ORIGINAL RESEARCH

EVALUATION AND ESTIMATION OF ENVIRONMENTAL BACKGROUND EXPOSURE AND ASSOCIATED RISK IN A RADIOLOGIC FACILITY

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Abstract

Background: Individuals are exposed to small amounts of ionizing radiation daily from the environment as background radiation. The study evaluated and estimated the environmental background exposure and associated risk in a radiologic facility.

Method: The study was an empirical study in a private radiodiagnostic facility in Port Harcourt. The universal coordinates of the specific locations around the facility were evaluated using a GPS machine while a survey meter Radiation Alert Inspector with a current calibration was used to obtain the background radiation exposure rate within and outside the facility. The background exposure rates were used to calculate the Annual Effective Dose Equivalent (AEDE) which was also later used to estimate the Excess Lifetime Cancer Risk (ELCR). Data obtained was collated and tabulated and then analyzed using descriptive statistics with the Statistical Package for Social Sciences (SPSS) windows version 22.30 statistical software (SPSS Inc, Chicago, Illinois, USA). The results obtained were presented in tables, charts and graphs.

Results: The mean outdoor and indoor background radiation exposure rates were 0.00296±0.003150mR/hr and 0.0046±0.0055124mR/hr respectively. The absorbed dose ranges from $8.7nGyh^{-1}$ to $130.5nGyh^{-1}$ with ELCR ranging from 4.670×10^{-5} to 70.020×10^{-5} respectively.

Conclusion: The mean indoor background radiation rate was higher than the mean outdoor background radiation exposure rate. The Excess Lifetime Cancer Risk outside ranges 4.670×10^{-5} to 70.020×10^{-5} which implies that 5 to 70 persons out of 10^5 individuals will develop some sort of ionizing radiation related diseases or cancer in their life.

Keywords: Background Exposure, Excess Lifetime Cancer Risk, Radiologic Facility, Annual Effective Dose Equivalent, Port Harcourt

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INTRODUCTION

Conventional radiography, fluoroscopy, mammography, and Computed Tomography (CT) are medical imaging modalities that provide essential support to medical diagnosis and treatment.[1,2,3] They are very valuable tools in the healthcare delivery system. These modalities (fluoroscopy, mammography, and Computed Tomography) use ionizing radiation in the form of x-rays which are produced when fast-moving high-energy electrons strike a tungsten.[3,4,5] However, radiation is also emitted to humans from the environment as cosmic rays. Ionizing radiations are radiations that ionize matter having a quantum energy that exceeds the ionization potential of atoms. The ionizing radiations have sufficient energy per quantum with the capability to remove an orbital electron from an atom. The process causes the atom to reduce to an ion which becomes highly reactive with the potential to cause harm to the environment or medium it interacts with.

Individuals are exposed to small amounts of ionizing radiation daily from the environment as background radiation. The basic sources of human exposure to radiation include the natural environment as well as artificial exposure such as the medical use of radiation.[6,7]

X-rays, gamma rays and particles such as electrons, protons, neutrons, protons and neutrons are forms of cosmic radiation with the atmosphere serving as a protective shield. Thus, the radiation dose received from cosmic rays depends on the altitude and latitude of the individual position[7]. The effect of exposure to ionizing radiation to human population has been widely documented by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR),[8] and the National Academy of Sciences Biologic Effects of Ionizing Radiation (BEIR).[9]

Exposure to natural background radiation by humans is approximately 1.1mSv annually.[6,7] Some other sources of artificial background ionizing radiation exposure are oil and gas exploration activities as well as nuclear accidents from nuclear programs.[6] The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[8] has documented four basic sources of natural radiation exposure to the public namely: cosmic, terrestrial, inhalation and by ingestion. Cosmic radiation consists of fast-moving particles present in the outer space, which could originate from diverse sources like the sun. The background natural radiation exposure rate depends on altitude as cosmic radiations increase with elevations above sea level.[7] This could explain the high background natural radiation exposure rate at North America due to their very high altitude[7]. Another source of background natural radiation resulting from the composition of the earth's crust is terrestrial radiation[10]. The elements that make up the earth's crust are a major source of natural radiation[10]. Available data shows that about 90 elements such as uranium, thorium and potassium approximating 11.9% make up the earth's crust and they are very radioactive[10,11]. Radioactive elements can be inhaled or ingested. The inhalation of radioactive gases resulting from radioactive minerals which are present in the soil and bedrock are documented as sources of exposure to natural radiation[10]. Example of such element is radon which is a colourless and odourless radioactive gas that results from uranium-238 decay.[10,11] Some radioactive minerals occur naturally in some foods and waters that are been ingested. Potassium-40 and carbon-14 are examples of naturally radioactive elements. The annual average exposure to natural sources of radiation globally is approximately 2.4mSv.

Medical radiation sources/ exposure has become the most frequent artificial source of radiation to humans following the use of radiation in medicine. Individuals are exposed during CT scan, conventional radiography, fluoroscopy, mammography or during therapeutic procedures.[1,2] Industrial sources are another source of artificial radiation exposure. This could be during sterilization of instruments, detection of pipeline leakages (non-destructive testing) and nuclear power plants (NPPs) among others. Annual effective dose equivalent is used in the assessment of radiation and to quantify the whole body absorbed dose in a year [8,12]. It is expressed in millisievert per year (mSv/yr). It is usually obtained from the background exposure rate[13]. Available data shows that out of every ten, there is the possibility that four will have a sort of cancer during their lifetime. The ionizing radiation has enough energy to damage DNA and cause cancer.[14,15] Excess Lifetime Cancer Risk (ELCR), is a very valuable tool in evaluating the population cancer risks with respect to pollutants, carcinogens, and routes of exposure. ELCR is also a measure to help in ascertaining additional cancer cases expected in a given population of one million people that is exposed to some pollutant or carcinogen concentration over a period of 70years life.

The evaluation of background radiation rate and excess lifetime cancer risk are crucial for assessing and managing radiation exposure risks. The study will provide a baseline measurement of the ambient radiation levels in a particular area. Monitoring the background radiation also helps to ensure that radiation levels in an environment are within safe limits. The study measured the background radiation which could assist in setting standardization in radiation protection. It would be a reference point for comparing radiation levels before and after events like nuclear accidents, to assess their impact. Excess Lifetime Cancer Risk would help to quantify the potential health risks associated with radiation exposure and estimate the additional probability of developing cancer due to exposure to radiation. Evaluating background radiation rates and excess lifetime cancer risks are essential for monitoring radiation levels, protecting human health, and making informed decisions regarding radiation exposure in various contexts, including environmental, industrial, and medical settings. The study therefore evaluated the environmental background exposure and associated risk in a radiologic facility.

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MATERIALS AND METHOD

The study was an empirical study is a private radiodiagnostic facility having computed tomography, conventional radiography and mammography services in Port Harcourt. The radiation exposure rate of the facility was evaluated using a well calibrated Radiation Alert Inspector machine (Inspector Model with serial number 34712 manufactured in 2018) and a Global Positioning System (GPS) device. The universal coordinates of the specific locations around the facility were evaluated using Garmin handheld GPS machine with model Etrex 32x machined manufactured 2016. The coordinates of the location obtained were documented at each point around the facility.

A survey meter Radiation Alert Inspector with a current calibration from the National Institute of Radiation Protection and Research (NIRPR) was used to obtain the background radiation exposure rate of each of the location. The measurements were taken within and outside the facility. The background exposure rates within (indoor) and outside (outdoor) the facility were calculated using both equation 1 and 2.[15,16]

$$1\mu Rh^{-1} = 8.7\eta Gyh^{-1} = \frac{8.7\times10^{-3}}{\left(1/_{8760y}\right)}\mu Gyy^{-1} \quad 1$$

$$1mRh^{-1} = 8.7\eta Gyh^{-1} \times 10^{3} = 8700\eta Gyh^{-1} \quad 2$$

The annual effective dose equivalent was obtained from the background exposure rate in milliroentgen per hour (mR/hr). The annual effective dose equivalent in millisievert per year (mSv/yr) was calculated using the relationship in equation 3 and 4 for outdoor and indoor exposure rates.[16]

$$AEDE\ (Outdoor)\ Sv/y = AD\ (\eta Gy/h) \times 8760h\ \times 0.7Sv/Gy \times 0.25 \times 10^{-3} \quad 3$$

$$AEDE\ (Indoor)\ Sv/y = AD\ (\eta Gy/h) \times 8760h\ \times 0.7Sv/Gy \times 0.8 \times 10^{-3} \quad 4$$

Excess Lifetime Cancer Risk (ELCR): The Excess Lifetime Cancer Risk (ELCR) was calculated from the Annual Effective Dose Equivalent (AEDE) using equation 5[17].

$$ELCR = AEDE \times DL \times RF \quad 5$$

A risk factor (RF) of 0.05 was used which the risk factor used for low dose background radiations according to ICRP 60 recommendation that could cause stochastic radiation effects following public exposure.[15]

Method of Data Analysis: A descriptive method was used to analyse the data that was obtained from the study. All other variables obtained from the study was collated and also documented into tabulated data sheet and then analyzed in accordance with the study objectives to obtain the mean, range and standard deviation using Statistical Package for Social Sciences (SPSS) windows version 22.30 statistical software (SPSS Inc, Chicago, Illionois, USA).

RESULTS

Table I illustrates the background exposure rates outdoor the facility. The table also shows the absorbed dose rates, the Annual Effective Dose Equivalent (AEDE) and the Excess Lifetime Cancer Risk (ELCR) from the background exposure rate outside the radiation area (outdoor). The result obtained shows that the outdoor background exposure rates ranged from 0.0010mR/hr to 0.0150mR/hr with a maximum of 0.0150mR/hr as shown on table I. The mean outdoor background radiation exposure rate (mean ± standard deviation) was 0.00296±0.003150mR/hr.

The absorbed dose from the background exposure ranges from $8.7nGyh^{-1}$ to $130.5nGyh^{-1}$. The maximum absorbed dose was higher than the mean global outdoor terrestrial gamma absorbed dose rate of ($54nGyh^{-1}$). The Annual Effective Dose Equivalent (AEDE) ranged from 0.133µSv/y to 1.667µSv/y while the Excess Lifetime Cancer Risk (ELCR) from the background exposure rate outside the facilities ranges 4.670×10^{-5} to 70.020×10^{-5}.

Tables II demonstrate the indoor environmental background exposure rates. The table also shows the absorbed dose from the background exposure, the Annual Effective Dose Equivalent (AEDE) and the Excess Lifetime Cancer Risk (ELCR) from the background exposure rate within the facility. The maximum indoor background radiation exposure rate value was 0.0250mR/hr with a mean indoor background radiation rate of 0.0046±0.0055124mR/hr (table II). The mean indoor background exposure rate was higher than the mean outdoor background radiation exposure rate (0.002964±0.0031502mR/hr).

Table III compares the mean outdoor background exposure rate with values obtained from other communities in other parts of Nigeria. The mean outdoor background exposure rate obtained from the Present Study was 0.003±0.003, which was lower than the values obtained from similar studies in Nigeria.

Table I. Outdoor background exposure rate, and AEDE associated risk

SN	Geographical coordinates	OUTDOOR (mR/hr)	ABS $nGyh^{-1}$	AEDE (μSv/y)	ELCR X 10^{-5}
1.	N4º47'11.98176'' E7º2'14.64972"	0.0020	17.4	0.267	9.334
2.	N4º47'11.98178'' E7º2'14.6498"	0.0031	26.97	0.413	14.471
3.	N4º47'12.19956'' E7º2'14.271"	0.0032	27.84	0.427	14.935
4.	N4º47'12.1996'' E7º2'14.273"	0.0021	18.27	0.280	9.803
5.	N4º47'12.33384'' E7º2'14.77572"	0.0026	22.62	0.347	12.137
6.	N4º47'12.3339'' E7º2'14.77573"	0.0018	15.66	0.240	8.402
7.	N4º47'12.35364'' E7º2'14.91"	0.0025	21.75	0.333	11.670
8.	N4º47'12.35374'' E7º2'14.913"	0.0110	95.7	1.467	51.348
9.	N4º47'12.17616'' E7º2'15.1008"	0.0023	20.01	0.307	10.736
10.	N4º47'12.17626'' E7º2'15.1111"	0.0013	11.31	0.173	6.068
11.	N4º47'12.156'' E7º2'15.15156"	0.0020	17.4	0.267	9.336
12.	N4º47'12.166'' E7º2'15.15167"	0.0012	10.44	0.160	5.602
13.	N4º47'11.88816'' E7º2'15.2124"	0.0022	19.14	0.293	10.270
14.	N4º47'11.8882'' E7º2'15.213"	0.0038	33.06	0.507	17.738
15.	N4º47'11.84964'' E7º2'15.2754"	0.0150	130.5	2.001	70.020
16.	N4º47'11.8497'' E7º2'15.2764"	0.0010	8.7	0.133	4.670
17.	N4º47'11.85'' E7º2'15.27612"	0.0024	20.88	0.320	11.203
18.	N4º47'11.862'' E7º2'15.27622"	0.0016	13.92	0.213	7.469
19.	N4º47'11.7718'' E7º2'15.06265"	0.0012	10.44	0.160	5.602
20.	N4º47'11.77121'' E7º2'15.06264"	0.0021	18.27	0.280	9.803
21.	N4º47'11.76623'' E7º2'15.04788"	0.0023	20.01	0.307	10.736
22.	N4º47'11.76625'' E7º2'15.04788"	0.0019	16.53	0.253	8.870
23.	N4º47'12.05422'' E7º2'14.64612"	0.0015	13.05	0.200	7.002
24.	N4º47'12.05523' E7º2'14.64632"	0.0012	10.44	0.160	5.602
25.	N4º47'12.03073'' E7º2'14.62669"	0.0028	24.36	0.373	13.070

Absorbed dose (ABS); Annual Effective Dose Equivalent (AEDE); Excess Lifetime Cancer Risk (ELCR)

Table II. Indoor background exposure rate, and AEDE with associated risk

	INDOOR (mR/hr)	ABS $nGyh^{-1}$	AEDE (µSv/y)	ELCR X 10^{-5}
1	0.0020	17.4	85.3574	29.8751
2	0.0031	26.97	132.304	46.3064
3	0.0032	27.84	136.572	47.8002
4	0.0021	18.27	89.6253	31.3689
5	0.0026	22.62	110.965	38.8376
6	0.0018	15.66	76.8217	26.8876
7	0.0025	21.75	106.697	37.3439
8	0.0110	95.7	469.466	164.3131
9	0.0023	20.01	98.1611	34.3564
10	0.0013	11.31	55.4823	19.4188
11	0.0020	17.4	85.3574	29.8751
12	0.0012	10.44	51.2145	17.9251
13	0.0022	19.14	93.8932	32.8626
14	0.0038	33.06	162.179	56.7627
15	0.0250	217.5	1066.968	373.4388
16	0.0010	8.7	42.6787	14.9376
17	0.0024	20.88	102.429	35.8501
18	0.0016	13.92	68.286	23.9001
19	0.0112	97.44	478.002	167.3006
20	0.0021	18.27	89.6253	31.3689
21	0.0023	20.01	98.1611	34.3564
22	0.0019	16.53	81.0896	28.3813
23	0.0115	100.05	490.805	171.7818
24	0.0122	106.14	520.68	182.2381
25	0.0028	24.36	119.5	41.8251

Absorbed dose (ABS);Annual Effective Dose Equivalent (AEDE); Excess Lifetime Cancer Risk (ELCR)

Table III. Comparison of the outdoor background exposure rate with other Nigerian studies

Variables	Outdoor (mR/hr)
Facility (Present Study)	0.003±0.003
Ogulagha (Esi et al 2019)	0.0157±0.002
Yeye (Esi et al 2019)	0.0140±0.003
Burutu(Esi et al 2009)	0.0159±0.003
Opuwade	0.022±0.003
Okpare	0.023±0.005
Otujeremi	0.019±0.003

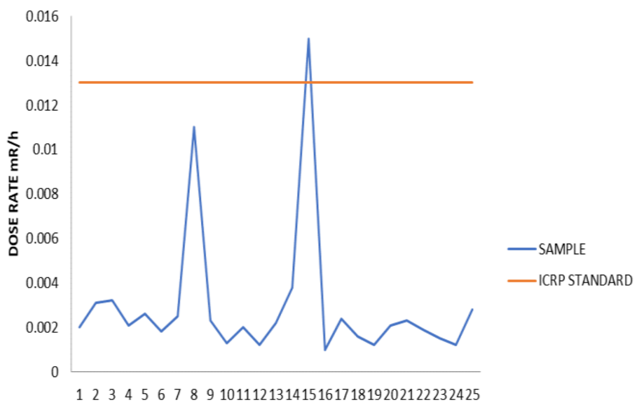

Figure 1. Comparision of background exposure rate with ICRP standard of 0.013mR/h

Comparison of the outdoor Background exposure rate with ICRP standard of 0.013mR/h was illustrated on figures 1 above. The result showed that all the values obtained from the study were below the ICRP standard of 0.013mR/h except one which measured 0.0150mR/h.

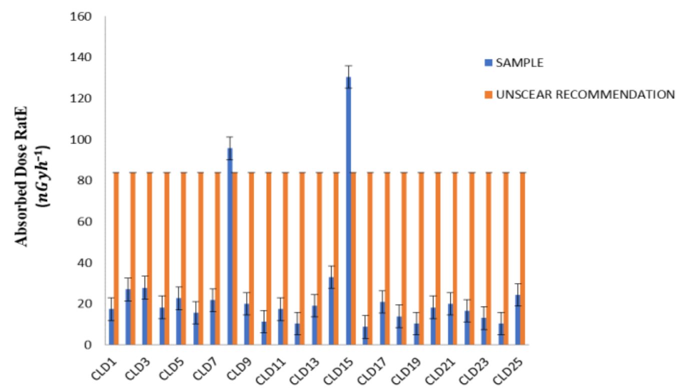

Figure 2 Comparision of absorbed dose rate with UNSCEAR recomendation $84nGyh^{-1}$

Figures 2 shows a comparison of absorbed dose rate with UNSCEAR recommendation of $84nGyh^{-1}$

Comparison of the absorbed dose rate with UNSCEAR recommendation of $84nGyh^{-1}$ shows that majority of the obtained values were below the UNSCEAR recommended values. However, two of the obtained values were higher than the UNSCEAR recommended values ($95.7nGyh^{-1}$ and$130.4nGyh^{-1}$). The mean value was also lower than the UNSCEAR recommended values

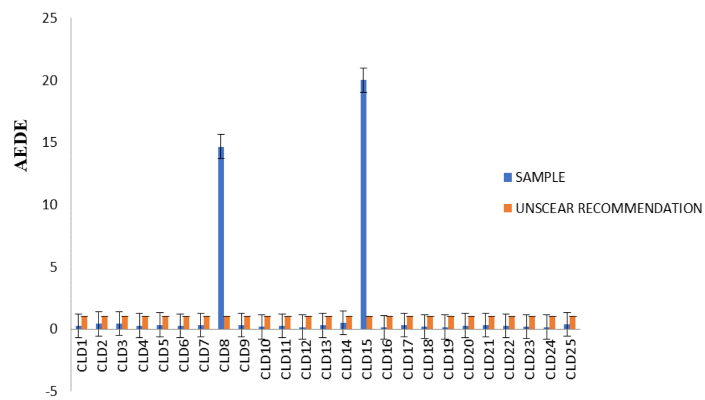

Figure 3. Comparision of AEDE with UNSCEAR recomendation

Figures 3 Comparison of AEDE with UNSCEAR recommendation of 1µSv/y. The result shows that the AEDE ranged from 0.1331µSv/y to 2.001µSv/y with over 90% of the obtained values below the UNSCEAR recommendation value.

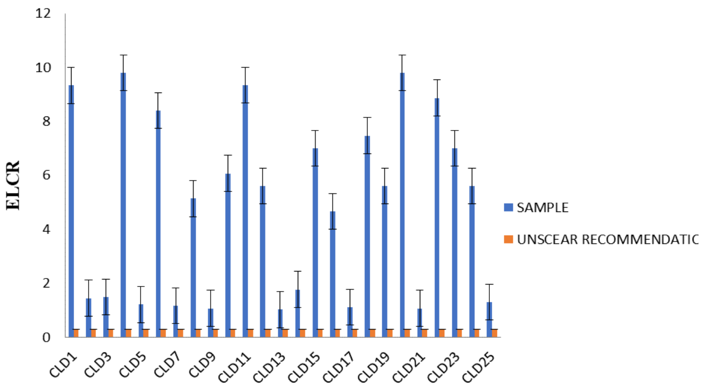

Figure 4. Comparision of ELCR with UNSCEAR recomendation

The comparison of the Excess lifetime Cancer Risk (ELCR) with UNSCEAR recommendation of 2.9×10-4 been the estimated global mean was illustrated on the figures 4 above. the values obtained in the present study were higher than the global mean Excess Lifetime Cancer Risk.

DISCUSSION

The mean outdoor background radiation exposure rate (mean ± standard deviation) was 0.00296±0.003150mR/hr which was lower than the exposure rates at Ogulagha,[19] Yeye[19] and Burutu[19] were 0.0157±0.002mR/hr, 0.0140±0.003mR/hr and 0.0159±0.003mR/hr respectfully in a study by Esi et al in 2019.[19] The low environmental background exposure rate obtained in the index study may be as a result of lower radiation emitting activities in those environments when compared to the other environments with higher radiation emitting activities like mining, crude exploitation and exploration are taking place. A study to determine the radioactivity of Aba River and estimation of radiation risk of the Populace revealed a mean exposure rate of 0.013±0.001, 0.015±0.001 and 0.014±0.001 for the Upstream, Midstream and Downstream respectively[20]. The values recorded in the study by Ononugbo et al[20] was slightly higher than the values obtained in the index study. The reason may also be attributed to the higher gamma radioactive substances in that environment where their study took place.[20] The findings of the index study was in keeping with that of Harb et al [21] which shows that the indoor dose level was higher than the outdoor exposure dose level. The higher indoor values obtained could be attributed to high amount of radiation coming out from the machine when the x-radiation-based imaging modalities are energized following the rotation of the x-ray tube.

The absorbed dose from the background exposure ranges from $8.7nGyh^{-1}$ to $130.5nGyh^{-1}$. The maximum absorbed dose in the facility was higher than the worldwide average outdoor terrestrial absorbed dose rate of $54nGyh^{-1}$ as documented in 2018[18]. The Annual Effective Dose Equivalent (AEDE) ranged from 0.133μSv/y to 1.667μSv/y. In a study to measure the outdoors and indoors level of Background Ionizing Radiation in Kwali General Hospital, Abuja, Nigeria by James *et al.* (2002) revealed that the dose equivalent range from 0.100±0.001μSv/h to 0.124±0.007μSv/h with a mean of 0.107±0.003μSv/h for indoor background exposure rate whereas the outdoor background exposure rate ranges from 0.100±0.001μSv/h to 0.122±0.003μSv/h with a mean of 0.108±0.003μSv/h.

The Excess Lifetime Cancer Risk (ELCR) from the background exposure rate outside the facility ranges 4.670×10^{-5} to 70.020×10^{-5}. This implies that approximately 70 persons out of 100,000 individuals will develop some sort of cancer related diseases. The values obtained in the present study are lower than that obtained in a study by Asere & Ajayi in 2017,[17] whereas 2.9×10^{-4} is the estimated global mean Excess lifetime cancer risk.[18,23] The values obtained were lower than the worldwide Excess lifetime cancer risk. This suggests that there is the tendency that, individuals exposed to some doses of ionising radiation may likely develop some radiation-related diseases due to long exposure. The background exposure rate in comparison with ICRP standard of 0.013[9] shows that majority of the obtained values were below the ICRP standard expect at one point where the obtained value was 0.015.

A comparison of the environmental absorbed dose rate with the UNSCEAR recommendation revealed that 92% of the obtained values were below the UNSCEAR recommended value likewise the comparison of the Annual Effective Dose equivalent (AEDE) with the UNSCEAR recommendation which also showed that majority (92%) were below the UNSCEAR recommended value. Whereas a comparison of the ELCR with the UNSCEAR recommendation showed that the values derived were higher than the UNSCEAR recommended value.

Conclusion

The mean indoor background radiation rate was higher than the mean outdoor background radiation exposure rate. Thus the Excess Lifetime Cancer Risk (ELCR) from the background exposure rate outside which ranges 4.670×10^{-5} to 70.020×10^{-5} hypothetically implies that approximately 5 to 70 persons out of 100,000 individuals will develop some form of ionizing radiation related diseases or cancer in their life time over a long duration of exposure. The study recommends the safe use of ionizing radiation.

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