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ESTIMATION OF RADIATION EXPOSURE ASSOCIATED WITH THE SALINE SOIL OF LAHORE, PAKISTAN

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Abstract: This investigation reports the amount of radioactivity in the barren soil of Lahore, Pakistan. For this purpose, an area of about 60 hectares of saline soil was selected in Rakh Dera Chal near the city of Lahore in the Punjab province of Pakistan. The technique of gamma ray spectrometry was applied using HPGe (high purity germanium) gamma ray detector and a PC based MCA. Activity concentration levels due to ^{40}K, ^{137}Cs, ^{226}Ra and ^{232}Th were measured in 125 saline soil samples collected at a spacing of about 4 hectares at depth level 0 – 25 cm with a step of 5 cm depth. Results indicated that activity concentration of saline soils the concerned radionuclides was as follows: ^{40}K, 524.84 − 601.62 Bq kg^{-1}, ^{137}Cs, not detected (less than the lower detection limit), ^{226}Ra, 24.73 − 28.17 Bq kg^{-1}, and ^{232}Th, 45.46 − 52.61 Bq kg^{-1}. Before the radiometric measurements, chemical analysis for concentration of Na, Ca and Mg was also carried out along with the measurement of electrical conductivity and pH of the soil samples. The range of values of Na (43-50 meq l^{-1}), Ca+Mg (0.3-0.9 meq l^{-1}), pH (8.1 – 9.21) and values of Ec (16.11-20.5 μs cm^{-1}).

Keywords: Environmental radioactivity, gamma spectrometry, HPGe detector, saline soil, ^{40}K, ^{137}Cs, ^{226}Ra, ^{232}Th.

INTRODUCTION

Soil is a collection of natural bodies on the surface of the earth, containing living matter and supporting or capable of supporting plants [Russal 1957]. Soil is a complex because of its extreme variability in physical and chemical composition. It consists of small but significant quantities of organic and in organic compounds, which are essential for plant growth. There are many types of soil depending upon the physical and chemical composition. The soil is classified as saline, saline sodic and alkl [Brady *et al*. 1990]. In Pakistan, the problem of soil salinity is 56% of total area and in Punjab 80%of area is salt affected [Muhammad 1983].

Man is dependent on soils and good soils are dependent upon man and the use he makes of them. In saline soil, the concentration of soluble salts is increased to the level at which the crop growth is adversely affected [Brady *et al.* 1990]. Saline soils have Ec>4.0dsm^{-1} (electrical conductivity of salt effected soil extract), SAR < 13.3 (sodium adsorption ratio) and pHs <8.5. The saline soils either reclaimed or utilized for crop production depending upon the extent of salinity or physical nature of the soil. Nuclear fission in connection with atomic weapons testing provides another source of soil contamination. Direct fall out of radionuclides from

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the atmosphere on vegetation was primary source of contamination [IAEA 1989]. The fission product ^{137}Cs is strongly adsorbed and retained by soil clay particles. Soil not only consists of organic and inorganic compounds but also of radionuclides such as uranium, thorium, radium, potassium etc. [Zahid *et al.* 1999], which occur in nature as a complex of oxides, hydrated oxides, carbonates, phosphates, sulphates, vanadates and silicates, which are randomly distributed at different depths of soil [Zahid *et al.* 2001]. The subject of radioactive contamination gained considerable public importance because of Chernobyl accident. Naturally occurring radionuclides uranium, thorium and potassium (uranium and thorium series etc.) are the largest contributors to radiation doses received by human beings from the soils. Keeping in view the above mentioned facts, the present study has been planned to investigate the radio active potent ional of the soil .

MATERIALS AND METHODS

The area under investigation consisted of 60 hectares of saline soil in the Rakh Dera Chal 30 km from the historical city of Lahore in the Punjab province of Pakistan. The lactation of the area is $31^o 6^/$ N and $74^o 7^/$ E.

Soil sampling was carried out in the month of May–June in 2002. Sampling from the saline patches was done using the Soil Sampling pattern recommended by the various agricultural agencies [Samaul *et al*. 1970]. The area was divided into 25 sites. The distance between every point was about 15–17 m. From every point (site), 5 samples were taken 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 was 125. The samples were properly marked, cataloged and brought to Health Physics Laboratory at NIAB, Faisalabad, Pakistan for processing before analysis.

The soil samples were air dried, grinded, pass through a 2 mm sieve and thoroughly mixed. The soil samples were analyzed for Ec, pH, CA^{+2}, Mg^{+2}, Na^+. The physico–chemical properties are listed in Table 1.

Table 1: Chemical analysis of saline soil.

Soil samples	Depth (cm)	Electrical conductivity Ec (μs cm^{-1})	pH	Concentration of Ca+Mg (meq l^{-1})	Concentration of Na (meq l^{-1})
F11	0-5	16.18	8.9	0.8	47
F21	5-10	16.33	8.5	0.9	49
F31	10-15	14.10	8.1	0.6	48
F41	15-20	14.11	8.5	0.5	50
F51	20-25	20.45	8.9	0.3	43

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 an oven at 105^oC until the moisture of the soil removed completely. The dried samples were ground, powdered and passed though a sieve of mesh size 200 μm. Plastic containers were used for filling and packing of the soil samples. 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. The containers were filled with soil from the samples and weighed again. The dry weight of the soil was noted. The containers were closed by screw capes and plastic tapes were put over the caps. Same procedure was adopted for the Soil–6 (standard reference material) obtained from IAEA. The samples and standards were stored for more than 40 days to achieve secular equilibrium between ^{222}Rn and ^{226}Ra.

The technique of gamma ray spectrometry was applied for determination of radioactivity of the samples under investigation. The spectrometry system consisted of a high purity germanium (HPGe) detector and an Multi Channel Analyzer (MCA) card with inbuilt power supply and amplifier. The card was installed in a personal computer (PC).

Table 2: Gamma ray energies used for calibration of spectrometer and measurement of activity of the radionuclides.

Parent Nuclide	Daughter Nuclide	γ-ray energy (keV)	Abundance (%)
^{226}Ra	^{214}Pb	241.98	07.12
	^{214}Pb	395.21	19.20
	^{214}Pb	351.92	35.10
	^{214}Bi	609.32	44.60
	^{214}Bi	768.30	04.76
	^{214}Bi	1120.28	14.70
	^{214}Bi	1238.11	05.78
	^{214}Bi	1764.52	15.10
^{228}Th	^{228}Ac	202.39	03.81
	^{212}Pb	238.63	43.50
	^{228}Ac	338.42	11.26
	^{228}Ac	463.10	04.50
	^{208}Tl	583.19	30.58
	^{212}Bi	727.33	06.64
	^{208}Tl	860.56	04.50
	^{228}Ac	911.16	26.60
	^{228}Ac	964.64	05.05
	^{228}Ac	968.97	16.23
	^{208}Te	2641.60	35.80
^{40}K		1460.80	10.67

Soil–6 of IAEA was used as a reference material for calibration of the spectrometer. Spectrum of every soil sample was collected for 65,000 seconds. Areas under the energy peaks, given in Table 2, were used for drawing the peak efficiency curve between log of efficiency versus log of peak energy. A polynomial was fitted to the curve and polynomial was stored in the computer for further use.

The lowest limits of detection (LLD) for ^{40}K, ^{137}Cs, ^{232}Th and ^{226}Ra were determined and are given in Table 3. Spectrum for every sample was collected for 65,000 second. Spectrum analysis was done with help of the computer software Gene 2000, and activity concentration for ^{40}K, ^{137}Cs, ^{226}Ra and ^{232}Th was determined.

Table 3: The lowest limit of detection (LLD) for the radionuclides for ^{40}K, ^{137}Cs, ^{232}Th and ^{226}Ra

Nuclide	Lowest detection limit (Bq kg^{-1})
^{40}K	59.0
^{137}Cs	01.3
^{226}Ra	03.3
^{232}Th	03.3

RESULTS AND DISCUSSION

By using gamma ray spectrometer, activity concentrations of the natural radionuclides of the uranium and thorium series, ^{40}K and a fission product ^{137}Cs were investigated in the soil samples from saline patch of Rakh Dera Chal near the city of Lahore. The average values of specific gamma ray activities due to ^{40}K, ^{137}Cs ,^{232}Th and ^{226}Ra are given in the Table 4 and the activity levels were found to fallow the normal distribution. Three most important primordial radionuclides investigated in the area of interest were ^{40}K, ^{226}Ra and ^{232}Th [Kohler *et al*. 2000].

Table 4: Activity of naturally occurring radioisotopes saline fertilized soil of Lahore.

Sample name	Depth from land surface (cm)	No. of Samples	Activity concentration (Bq kg^{-1})			
			^{40}K	^{232}Th	^{226}Ra	^{137}Cs
F1	00—05	25	546.3±21.5	48.5±1.9	24.7±1.2	Below LLD
F2	05—10	25	594.9±21.8	49.7±2.0	29.2±1.3	Below LLD
F3	10—15	25	525.8±21.4	51.6±2.0	25.5±1.2	Below LLD
F4	15—20	25	602.6±21.8	52.6±2.0	26.2±1.2	Below LLD
F5	20—25	25	546.3±21.5	44.5±1.9	26.5±1.2	Below LLD

Natural potassium has three isotopes; ^{39}K, ^{40}K and ^{41}K, among them only ^{40}K ($T_{1/2}$ = 1.3x10^{9} yr) possesses natural gamma radioactivity and its abundance in nature is 0.012 % of all Potassium. During decay ^{40}K produces two daughter products, ^{40}Ca and ^{40}Ar, with the emission of beta and gamma radiation. The use of fertilizers in large extent have affected radio nuclides concentration, specially potassium containing fertilizers are the one of the cause of presence of high activity of ^{40}K in soils. The high value of 40K may be also due to their soil origin [Tzortzis *et al*. 2003]. Concentration range of ^{40}K in soil was 524.8–601.6 Bq kg^{-1} with and average value of 561.6 Bq kg^{-1}.

In addition to ^{40}K, other naturally occurring radionuclides measured were ^{226}Ra and ^{232}Th. Radium-226 (a member of ^{238}U series) is considered as the highly radiotoxic natural radionuclide. The range of measured activity of ^{226}Ra was 24.7–28.2 Bq kg^{-1} with an average of 25.8 Bq kg^{-1}. The range of measured specific activity of ^{232}Th ($T_{1/2}$ = 1.4 x 10^{10} yr) was 45.5–52.6 Bq kg^{-1} with an average of 49.2 Bq kg^{-1}. The average activity value of ^{232}Th was two times higher than that of ^{226}Ra [Miah *et al*. 1998]. The activity concentration of ^{40}K in soil is order of magnitude higher than that of ^{226}Ra and ^{232}Th.

It has been reported since early in this century that phosphate rocks contain substantial concentration of uranium, thorium and radium and radium decay products [Skorovarov *et al*. 1996]. Since phosphate rock is an important raw material used for the manufacturing of different types of phosphatic fertilizers. Therefore, when this rock is processed in to phosphatic fertilizers, most of the uranium and some of the radium accompanies the fertilizers [Hussain 1994]. It has also been estimated earlier that phosphatic fertilizers applied to the fields in recommended amounts could raise radioactivity level in soils [Bhatti 1994].

The activity of ^{137}Cs in all the samples was found below the lowest limit of detection (Table 3). The reasons of non existence of ^{137}Cs in the soil of Rakh Dera Chal may be that the trees and grass in the land might have provided shield to the land for the reach of ^{137}Cs (from the nuclear fall) to the land. The grass contaminated with ^{137}Cs might have been grazed by the cattles and most of the remaining ^{137}Cs would have been eroded by rain, wind, etc (Miah *et al.* 1998]. The variations in the activity levels of natural radionuclides (^{40}K, ^{232}Th, ^{226}Ra) have been observed to be lying within the activity values measured all over the world [UNSCEAR 2000]. The comparison of activity levels with that of the world level is presented in Table 5.

Table5: Comparison of activity levels in the saline soil of Lahore area and the world average.

Location	Activity concentration (Bq kg^{-1})		
	^{40}K	^{226}Ra	^{232}Th
Saline soil of Lahore	526–602	23–28	46–53
World average [UNSCEAR 2000]	140–850	17–60	11–64

The decay of naturally occurring radionuclides in soil produces a gamma–beta radiation fields in soil that also crosses the soil–air interface to produce exposures to humans [Selvasekarapandia *et al*. 2000]. External exposures outdoors arise from terrestrial radionuclides present at trace levels in all soils. The external gamma dose rate in air is calculated from measurement of concentration of the relevant radionuclide in soil. The dose coefficients for conversion of activity concentration to absorbed dose rate in air are given in a report [UNSCEAR 2000] and are reproduced in Table 6. The results of present measurements are given in Table 7. The calculated value is 65 n Gy h^{-1} which lies between the dose rate range of 18–93 n Gy h^{-1} given for the world in UNSCEAR report [2000].

Table 6: Activity to dose rate conversion factors (UNSCEAR, 2000)

Radionuclide	Dose coefficient (n Gy h^{-1} per Bq kg^{-1})
^{40}K	0.0417
^{238}U	0.4620
^{232}Th	0.6040

Table 7: Radiation absorbed dose in air due to natural radioactivity in the saline soil of Lahore area.

Radionuclide	Average Activity (Bq kg^{-1})	Absorbed dose in air (n Gy h^{-1})
^{40}K	561.6	23.4
^{238}U	25.8	11.9
^{232}Th	49.2	29.7
	Total	65.0
World range [UNSCEAR 2000]		18–93

CONCLUSIONS

- The saline soil of Rakh Dera Chal near Lahore possesses no Radionuclide hazards for humans.
- This patch of soil presently has no nuclear fall of any type.
- By comparing with the values of exposures in different parts of world the present value is of intermediate level.

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