213	0.57	0.75
Chhatrapur	1621	3811	10.30	10.92
Gudalore	71	160	0.43	0.53
Kaiga	38	83	0.22	0.31
Kalpakkam	279	645	1.74	1.81
Kangra	258	595	1.60	1.67
Karnataka	2058	4811	13.00	14.48
Karnataka	39	87	0.23	0.33
Madurai	50	113	0.31	0.42
Pathankot	91	206	0.56	0.73
PAKISTAN				
Bahawalpur	75	160	0.43	0.52
Charsaddah	95	203	0.55	0.68
D.I. Khan	82	177	0.47	0.58
Faisalabad (Avg)	73	156	0.42	0.50
ARRI Farm	49.52	159.74	0.42	0.50
NIAB Farm	47.55	145.01	0.41	0.51
UAF Farm	52.99	163.67	0.40	0.49
Islamabad	82	175	0.47	0.57
Lahore	75	159	0.43	0.50
Lahore	60	102	0.27	0.32
Mianwali	69	150	0.40	0.49
Nowshera	82	175	0.47	0.59
Peshawar	77	165	0.44	0.56
WORLD	18–93	370	≥ 1	≥ 1

The time spent outdoors in the study areas depends on the climate conditions. The climate of the area is semiarid subtropical continental and is characterized by the intense heat and cold winters. The mean annual air temperatures range between 13–25 ^{o}C for minimum and 20–38 °C for maximum. May and June are the hottest months in which ambient air temperature may rose up to 47 °C. January is the coldest month with a mean minimum of 3 °C. Average annual rainfall is about 500 mm. About two third of the total annual precipitation is received during the monsoon season, which extends from the last days of June to mid September. October and November are the driest months. Keeping in view the atmospheric conditions of the area, the population of the area spends about 50% of the time outdoors. Therefore, the value of the occupancy factor 'O' was taken as 0.5 and the following simplified formula was applied for the calculation of effective dose.

$$H = 3.066 \times 10^{-3} \times \dot{D} \qquad \textbf{(4)}$$

The estimated annual mean effective dose for the Faisalabad Farms: ARRI, NIAB and UAF were calculated as 0.152, 0.145 and 0.162 $mSvy^{-1}$, respectively. It is not appropriate to compare the effective dose with the other countries of the world because climatic and atmospheric conditions and living habits are not same thoroughout the world. The distribution of ^{226}Ra, ^{232}Th and ^{40}K in the soil is not uniform. Uniformity with respect to exposure to radiation has been defined in terms of radium equivalent activity (Ra_{eq}) in $Bqkg^{-1}$ to compare specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th, and ^{40}K. It is calculated through the following relation (Tufail *et al*., 1992).

$$Ra_{eq} = (C_{th} \times 1.43) + C_{Ra} + (C_K \times 0.077) \qquad \textbf{(5)}$$

Where C_{th} is the ^{232}Th activity concentration in $Bqkg^{-1}$ and C_{Ra} is the ^{226}Ra and C_k is the ^{40}K concentrations in $Bqkg^{-1}$. By using Eq-5, the calculated values of radium equivalent activity for Faisalabad area: ARRI, NIAB and UAF were 145.01, 159.74 and 163.67 $Bqkg^{-1}$, respectively. It is observed that the calculated value of radium equivalent activity is lower than the recommended maximum value 370$Bqkg^{-1}$ (Berkata and Methew, 1985).

The external hazard index due to the emitted gamma-ray of the sample are calculated and examined according to the following criterion:

$$Hex = \frac{Cra}{370} + \frac{Cth}{259} + \frac{Ck}{4810} < 1 \qquad \textbf{(6)}$$

The calculated value of external hazard (Eq. 6) index was found to be 0.41, 0.42 and 0.40 for Faisalabad farms: ARRI, NIAB and UAF, respectively. It may be observed that external hazard values are less than one for all the study farms.

The internal hazard index due to the internal gamma-ray of the sample are calculated and examined according to the following criterion:

$$Hint = \frac{Cra}{185} + \frac{Cth}{259} + \frac{Ck}{4810} < 1 \qquad \textbf{(7)}$$

The calculated value of internal hazard (Equation 7) index was found to be 0.51, 0.50 and 0.49 for Faisalabad farms ARRI, NIAB and UAF, respectively. It may be observed that it is less than 1 for all the study farms as given in the Table 4.

In Table 4, comparison of the absorbed dose, Radium Equivalent Activity, Internal Hazard Indices and External Hazard Indices with Indo-Pak Subcontinent. From the Table 4, some cities of India possess very high radiation levels and are the source of radiation risk. Karnataka and Chatarapur lies at the maximum level of background having values of 2058 and 1621 nGy h^{-1}, respectively, which is about 50% world average value. These places represent hazard place for the public to live in. By viewing the radiation background level in the Indian cities, Table-4 indicate that two extremes level are available in India. Among the given cities of India, Kaiga represent the minimum radiation hazard, which is also less then the world average value of 57 nGy h^{-1}.

Maximum dose was absorbed from Charsaddah city of Pakistan which is 95 nGy h^{-1}, it is greater than world range 18–93 nGy h^{-1} doses from Islamabad. Noshorha and D.I. Khan have equal values of 82 nGy h^{-1}, which may be due to similar geological makeup of these areas. Doses from Behawalpur, Faisalabad, Peshawar and Lahore nearly lie in same range of 47–77 nGy h^{-1}. This is within the world range, but greater than the world average of 55 nGy h^{-1}. Mianwali and Lahore have same pattern of radiation levels of dose ranging from 62-69 nGy h^{-1}. Overall doses from Pakistani cities are less than the doses from other areas belonging to Bangladesh and India. Study farms in Faisalabad possess the least hazard for the general public as compared to other areas of Indo-Pak.

Conclusion

The detected values of the natural radioactivity show that the isotope ^{40}K is abundant in all the soils of Faisalabad. The values of natural radionuclides are more in the soils of Agriculture University Faisalabad, which are the oldest farms among the study area. The values of the natural radioactivity are less in the NIAB Farm, which is comparatively younger farm among the studied soils. The comparison of data shows that regular use of phosphate fertilizers for greater times enhance the natural radioactivity in soils. The indication of ^{137}Cs shows that this area might have received the nuclear fall, which have leached down by ploughing and irrigation practices. The external and internal hazard index values are less than 1, which shows that these soils pose immediately no hazard to the public. However, with the passage of time, these farms may pose risk for the general public. The values of the natural radioactivity, absorbed dose, and Radium equivalent activity falls in the limit as recommended by United Nations Scientific Committee on Effects of Atomic Radiations.

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