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ASSESSMENT OF OUTDOOR RADIATION EXPOSURE LEVELS AND HUMAN HEALTH RISK IN A MAJOR SCRAP METAL MARKET IN ABUJA

[1]James, I. U[*]; [2]Onuh E; [3]Moses, I. F; [4]Ukeme U. E and [5]Vandi, J. N
[1, 3, 4, 5]Nuclear Technology Centre, Nigeria Atomic Energy Commission, Abuja,
[2]Department of Physics, Ahmadu Bello University, Zaria
***Corresponding Author Email: jamesfam2002@yahoo.com**

ABSTRACT

Background: *Scrap metal can contain sources of radiation with the associated environmental and health risks. Radioactive substances can become associated with scrap metal in various ways and if not discovered they can be incorporated into steel and non-ferrous metals through the melting process. This can cause health hazards to workers and to the public as well as environmental concerns*

Objectives: *this study aimed at assessing the outdoor radiation exposure levels and human health risk in a major scrap metal market in Abuja, FCT.*

Method: *An in-situ measurement approach was adopted using a factory calibrated Radiagem-2000 Universal Survey Meter and a handheld Global Positioning System (Garmin GPS 76S) equipment. The monitor was suspended in air at one meter above the ground level. Readings were obtained between the hours of 1200 and 1600 hours since the exposure rate meter has a maximum response to environmental radiation within these hours.*

Results: *The results showed that the average values for the outdoor exposure dose rate for the three location ranges from 0.173±0.042 µSv/h to 0.177±0.046 µSv/h with a mean of 0.176±0.045 µSv/h. These values, though, slightly higher than the standard background radiation of 0.133 µSv/h,are below the ICRP maximum permissible limit of 0.57 µSv/h. The results also show that the AEDE values are lower than the ICRP recommended limits of 1.0 mSv/y for the public and 20 mSv/y for occupationally exposed workers. The ELCR ranges from 0.5926 x 10^{-3} to 0.6049 x 10^{-3} with a mean of 0.6008 x 10^{-3} which is 2.1 times higher than the world's average. The dosage to organs received shows that the testes have the highest dose while the liver has the lowest dose. The result of the dose to the organs showed that all the values are below the international tolerable limits.*

Conclusion: *Generally, The radiological assessment shows that the study area does not constitute any immediate radiological health effect on the workers and the general public due to radiation exposure rate.*

Keywords: Scrap metals, radioactive substance, in-situ, health risk

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INTRODUCTION

The current study is hinged on the recommendation of the International Commission on Radiological Protection, ICRP 103 (2007). This recommendation states that "The likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should be kept **A**s **L**ow **A**s **R**easonably **A**chievable (**ALARA**), taking into account economic and societal factors. Also the International Basic Safety Standards (**BSS**) states that "Radiation sources and installations should be provided with the best available protection and safety measures under the prevailing circumstances, so that the magnitudes and likelihood of exposures and the numbers of individuals exposed be as low as reasonably achievable, economic and social factors being taken into account, and the doses they deliver and the risk they entail be constrained" (IAEA, Safety Series 115. 1996).

Radioactive sources are used in a wide variety of applications in medicine, industry and research for societal benefits. These applications involve use of both sealed and unsealed sources. Radioactivity in such sources varies from a few kBq (μCi) to hundreds of TBq (thousands of curies) ICCMRM [2009). The national regulatory bodies in each country control the use of such radioactive sources. A lost source accident occurs when a radioactive object is lost or stolen. Such objects may appear in the scrap metal industry if people mistake them for harmless bits of metal (UNECE, 2006). It has been observed that in spite of regulatory control there are incidents of theft, loss or abandoned radioactive sources worldwide. These lost or stolen sources sometimes get into the metal scrap used in metal recycling industry and ultimately end up as a consumer product with radioactive contamination. Incidents related to the export of contaminated steel products such as steel handle doors, manhole covers, steel tension bars, copper coated steel grounding rods, steel wires, nails and metal straps used for packaging, metal fittings used in hand bags etc. have been reported (ICCMRM 2009).

Scrap metal can contain sources of radiation with the associated environmental and health risks. Higher levels of radiation are possible and may stem from losses, accidents or the inadvertent disposal of radioactive material (Lenka and Peter, 2010). Radioactive metal scrap may also come from military applications (such as depleted uranium), industrial and research irradiator activities, teletherapy, industrial radiography, discarded medical equipment, gauges, logging, and pipes from the potash industry, building or storage material from nuclear power plants (particularly nickel scrap) or trace amounts found elsewhere, such as Americium (Am-241), found in smoke detectors(OSHA, 2008). Exposure to radiation from radioactive sources mixed with metal scrap can be significant, even injurious.

The detection of, and the response to, radioactive scrap metal is complicated by the fact that radioactive substances are ubiquitous in nature and, specifically, that metal ores contain radioactive elements. When low levels of radionuclides are detected in scrap metal it is sometimes difficult to determine whether the radionuclides are naturally occurring or have been added through human activities. The frequency at which radioactive scrap metal is detected may be expected to continue to rise with the ever-increasing use of scrap to produce processed materials, the wider application of radiation monitoring procedures and the ever-increasing effectiveness of radiation detection equipment (UNECE, 2006).

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Several measures have been aimed at detecting radioactive scrap metal at the earliest possible stage in the recycling chain, but its detection is not an easy task. Even with the most sensitive and sophisticated equipment, radioactive scrap metal may be undetected and be introduced into the recycling process. Radioactive scrap metal is an issue in both developed and developing countries, but the developing countries are generally less well equipped and have a lesser capacity for dealing with the problem. This research aims at assessing the outdoor radiation exposure level and human health risk in a major scrap metal market in Abuja, Nigeria.

MATERIALS AND METHODS

2.1 Study Area

Abuja, Nigeria's capital city is located in the middle of the country. The Federal Capital Territory has a land area of 8,000 square kilometers, which is two and half times the size of Lagos, the former capital of Nigeria. The FCT is bounded on the north by Kaduna State, on the west by Niger State, on the east and south-east by Nasarawa State, and on the south-west by Kogi State. Abuja lies at latitude 9º4´0´´N and Longitude 7º29´0´´E. The FCT is made up of six (6) area councils-Abaji, Abuja Municipal, Bwari, Gwagwalada, Kuje and Kwali.

The area under investigation is Dei Dei International Market which houses the International Building Materials market located in Abuja Municipal area council. The International Building Materials market is a very large market by all standards. A lot of business activities are carried out in the market. The scrap metal market is a section of the International Building Materials market. The scrap metal market is divided into three (3) sections; the Automobile/Heavy Duty Equipment scrap (**Site A**), Building Materials scrap (**Site B**) and Medical/Industrial scraps (**Site C**).

2.2 Instrumentation

An in-situ approach of background radiation measurement was adopted and preferred to enable samples maintain their original environmental characteristics. A portable Dose rate meter, Radiagem 2000 and a Geographical Positioning System (GPS) Garmin 76S were used for the measurement. The Radiagem 2000 portable Dose rate Meter is an excellent, portable multipurpose radiation meter for a wide range of applications. It is a survey meter that includes an energy-compensated Geiger-Muller tube that measures the dose equivalent. It is especially designed for situations where accurate measurements at low dose rate levels are of importance. The assessment was achieved using a factory calibrated Radiagem 2000.Portable survey meter (SN: 4423, Canberra, France). The monitor was suspended in air at one meter above the ground level. Readings were obtained between the hours of 1200 and 1600 hours since the exposure rate meter has a maximum response to environmental radiation within these hours as recommended (NCRP, 1976; Oyeyinka et al, 2012). Three readings were taken at each outdoor location and the mean values were recorded.

2.3 Radiation Health Risk Assessment

Different known radiation health hazard indices analysis is been use in radiation studies to arrive at a better and safer conclusion on the health status of a radiated or irradiated person and

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environment (Avwiri *et al*., 2012). The measured results (raw data) obtained from the study area were analyzed and compared with regulatory standards. For effective computation of the experimental data from Exposure rate (in µSv/hr) to Absorbed Dose (in nGy/hr), to calculate the Annual Effective Dose Equivalent (in mSv/yr), Excess Lifetime Cancer Risk (in mSv/y), Effective dose rate to the organ (Dorgan) (in mSv/y) the following conversion formula was used;

To Convert from Exposure rate (in µSv/hr) to Absorbed Dose (in nGy/hr)

$$1\ \mu Sv/hr = 10^{-3} nGy/hr \tag{1}$$

To Calculate the Annual Effective Dose Equivalent (in mSv/y)

$$E\ (mSv/y) = D\ (nGy/hr) \times T \times OF \times CC \times 10^{-6} \tag{2}$$

Where,

E = Annual Effective Dose Equivalent (mSv/y)

D = Absorbed Dose (nGy/hr)

T = Working Hours per Year = 8760 h/y

OF = Occupancy Factor = 0.2 (Outdoor)

CC = Conversion Coefficient = 0.7 Sv/Gy

To Calculate the Excess Lifetime Cancer Risk (in mSv/y)

$$ELCR = AEDE \times LE \times RF \tag{3}$$

Where,

AEDE = Annual Effective Dose Equivalent

LE = Life Expectancy = 55.8 years (www.worldometer.info/Nigeria)

RF = Risk Factor = 0.05 Sv^{-1}. For stochastic effects ICRP 60 recommend RF = 0.05 for the public (Taskin et al., 2009).

To calculate the Effective dose rate to the organ (D_{organ})

$$D_{organ}\ (mSv/y) = AEDE \times F \tag{4}$$

Where F is the conversion factor of organ dose from air dose.

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RESULTS AND DISCUSSION

Exposure Dose Rate: The outdoor data obtained from the in-situ measurement for the three locations within the study area were processed for mean value by adding up all the raw data obtained for each location and divided by the number of data taken to get the mean value for the location. The result is as shown in Tables 1-3. A summary of the Outdoor Exposure Dose Rate and calculated hazard Indices for the three locations (Table 4) shows that the outdoor exposure dose rate ranges from 0.173±0.042µSv/h to 0.177±0.046 µSv/h with a mean of 0.176±0.045 µSv/h. These values, though, slightly higher than the standard background radiation of 0.133 µSv/h, but are below the ICRP maximum permissible limit of 0.57 µSv/h.

Annual Effective Dose Equivalent (AEDE): Radiation absorbed dose is a measure of the amount of energy absorbed per unit mass. It quantifies the radiation energy that might be absorbed by a potentially exposed individual as a result of a specific exposure. For whole body exposure, the quantity effective dose equivalent is used to measure the whole body absorbed dose. The annual effective dose equivalent (AEDE) is used in radiation assessment and protection to quantify the whole body absorbed dose per year. The AEDE for the three locations is shown in (Tables 1-3). A summary of the AEDE (Table 4) shows that the outdoor AEDE ranges from 0.2124±0.0512 mSv/y to 0.2168±0.0572 mSv/y with a mean of 0.2153±0.0552 mSv/y. These values are lower than the ICRP recommended limits of 1.0 mSv/y for the public and 20 mSv/y for occupationally exposed workers. This indicates that the studied areas are in good agreement with permissible limit and do not constitute any immediate radiological health effect on the workers and the general public due to background ionizing radiation (BIR) exposure. However, periodic assessment of activity concentration of natural radionuclides and BIR levels in the study area should be carried out in order to ensure that exposure to radiation within the areas is kept to as low as reasonably achievable.

Excess Lifetime Cancer Risk (ELCR): The excess lifetime cancer risk is used in radiation protection assessment to predict the probability of an individual developing cancer over his lifetime due to low radiation dose exposure, if it will occur at all. The ELCR for the three locations is shown in shown in (Tables 1-3). A summary of the ELCR (Table 4) showsthat the Outdoor ELCR ranges from $0.5926 \times 10^{-3}$to 0.6049×10^{-3} with a mean of 0.6008×10^{-3} which is 2.1 times higher than the world's average of 0.29×10^{-3} (Qureshi et al., 2014). These values for excess lifetime cancer risk indicate that the probability of cancer development by workers and residents who wish to spend all their life time in the area is very low. The ELCR values reported in this study are lower than those reported for industrial areas of Warri and Effurun, Delta State, Nigeria (Agbalagba. 2017), and also lower than those for the salt lake environment of Okposi Okwu and Uburu of Ebonyi State, Nigeria (Avwiri et al., 2016). It is slightly higher than the values from some scrap metal dumpsites in Nasarawa state (Kerinja et al.,2020), Emene Industrial Layout, Enugu (Ugbede and Benson, 2018), Unity park, Uyo, Akwa Ibom state, Nigeria (Etuk et al., 2017) and river sediments from Northern Pakistan (Qureshi et al, 2014).

Effective dose rate (D_{organ}) to different body organs and tissues: The effective dose to organs (D_{organ}) estimates the amount of radiation dose intake to various body organs and tissues. The result of the effective dose rate delivered to the different organs in the three locations is presented in Figure 1, with the F values for Lungs, Ovaries, Bone marrow, Testes, Kidneys,

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Liver and Whole body given as 0.64, 0.58,0.69, 0.82, 0.62, 0.46 and 0.68 respectively**,** obtained from ICRP [1996]. The estimated average D_{organ} values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body due to radiation exposure and inhalation in the three location (sites A-C) are 0.026, 0.024,0.028, 0.033, 0.025, 0.019, 0.028 respectively. These results are all below the international tolerable limits of 1.0 mSv/y (Agbalagba, 2017, Ugbede and Benson, 2018) which further shows that the radiation levels do not constitute any immediate health effect on workers and residents of the study area. From the results, it is concluded that the testes and liver have highest and lowest sensitivity to radiation. The relatively higher dose to the testes and low dose intake to the liver is justifiable from food nutrient absorption rate (Zaid et al., 2010). This shows that the impact of exposure to background ionizing radiation levels in the study area contributes insignificantly to the radiation dose to these organs of the adult. Similar conclusion has also been made by Agbalagba (2017), and Ugbede and Benson, (2018).

Table 1: Measured Outdoor Exposure Dose Rate and Calculated Hazard Indices in site A

Sampling point code	Latitude	Longitude	Exposure Rate (uSv/hr)	Absorbed Dose (nG/hr)	AEDE (Outdoor) (mSv/y)	ELCR (Outdoor) $x10^{-3}$
A1	09° 06.411'N	007° 16.195'E	0.100	100	0.1226	0.3422
A2	09° 06.415'N	007° 16.192'E	0.140	140	0.1717	0.4790
A3	09° 06.420'N	007° 16.192'E	0.140	140	0.1717	0.4790
A4	09° 06.413'N	007° 16.189'E	0.100	100	0.1226	0.3422
A5	09° 06.408'N	007° 16.187'E	0.100	100	0.1226	0.3422
A6	09° 06.409'N	007° 16.182'E	0.160	160	0.1962	0.5475
A7	09° 06.413'N	007° 16.183'E	0.160	160	0.1962	0.5475
A8	09° 06.419'N	007° 16.181'E	0.130	130	0.1594	0.4448
A9	09° 06.408'N	007° 16.213'E	0.180	180	0.2208	0.6159
A10	09° 06.396'N	007° 16.215'E	0.240	240	0.2943	0.8212
A11	09° 06.401'N	007° 16.210'E	0.140	140	0.1717	0.4790
A12	09° 06.392'N	007° 16.209'E	0.160	160	0.1962	0.5475
A13	09° 06.390'N	007° 16.213'E	0.110	110	0.1349	0.3764
A14	09° 06.385'N	007° 16.213'E	0.100	100	0.1226	0.3422
A15	09° 06.382'N	007° 16.210'E	0.140	140	0.1717	0.4790
A16	09° 06.378'N	007° 16.213'E	0.110	110	0.1349	0.3764
A17	09° 06.374'N	007° 16.208'E	0.100	100	0.1226	0.3422
A18	09° 06.373'N	007° 16.214E	0.100	100	0.1226	0.3422
A19	09° 06.365'N	007° 16.214'E	0.170	170	0.2085	0.5817
A20	09° 06.362'N	007° 16.215'E	0.160	160	0.1962	0.5475
A21	09° 06.356'N	007° 16.210'E	0.240	240	0.2943	0.8212
A22	09° 06.353N	007° 16.213'E	0.160	160	0.1962	0.5475
A23	09° 06.351'N	007° 16.208'E	0.190	190	0.2330	0.6501
A24	09° 06.250'N	007° 16.205'E	0.140	140	0.1717	0.4790
A25	09° 06.339'N	007° 16.206'E	0.180	180	0.2208	0.6159
Mean±SD			**0.146±0.04**	**146±40.4**	**0.1791±0.0495**	**0.4996±0.1382**

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Table 2: Measured Outdoor Exposure Dose Rate and Calculated Hazard Indices in site B

Sampling point code	Latitude	Longitude	Exposure Rate (uSv/hr)	Absorbed Dose (nG/hr)	AEDE (Outdoor) (mSv/y)	ELCR (Outdoor) $x10^{-3}$
B1	09° 06.339'N	007° 16.214' E	0.200	200	0.2453	0.6843
B2	09° 06.338'N	007° 16.218' E	0.220	220	0.2698	0.7528
B3	09° 06.337'N	007° 16.225' E	0.140	140	0.1717	0.4790
B4	09° 06.334'N	007° 16.232' E	0.200	200	0.2453	0.6843
B5	09° 06.325'N	007° 16.230' E	0.180	180	0.2208	0.6159
B6	09° 06.324'N	007° 16.230' E	0.210	210	0.2575	0.7185
B7	09° 06.303'N	007° 16.228' E	0.180	180	0.2208	0.6159
B8	09° 06.291'N	007° 16.227' E	0.140	140	0.1717	0.4790
B9	09° 06.284'N	007° 16.221' E	0.140	140	0.1717	0.4790
B10	09° 06.271'N	007° 16.227' E	0.180	180	0.2208	0.6159
B11	09° 06.270'N	007° 16.230' E	0.200	200	0.2453	0.6843
B12	09° 06.254'N	007° 16.227' E	0.240	240	0.2943	0.8212
B13	09° 06.252'N	007° 16.230' E	0.220	220	0.2698	0.7528
B14	09° 06.241'N	007° 16.230' E	0.180	180	0.2208	0.6159
B15	09° 06.240'N	007° 16.226' E	0.180	180	0.2208	0.6159
B16	09° 06.233'N	007° 16.232' E	0.160	160	0.1962	0.5475
B17	09° 06.225'N	007° 16.228' E	0.200	200	0.2453	0.6843
B18	09° 06.215'N	007° 16.225' E	0.100	100	0.1226	0.3422
B19	09° 06.205'N	007° 16.227' E	0.200	200	0.2453	0.6843
B20	09° 06.194'N	007° 16.227' E	0.220	220	0.2698	0.7528
B21	09° 06.198'N	007° 16.214' E	0.220	220	0.2698	0.7528
B22	09° 06.201'N	007° 16.206' E	0.090	90	0.1104	0.3079
B23	09° 06.215'N	007° 16.214' E	0.080	80	0.0981	0.2737
B24	09° 06.215'N	007° 16.200' E	0.100	100	0.1226	0.3422
B25	09° 06.213'N	007° 16.199' E	0.240	240	0.2943	0.8212
Mean± SD			**0.177±0.046**	**176.8±46.7**	**0.2168±0.0572**	**0.6049±0.1597**

Table 3: Measured Outdoor Exposure Dose Rate and Calculated Hazard Indices in site C

Sampling point code	Latitude	Longitude	Exposure Rate (uSv/hr)	Absorbed Dose (nG/hr)	AEDE (Outdoor) (mSv/y)	ELCR (Outdoor) x10^{-3}
C1	09° 06.224'N	007° 16.179'E	0.170	170	0.2085	0.5817
C2	09° 06.226'N	007° 16.217'E	0.140	140	0.1717	0.4790
C3	09° 06.236'N	007° 16.242'E	0.140	140	0.1717	0.4790
C4	09° 06.242'N	007° 16.212'E	0.160	160	0.1962	0.5475
C5	09° 06.245'N	007° 16.207'E	0.140	140	0.1717	0.4790
C6	09° 06.256'N	007° 16.213'E	0.200	200	0.2453	0.6843
C7	09° 06.257'N	007° 16.210'E	0.180	180	0.2208	0.6159
C8	09° 06.265'N	007° 16.214'E	0.140	140	0.1717	0.4790
C9	09° 06.270'N	007° 16.209'E	0.220	220	0.2698	0.7528
C10	09° 06.276'N	007° 16.208'E	0.180	180	0.2208	0.6159
C11	09° 06.282'N	007° 16.210'E	0.260	260	0.3189	0.8896
C12	09° 06.280'N	007° 16.210'E	0.140	140	0.1717	0.4790
C13	09° 06.280'N	007° 16.212'E	0.130	130	0.1594	0.4448
C14	09° 06.286'N	007° 16.209'E	0.130	130	0.1594	0.4448
C15	09° 06.283'N	007° 16.201'E	0.180	180	0.2208	0.6159
C16	09° 06.346N	007° 16.209'E	0.180	180	0.2208	0.6159
C17	09° 06.352'N	007° 16.214'E	0.100	100	0.1226	0.3422
C18	09° 06.357'N	007° 16.209'E	0.120	120	0.1472	0.4106
C19	09° 06.311'N	007° 16.213'E	0.180	180	0.2208	0.6159
C20	09° 06.363'N	007° 16.207'E	0.260	260	0.3189	0.8896
C21	09° 06.396'N	007° 16.212'E	0.220	220	0.2698	0.7528
C22	09° 06.373'N	007° 16.209'E	0.160	160	0.1962	0.5475
C23	09° 06.396'N	007° 16.200'E	0.180	180	0.2208	0.6159
C24	09° 06.386'N	007° 16.193'E	0.230	230	0.2821	0.7870
C25	09° 06.381'N	007° 16.180'E	0.190	190	0.2330	0.6501
Mean±SD			**0.173±0.042**	**173.2±41.7**	**0.2124±0.0512**	**0.5926±0.1427**

Table 4: Summary of Exposure Dose Rate and Calculated Hazard Indices for the three Location

Location	Exposure Rate (uSv/hr)	Absorbed Dose (nG/hr)	AEDE (Outdoor) (mSv/y)	ELCR (Outdoor) x10^{-3}
Site A	0.177±0.046	176.8±46.7	0.2168±0.0572	0.6049±0.1597
Site B	0.177±0.046	176.8±46.7	0.2168±0.0572	0.6049±0.1597
Site C	0.173±0.042	173.2±41.7	0.2124±0.0512	0.5926±0.1427
Mean	**0.176±0.045**	**175.6±45.03**	**0.2153±0.0552**	**0.6008±0.1540**

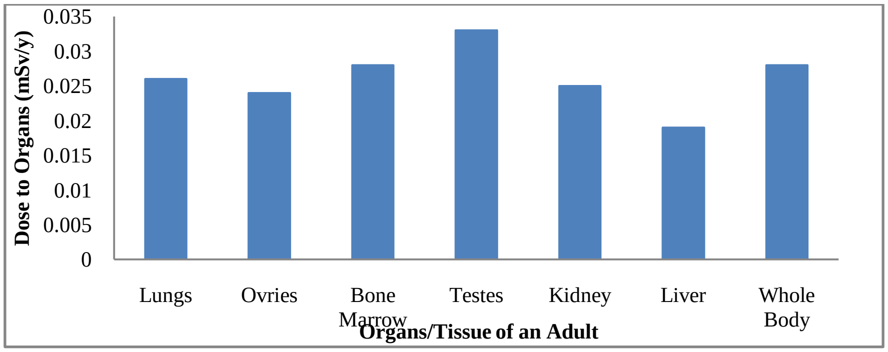

Figure 1: Effective Dose Rate to different Organs/Tissue

CONCLUSION

This study so far has assessed the radiological impact of activities in a major scrap metal market by the assessment of the outdoor radiation exposure levels and human health risk in the area.

From the study, the following conclusions are made:

1. The mean outdoor radiation exposure rate is 0.176±0.045 μSv/h, which is slightly higher than the standard background radiation of 0.133 μSv/h, but is below the ICRP maximum permissible limit of 0.57 μSv/h.

2. The AEDE ranges from 0.2124±0.0512 mSv/y to 0.2168±0.0572 mSv/y with a mean of 0.2153±0.0552 mSv/y. These values are lower than the ICRP recommended limits of 1.0 mSv/y for the public and 20 mSv/y for occupationally exposed workers. However, periodic assessment of activity concentration of natural radionuclides and background radiation exposure levels in the study area should be carried out in order to ensure that exposure to radiation within the area is kept to as low as reasonably achievable.

3. The mean excess lifetime cancer risk values suggest that the probability of cancer development by workers and residents who wish to spend all their life time in the area is not probable.

4. The effective dose to organs are all below the international tolerable limits of 1.0 mSv/y. These suggest that the impact of exposure to background ionizing radiation levels in the study area contributes insignificantly to the radiation dose to these organs of the adult.

4) Generally, The radiological assessment shows that the study area does not constitute any immediate radiological health effect on the workers and the general public due to radiation exposure rate.

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