

Cesium-137 activity concentrations in soil and brick samples of Mirpur, Azad Kashmir; Pakistan

M. Rafique

Department of Physics University of Azad Jammu and Kashmir Muzaffarbad, 13100, Azad Kashmir, Pakistan

ABSTRACT

► Original article

* Corresponding author:

Dr. M. Rafique,

Fax: +92 5822960402

E-mail: mrafique@ajku.edu.pk

Submitted: Sept. 2012

Accepted: April 2013

Int. J. Radiat. Res., January 2014;
12(1): 39-46

Background: The aim of this study was to measure ^{137}Cs levels in soil and brick samples to set the baseline data and an indicator of fallout radioactivity for this part of the world. This study will help to probe, if there is any health threat posed by ^{137}Cs exposure to the residents of the area. **Materials and Methods:** Twenty five samples of soil and 6 samples of bricks were collected from different locations of Mirpur of Azad Kashmir. A P-type HPGe detector was used to measure gamma spectra of samples. **Results:** Results showed that for soil samples activity concentration range from 0.076 ± 0.071 to 2.94 ± 0.17 Bq.Kg $^{-1}$ with average value of 1.39 ± 0.17 Bq.Kg $^{-1}$. Similarly activity concentration of ^{137}Cs in Brick samples range from 0.22 ± 0.09 Bq.Kg $^{-1}$ to 2.14 ± 0.13 Bq.Kg $^{-1}$ with average value of 0.73 ± 0.10 Bq.Kg $^{-1}$. For soil samples the average values of outdoor, indoor and annual effective dose were found to be 5.12×10^{-5} , 20.47×10^{-5} and 25.58×10^{-5} mSv.y $^{-1}$ respectively. For brick samples specific activity of the ^{137}Cs range from 0.22 ± 0.09 to 2.14 ± 0.13 Bq Kg $^{-1}$. The average values of outdoor, indoor and annual effective dose for brick samples were 2.71×10^{-5} , 10.52×10^{-5} and 13.23×10^{-5} mSv.y $^{-1}$ respectively. **Conclusion:** The results indicate that the measured values were extremely small when compared with the annual dose rate recommended by ICRP (1.0 mSv.y $^{-1}$), as well as the annual external gamma radiation dose (0.48 mSv.y $^{-1}$) received per head from the natural sources of radiation.

Keywords: Background radiations, fallout radionuclide, annual effective dose, gamma radiation dose, Mirpur, Azad Kashmir.

INTRODUCTION

Ionizing radiations are the part of human environment from the time of earth formation. These radiations can be divided in to three groups according to their origin; (1) radiations coming from primordial radionuclides with long half-lives along with their progenies; (2) radiations coming from other sources than by the decay of primordial radionuclides; and (3) radiations coming from manmade sources⁽²⁾. Once the detrimental effects associated with radiations have been identified, since than this subject has got considerable importance. Several studies have been conducted throughout the world for monitoring and identification of

health effects linked with radiation exposure.

An extensive data related with monitoring of radioactivity originated from primordial and man-made radionuclides⁽³⁻¹⁷⁾ is available in the literature. A significant proportion of environmental radioactive contamination has been resulted from past nuclear power plant accidents, nuclear weapons testing, nuclear waste disposal and embezzlement of radioactive sources⁽¹⁸⁾. After the Chernobyl nuclear power plant accident (on 26th of April 1986) radioactive contaminations has got the public attention. This accident has not only affected Ukraine, Belarus and Russia but the whole world and changed the public and government attitudes to nuclear safety on an international scale⁽¹⁹⁾.

The most important anthropogenic radionuclides widely distributed in global fallout due to nuclear weapon testing and nuclear power plants accidents are ⁹⁰Sr and ¹³⁷Cs. ⁹⁰Sr with half-life of 28.78 years dowries a significant health threat since it replaces for calcium in bone (20). On the other hand ¹³⁷Cs with half-life of about 30.17 years reacts with water producing cesium hydroxide (21).

¹³⁷Cs exposure is of much concern for human health. Energy released by radioactive ¹³⁷Cs can cause a substantial damage to living cells. Since ¹³⁷Cs emits beta and gamma particles which may damage to tissue and cellular functions due to ionization of molecules with in cells of body. Most prominent health threat route due to exposure of ¹³⁷Cs is the ingestion of radioactive cesium-contaminated food (US DHHS 2001). In case of fallout from nuclear weapons tests, or from reactor accidents, milk is an important source of ¹³⁷Cs. Another route of radioactivity ¹³⁷Cs exposure for human is through the entrance in plants by direct deposition or uptake from the soil.

¹³⁷Cs uptake from soil has been studied in the 1960s (22) and to observe long-term effects of the Chernobyl accident there has been renewed interest in the subject. ¹³⁷Cs uptake is very much reliant on the type of soil. Within plants ¹³⁷Cs is more movable as compared to ⁹⁰Sr. It moves readily from leaves to seeds within plants (23). Besides these routes of exposures Inhalation and dermal exposure routes may also present a significant health threat.

This study aims at the measurement of ¹³⁷Cs levels in soil and brick samples, in order to set the baseline data for this part of world. ¹³⁷Cs presence in soil and brick samples will be the indicator of fallout radioactivity in the area under investigation. Results will be compared with the standards set by international organizations in order to assess the level of threat posed by ¹³⁷Cs exposure to local population.

Area under study

Current study has been carried out for the soil and brick samples collected from the

district Mirpur of Azad Kashmir. Mirpur is the largest city of Azad Kashmir, and it is located at the extreme south of Azad Kashmir at an elevation of 459 meters (1509ft). Its coordinates are 33°9'4" N 73°44'10" E / / 33.1425; 73.75611. District Mirpur is the industrial hub of Azad Kashmir, having industries of Foam, Polypropylene, Synthetic yarn, Motorbikes, Textile, vegetable ghee, logging and sawmills, soap, cosmetics, marble, ready-made garments, matches, rosin etc. Along with all these there is a huge investment in the field of construction building materials. These industries include brick factories, Marble factories and crush/concrete factories etc.

MATERIALS AND METHODS

Sampling procedures

Thirty one samples of soil and bricks were collected from different places of the district Mirpur in the month of June, 2010. These included 25 samples of soil and 6 samples of bricks. The samples were initially packed in polythene bags and properly catalogued in accordance with the location of sampling site, brought to the Physics laboratory of University of Azad Jammu & Kashmir for processing before analysis. The collected samples were crushed, sieved and dried at 110 ±1 °C for 4 to 6 hours. These samples were then placed in Marinelli beakers and hermitically sealed. In order to attain equilibrium between ²²⁶Ra and ²²²Rn, beakers were placed in an undisturbed position for a period of 60 days.

Gamma Spectrometry and Analysis

A P-type HPGe detector was used to measure gamma spectra of soil and brick samples. The resolution and relative efficiency of the detector for 1332 keV (⁶⁰Co) was 2.5 keV and 90 %, respectively. In order to perform the data acquisition, the packed soil and brick samples were placed inside the lead castle in which detector is present. The Marinelli beaker were placed on the detector so that detector occupies

the hollow region of the beaker and detector was covered from the material sample by all its dimensions. The samples are in this way exposed to the detector for sixteen hours (57600 seconds) individually.

Initially the detector was calibrated so that the energy of each peak should be in accordance with corresponding channel number. Here in this study the reference material used for the calibration was mix Radionuclide Gamma Reference Source, supplied by AEA technology QSA GmH Germany. The calibration was made for the naturally occurring radio nuclides of uranium series, thorium series, cesium and potassium respectively.

¹³⁷Cs concentration was measured directly through its gamma-ray energy peak of 661.66 keV. The software Personnel Computer Analyzer (PCA-II) was used for the collection of the spectra. The lowest limit of detection (LLD) for ¹³⁷Cs was found as 0.12 Bq.Kg⁻¹. LLD was calculated using formula.

$$LLD = \frac{4.66 \times \sqrt{\text{BackGround Counts}}}{\text{LiveTime} \times \text{Yield} \times \text{Efficiency}} \quad (1)$$

For the anthropogenic nuclide ¹³⁷Cs, the formula of dose rate calculation was used as below:

$$\dot{D}_{Cs} = 0.03 \times A_{Cs} \quad (2)$$

Here "A_{Cs}" is the specific activity of the ¹³⁷Cs and 0.030 nGyh⁻¹ per BqKg⁻¹ is the dose conversion factor for the ¹³⁷Cs and it should be noted that dose rate is expressed in the units of nGyh⁻¹.

Effective dose rates

The effective dose of gamma radiation received annually by an individual depends upon the time for which the person is exposed to the gamma radiations. According to a report prepared by UNSCEAR, 2000 it is assumed that the populations of urban locations spend eighty percent of their time of the solar day in indoor environment whereas twenty percent of the time is spent outdoors. Thus for the indoor exposure of the public the occupancy factor is

0.8 and for the outdoor radiation exposure the outdoor occupancy factor is 0.2 as indicated in the UNSCEAR, 2000 ⁽¹⁾. Therefore to estimate the annual effective dose for an individual a conversion factor (Q = 0.7 SvGy⁻¹) is used to cover the absorbed dose in air to the annual effective dose ⁽²⁴⁾.

Thus the annual effective dose has been calculated by following relation:

$$E = Q \times T \times O \times \dot{D} \times 10^{-6} \quad (3)$$

Where the term on left side of the above equation represents annual effective dose equivalent in mSvy⁻¹, "T" is the time in hours for one year, i.e. 8760 hours, "D" is the dose rate in nGyh⁻¹ and "O" is the occupancy factor for outdoor and indoor circumstances. For indoor exposure occupancy factor is taken as 0.8 and for outdoor 0.2 (UNSCEAR 2000) ⁽¹⁾.

RESULTS AND DISCUSSION

The data obtained for ¹³⁷Cs in soil and brick samples collected from Mirpur, indicates significant variability. For soil samples, ¹³⁷Cs activity levels vary from 0.076±0.071 to 2.94±0.17 Bq. Kg⁻¹ (as may be seen from table 1) with average value of 1.39±0.17 Bq. Kg⁻¹. Similarly dose rates measured for corresponding values of specific activities ranged from (0.2 to 8.8) × 10⁻² nGy h⁻¹ and with average value of 4.2 nGy h⁻¹ (see table 1). It can be seen from the table 1 that specific activity and dose rate due to ¹³⁷Cs are lowest for the soil sample #20, collected from the bank of Mangla dam Mirpur. The maximum value of specific activity and dose rate are associated with the soil sample # 12, collected from Wespa factory Mirpur. Table 2 shows the outdoor, indoor and annual effective dose equivalent which is received by an individual from the anthropogenic radionuclide ¹³⁷Cs. Results shows that the outdoor, indoor and annual effective dose received from the soil of Mangla dam Mirpur is minimum with the values of 0.25 × 10⁻⁵, 0.98 × 10⁻⁵ and 1.23 × 10⁻⁵ mSv.y⁻¹ respectively, whilst the maximum values

of outdoor, indoor and annual effective dose (10.79, 43.17 and 53.96) × 10⁻⁵ mSv. y⁻¹ were recorded for samples collected from Wespa Factory Mirpur. The average values of outdoor, indoor and annual effective dose are (5.12, 20.47 and 25.58) × 10⁻⁵ mSv.y⁻¹ respectively.

Spectral analysis of bricks samples used in Mirpur Azad Kashmir also showed the presence of the ¹³⁷Cs in the bricks. The specific activity and dose rate are described in the table 3. The table shows that the specific activity of the ¹³⁷Cs has a minimum value of 0.22±0.09 BqKg⁻¹ for the bricks of trademark A.A.P Mirpur which delivers a minimum dose rate of 0.01nGyh⁻¹.

The maximum value of specific activity of ¹³⁷Cs and dose rate was found in bricks with trademark M.A. Mirpur whose values are 2.14±0.13 BqKg⁻¹ and 0.06 nGyh⁻¹ respectively.

Results (see table 4) shows that the outdoor, indoor and annual effective dose received from the bricks. Minimum values for outdoor, indoor and annual effective dose were found as with the values of 0.81 c, 3.24 × 10⁻⁵ and 4.05 × 10⁻⁵ mSv.y⁻¹ respectively, whilst the maximum values of outdoor, indoor and annual effective dose (7.87, 30 and 30.87) × 10⁻⁵ mSv. y⁻¹, were recorded for Brick samples with trademark name M. A Mirpur. The average values of outdoor, indoor

Table 1. Specific activity and dose rate due to ¹³⁷Cs in soil of Mirpur Azad Kashmir.

| Sample Code | Location | Activity of ¹³⁷ Cs A _{Cs} (BqKg ⁻¹) | Dose rate Ḋ (× 10 ⁻²) (nGyh ⁻¹) |
|---|---------------------------|--|---|
| Soil-1 | Industrial area Mirpur | Below L.L.D ^a | N.D ^b |
| Soil-2 | Bohar colony Mirpur | 0.55±0.12 | 1.7 |
| Soil-3 | MUST Mirpur | 2.93±0.21 | 8.8 |
| Soil-4 | Naangi Mirpur | 0.33±0.08 | 1 |
| Soil-5 | Bailyan Mirpur | 0.96±0.15 | 2.9 |
| Soil-6 | NAB office Fazalabad | 1.45±0.17 | 4.4 |
| Soil-7 | Chaichyan-1 | 0.69±0.10 | 2.1 |
| Soil-8 | Khari Shareef-1 | 1.20±0.16 | 3.6 |
| Soil-9 | Nagyal Mirpur | 0.38±0.09 | 1.1 |
| Soil-10 | Jatlaan Mirpur | 2.08±0.20 | 6.2 |
| Soil-11 | Jordiyan Mirpur | 2.13±0.20 | 6.4 |
| Soil-12 | Wespa Factory -1 | 2.94±0.21 | 8.8 |
| Soil-13 | Kotli Road Mirpur | 1.74±0.17 | 5.2 |
| Soil-14 | MUST Mirpur | 2.56±0.21 | 7.7 |
| Soil-15 | Khalaqabad Mirpur | Below L.L.D | N.D |
| Soil-16 | Tarpa stop Mirpur | 1.42±0.17 | 4.3 |
| Soil-17 | New city Mirpur | Below L.L.D | N.D |
| Soil-18 | Kotli Road Mirpur | 0.87±0.14 | 2.6 |
| Soil-19 | Industrial area Mirpur | 1.53±0.16 | 4.6 |
| Soil-20 | Bank of Mangla Dam Mirpur | 0.076±0.071 | 0.2 |
| Soil-21 | Dahola | 2.2±0.18 | 6.6 |
| Soil-22 | Mangla Fort & Museum | 2.4±0.19 | 7.2 |
| Soil-23 | Wespa Factory -2 | 1.94±0.17 | 5.8 |
| Soil-24 | Chaichyan-2 | 2.46±0.19 | 7.4 |
| Soil-25 | Khari Shareef-2 | 1.81±0.18 | 5.7 |
| Over all mean value (BqKg ⁻¹) | | 1.39±0.17 | 4.2 |

^aBelow LLD=Below lowest limit of detection

^bN.D= Not detected

and annual effective dose are (2.71, 10.52 and 13.23) × 10⁻⁵ mSv. y⁻¹ respectively.

At some sampling points the activity levels of ¹³⁷Cs in soils samples was below the detection limit and mean level of activity for other sampling positions was found as average value of 1.39±0.17 Bq. Kg⁻¹. This activity might be due to anthropogenic radionuclides fallout of previous worldwide nuclear explosion and nuclear reactor accidents. Due to the consequences of nuclear activities, the radionuclide ¹³⁷Cs enters into the atmosphere and most of the fallout radiation accumulates in the soil.

Table 3. Specific activity of ¹³⁷Cs and dose rate associated with bricks used in Mirpur Azad Kashmir.

| Sample code | Location | Activity of ¹³⁷ Cs A _{Cs} (BqKg ⁻¹) | Dose rate D ⁰ (nGyh ⁻¹) |
|---------------------|--------------|---|--|
| B-1 | M.S Mirpur | 0.72±0.12 | 0.02 |
| B-2 | R.Y Mirpur | 0.66±0.12 | 0.02 |
| B-3 | M.A Mirpur | 2.14±0.13 | 0.06 |
| B-4 | A.A.P Mirpur | 0.22±0.09 | 0.01 |
| B-5 | A.G Mirpur | 0.40±0.09 | 0.01 |
| B-6 | W.Z Mirpur | 0.29±0.07 | 0.01 |
| Over all mean value | | 0.73±0.10 | 0.02 |

Table 2. Annual effective dose equivalent, outdoor and indoor average annual effective dose equivalent in soil samples used of Mirpur Azad Kashmir for ¹³⁷Cs.

| Sample code | Sample location | Annual effective dose equivalent E (mSvy ⁻¹) × 10 ⁻⁵ | Outdoor average annual effective dose E _{out} (mSvy ⁻¹) × 10 ⁻⁵ | Indoor average annual effective dose E _{in} (mSvy ⁻¹) × 10 ⁻⁵ |
|---------------------|----------------------|---|---|---|
| Soil-1 | Industrial area | N.D | N.D | N.D |
| Soil-2 | Bohar colony | 10.42 | 2.08 | 8.34 |
| Soil-3 | MUST-1 | 53.96 | 10.79 | 43.17 |
| Soil-4 | Naangi | 6.14 | 1.23 | 4.91 |
| Soil-5 | Bailyan | 17.79 | 3.56 | 14.23 |
| Soil-6 | NAB office Fazalabad | 26.98 | 5.4 | 21.58 |
| Soil-7 | Chaichyan | 12.88 | 2.58 | 10.3 |
| Soil-8 | Khari Shareef | 22.08 | 4.42 | 17.66 |
| Soil-9 | Nagyal | 6.75 | 1.35 | 5.4 |
| Soil-10 | Jatlaan | 38.01 | 7.6 | 30.41 |
| Soil-11 | Jordiyen | 39.25 | 7.85 | 31.4 |
| Soil-12 | Wespa Factory | 53.96 | 10.79 | 43.17 |
| Soil-13 | Kotli Road | 31.89 | 6.38 | 25.51 |
| Soil-14 | MUST-2 | 47.21 | 9.44 | 37.77 |
| Soil-15 | Khalaqabad | N.D | N.D | N.D |
| Soil-16 | Tarpa stop | 26.36 | 5.27 | 21.09 |
| Soil-17 | New city | N.D | N.D | N.D |
| Soil-18 | Kotli Road | 15.94 | 3.19 | 12.75 |
| Soil-19 | Industrial area | 28.21 | 5.64 | 22.57 |
| Soil-20 | Bank of Mangla Dam | 1.23 | 0.25 | 0.98 |
| Soil-21 | Dahola | 40.47 | 8.09 | 32.38 |
| Soil-22 | Mangla Fort & Museum | 44.15 | 8.83 | 35.32 |
| Soil-23 | Wespa Factory -2 | 35.56 | 7.11 | 28.45 |
| Soil-24 | Chaichyan-2 | 45.38 | 9.08 | 36.3 |
| Soil-25 | Khari Shareef-2 | 34.95 | 6.99 | 27.96 |
| Over all Mean value | | 25.58 | 5.12 | 20.47 |

Table 4. Annual effective dose equivalent, outdoor and indoor average annual effective dose equivalent due to ¹³⁷Cs in bricks samples used in Mirpur.

| Sample code | Location | Annual effective dose equivalent | Outdoor average annual effective dose | Indoor average annual effective dose |
|---------------------|--------------|---|--|---|
| | | E (mSvy ⁻¹) × 10 ⁻⁵ | E _{out} (mSvy ⁻¹) × 10 ⁻⁵ | E _{in} (mSvy ⁻¹) × 10 ⁻⁵ |
| B-1 | M.S Mirpur | 12.65 | 2.65 | 10 |
| B-2 | R.Y Mirpur | 12.14 | 2.43 | 9.71 |
| B-3 | M.A Mirpur | 37.87 | 7.87 | 30 |
| B-4 | A.A.P Mirpur | 4.05 | 0.81 | 3.24 |
| B-5 | A.G Mirpur | 7.36 | 1.47 | 5.89 |
| B-6 | W.Z Mirpur | 5.34 | 1.07 | 4.27 |
| Over all mean value | | 13.23 | 2.71 | 10.52 |

Above scatter graph shows a correlation between the data obtained for ¹³⁷Cs concentration with the year in which study is undertaken. A linear relationship is evident from the regression plot. From the graph a decrease in the values of ¹³⁷Cs concentration can be seen. Maximum value has been recorded by Hassan *et al.* (3) carrying his study for Charsaddah district of Pakistan in 1994. The regression equation, $y = -0.2922x + 589.48$, represents least square line drawn through the scatter points. The coefficient R² also referred as co-efficient of determinations measures fit of regression line to the data. Value obtain for R²= 0.8115 shows strong correlation between year of measurement with concentration of ¹³⁷Cs.

Here we cannot predict exactly about the source of ¹³⁷Cs in Mirpur, Azad Kashmir other than past fallout deposition from nuclear testing or reactor accident. As may be seen from figure

1 a decreasing activity concentration of ¹³⁷Cs trend can be due to no more significant reactor accident or atmospheric weapon testing have been done since major nuclear reactor accident of Chernobyl in 1986. ¹³⁷Cs activity concentration found in soil and brick samples may be attributed due to global fallout (Chernobyl fallout).

In this study, the observed ¹³⁷Cs concentrations are consistent with the world average.

¹³⁷Cs activities (for soil samples, mean value 1.39±0.17 Bq. Kg⁻¹) found for current study are consistent with values reported for other parts of Pakistan. For example the average value of activity concentration of ¹³⁷Cs in barren and cultivated soils of Pakka Anna was found as 3.6 (3.57-3.63) Bq kg⁻¹ and 4 (1.98-5.42) Bq kg⁻¹, respectively (13). For Southern part of Punjab, Pakistan, mean value of ¹³⁷Cs for soil samples

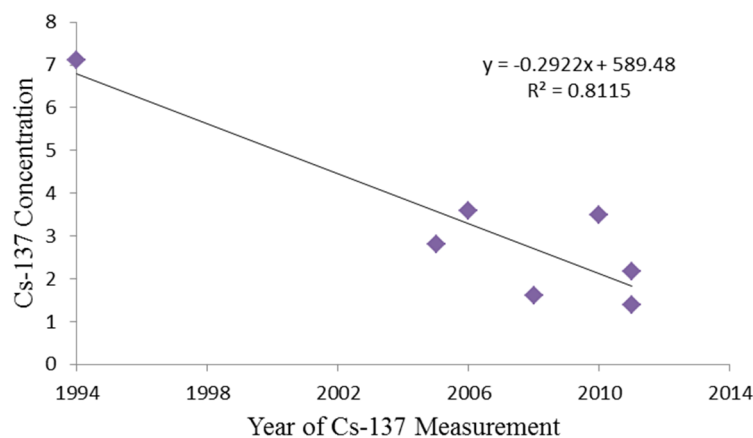


Figure 1. Correlation between the data obtained for ¹³⁷Cs concentration with the year of measurement.

was reported as 1.6 Bq. Kg⁻¹ (14) and for Mid-Rechna, Pakistan the mean values is found as 3.5 Bq. Kg⁻¹ (15). For some districts of Punjab Province Pakistan, mean value of ¹³⁷Cs was found as 2.18 Bq. Kg⁻¹ (16) and for Charsaddah mean value of ¹³⁷Cs activity is reported as 7.1±2.0 Bq. Kg⁻¹ (3).

Comparison of current study results with the data available in literature for other countries has also been made in table 5. As may be seen from the table the range of activity concentration of ¹³⁷Cs is much smaller than the values reported for Venezuela, 5 Bq. Kg⁻¹ (25), Bangladesh 7 Bq. Kg⁻¹ (26). Majorca (Spain) (10–60 Bq. Kg⁻¹) (4), Inshass, Cairo (Egypt) (1.6–19.1 Bq. Kg⁻¹) (7), Algeria (15–35 Bq. Kg⁻¹) (5), Kocaeli basin (Turkey) (2–25 Bq. Kg⁻¹) (11), Louisiana (USA) (5–58 Bq. Kg⁻¹) (11), Montenegrin coast (Yugoslavia) (1.5–28.4 Bq. Kg⁻¹) (8), Sudan (0–18.5 Bq. Kg⁻¹) (27), North-western Libya (0.9–1.7 Bq. Kg⁻¹) (9), Riyadh (Saudi Arabia) (0–2 Bq. Kg⁻¹) (10), Northern Taiwan (1.48–27 Bq. Kg⁻¹) (6), Ordu, Turkey (67.4 to 275.3 Bq kg⁻¹) (28).

The activity concentration and resulting doses due to ¹³⁷Cs exposure are too small to add

to the total radiation exposure. The values of activity concentration and the estimated dose rates are towards the lower side when compared with that of other countries and standards set by different world organizations like ICRP and in UNSCEAR 2000 report (1).

CONCLUSIONS

Based on the obtained data, it is concluded that

- (i) Activity concentration of ¹³⁷Cs in soil samples is found to be in the range from 0.076±0.071 to 2.94±0.17 Bq. Kg⁻¹ with average value of 1.39±0.17 Bq. Kg⁻¹.
- (ii) Activity concentration of ¹³⁷Cs in Brick samples is found to be in the range from 0.22±0.09 BqKg⁻¹ to 2.14±0.13 BqKg⁻¹ with average value of 1.39±0.17 Bq. Kg⁻¹.
- (iii) Outdoor, indoor and annual effective dose received from the soil samples of Mangla dam Mirpur is minimum with the values of (0.25-10.79, 0.98-43.17 and 1.23- 53.96) × 10⁻⁵ mSv.y⁻¹ respectively. The average values of outdoor, indoor and annual effective dose are

Table 5. Comparison of current results with data available in literature.

| Country | Concentration (Bq kg ⁻¹) | References |
|-----------------------------------|--------------------------------------|---------------|
| Ordu, Turkey | 67.4 - 275.3 | (28) |
| Venezuela | 5 | (25) |
| Bangladesh | 7 (3-10) | (26) |
| Majorca (Spain) | 10–60 | (4) |
| Inshass, Cairo (Egypt) | 1.6–19.1 | (7) |
| Algeria | 15–35 | (5) |
| Louisiana (USA) | 5–58 | (11) |
| Montenegrin coast (Yugoslavia) | 1.5–28.4 | (8) |
| Sudan | 0–18.5 | (27) |
| North-western Libya | 0.9–1.7 | (9) |
| Riyadh (Saudi Arabia) | 0–2 | (10) |
| Northern Taiwan | 1.48–27 | (6) |
| Punjab province (Pakistan) | 2.8±1 (1.1–5.3) | (12) |
| Pakka Anna, Pakistan | 3.6(3.57-3.63) | (13) |
| Southern part of Punjab, Pakistan | 1.6 | (14) |
| Mid-Rechna, Pakistan | 3.5 | (15) |
| Punjab Province, Pakistan | 2.18 | (16) |
| Charsaddah, Pakistan | 7.1±2.0 | (3) |
| Mirpur Azad Kashmir | 1.39±0.17 | Present study |

found as (5.12, 20.47 and 25.58) × 10⁻⁵ mSv.y⁻¹ respectively. These measured values are relatively small when compared with the recommended annual dose rate limit of 1.0 mSv set by ICRP and action level for annual external gamma radiation dose (0.48 mSv.y⁻¹) received per head from the natural sources of radiation recommended in UNSCEAR (2000) report ⁽¹⁾.

(iv) To conclude, it is expected that ¹³⁷Cs exposure to the local population will not pose any significant health threat.

REFERENCES

1. UNSCEAR (2000) Sources and effects of ionizing radiation. United Nations, New York.
2. NCRP REPORT No. 50 (1976) Environmental Radiation Measurements Recommendations of the National council on radiation protection and measurements Issued December 27, First Reprinting February 28, 1992 National Council on Radiation Protection and Measurements 7910 WOODMONT AVENUE / Bethesda, MD 20814.
3. Hassan M Khan, Khalid K, Atta MA, Farooq J (1994) Measurement of Gamma Activity in soil samples of Charsaddah district of Pakistan Jour. *Chem Soc Pak*, **16**: 183-185.
4. Gomez E, Garcias F, Casas M, Cerda V (1997) Determination of ¹³⁷Cs and ⁹⁰Sr in Calcareous soils: Geographical distribution on the Island of Majorca. *Appl Radiat Isot*, **48**: 699-704.
5. Nouredin A, Baggoura B, Larosa J J, Vajda N (1997) Gamma and alpha emitting radionuclides in some Algerian soil samples. *Appl Radiat Isot*, **48**: 1145-1148.
6. Wang CJ, Lai SY, Wang JJ, Lin YM, (1997) Transfer of radionuclides from soil to grass in Northern Taiwan. *Appl Radiat Isot*, **48**: 301-303.
7. Higgs RH, Pimpl M (1998) Natural and man-made radioactivity in soils and plants around the research reactor of Inshass. *Appl Radiat Isot*, **49**: 1709-1712.
8. Vukotic P, Borisov G I, Kuzmic VV, Antovic N, Dapcevic S, Uvarov VV, Kulakov VM (1998) Radioactivity on the Montenegrin Coast, Yugoslavia. *J Radioanal Nucl Chem*, **235**: 151-157.
9. Shenber MA (2001) Fallout ¹³⁷Cs in soils from North Western Libya. *J Radioanal Nucl Chem*, **250**: 193-194.
10. Al-Kahtani SA, Farouk MA, Al-Zahrani AA (2001) Radioactivity levels in soil of three selected sites at and around Riyadh City. *J Radioanal Nucl Chem*, **250**: 93-95.
11. Karakelle B, Ozturk N, Kose A, Varinlioglu A, Erkol AY, Yilmaz F (2002) Natural radioactivity in soil samples of Kocaeli basin, Turkey. *J Radioanal Nucl Chem*, **254**: 649-651.
12. Tahir SNA, Jamil K, Zaidi JH, Arif M, Ahmed N, Ahmad SA (2005) Measurements of Activity Concentrations of Naturally Occurring Radionuclides in Soil Samples from Punjab Province of Pakistan and Assessment of Radiological Hazards. *Radiat Prot Dosimetry*, **113**: 421-427.
13. Tufail M, Akhtar N, Waqas W (2006) Measurement of terrestrial radiation for assessment of gamma dose from cultivated and barren saline soils of Faisalabad in Pakistan. *Radiation Measurements*, **41**: 443-451.
14. Fatima I, Zaidi JH, Arif M, Daud M, Ahmad SA, Tahir SNA (2008) Measurement of natural radioactivity and dose rate assessment of terrestrial gamma radiation in the soil of southern Punjab. *Radiat Prot Dosim*, **128**: 206-212.
15. Jabbar A, Arshed W, Bhatti AS, Ahmad SS, Rehman SU, Dilband M (2010) Measurement of soil radioactivity levels and radiation hazards assessment in mid Rechna interfluvial region, Pakistan. *J Radioanal Nucl Chem*, **283**: 371-378
16. Rahman SU, Matiullah, Malik F, Rafique M, Anwar J, Ziafat M, Jabbar A (2011) Measurement of naturally occurring fallout radioactive elements and assessment of annual effective dose in soil samples collected from four districts of the Punjab Province, Pakistan. *J Radioanal Nucl Chem*, **287**: 647-655.
17. Rafique M, Rehman H, Matiullah, Malik F, Rajput MU, Rahman SU et al. (2011) Assessment of radiological hazards due to soil and building materials used in Mirpur Azad Kashmir; Pakistan. *Iranian Journal of Radiation Research*, **9**: 77-87.
18. http://www.who.int/ionizing_radiation/en/, accessed on 30th April 2012.
19. http://en.wikipedia.org/wiki/Chernobyl_disaster, accessed on 30th April 2012.
20. <http://en.wikipedia.org/wiki/Strontium>, accessed on 30th April 2012.
21. <http://en.wikipedia.org/wiki/Caesium-137>, accessed on 30th April 2012.
22. Fredriksson L, Garner RJ, Russell RS (1966) Caesium-137. In: *Radioactivity and Human Diet*, ed. R.S. Russell. Pergamon, Oxford, 319-53.
23. Middleton LJ, (1959) Radioactive strontium and cesium in the edible parts of crop plants after foliar contamination. *International Journal of Radiation Botany*, **1**: 387-402.
24. Asha R and Surinder S (2005) Natural radioactivity levels in soil samples from some areas of Himachal Pradesh by using γ-spectrometry. *Atmospheric Environment* **39**: 6306-6314.
25. LaBrecque JJ (1994) Distribution of ¹³⁷Cs, ⁴⁰K, ²³⁸U and ²³²Th in soils from Northern Venezuela. *J Radioanal Nucl Chem*, **178**: 327-336.
26. Miah FK, Roy S, Touhiduzzaman M, Alam B (1998) Distribution of radionuclides in soil samples in and around Dhaka city. *Appl Radiat Isot*, **49**: 133-137.
27. Sam AK, Ahmed MMO, El-Khanghi FA, El-nigumi YO, Holm E (1997) Assessment of terrestrial gamma radiation in Sudan. *Radiat Prot Dosim*, **71**: 141-145.
28. Celik N, Damla N, Cevik U (2010) Gamma ray concentrations in soil and building materials in Ordu, Turkey *Radiation Effects and Defects in Solids*, **165**: 1-10.