

Annual Effective Dose of Gamma Ray for Radiological Workers in Radiation Measurements Labs

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Abstract: Ionizing radiation is harmful to human health so safety has been studied by many researchers. All these efforts are to minimize causes deterministic health effects of radiation. The radiation risks that arise from the use of radioactive sources on workers, in the field of radiation applications, and in the environment have to be assessed. Absorbed dose and Annual effective dose of gamma rays in the body were measured for workers in one of the laboratories dealing with gamma radioactive sources. The six gamma radioactive sources and Portable sodium iodide were used in this study. The average level of accumulated Annual effective dose value received from the used radioactive sources was extended from 0.422 to 5.56 mSv.y⁻¹ In addition to this, using risk factors indicates a very low probability of cancer injury for workers which refers to safe conditions work environment with these kinds of labs.

Keywords: Ionizing Radiation; Human Health; Environment; Annual Effective Dose Value.

Introduction

Any plan of radiation safety must emphasize reducing the exposure to radiation whether it was external or internal to the smallest limits to protect workers from ionizing radiation [1]. Scientists assume tiny doses of radiation have health effects in direct proportion to the known effects of large doses even though no health effects are noticed at low doses [2]. The main purpose of this paper is to evaluate the annual effective dose for radiological workers in one of the labs of radiation measurements, because exposure to high levels of radioactive waste may cause serious harm or death. They expose tissue to large amounts of ionizing radiation more than 2 Gy per fraction that may lead to erythema of skin within several hours. According to the ICRP report, exceeding the determined limits of exposure dose for individuals may lead to erythematic and cancerous effects within considerable probability [3]. The measurements of radiation were achieved by measuring the unit of the rate of exposure to radiation and measuring the quantity of accumulated radiation over exposure time. Many previous research and studies have been done on radiation effects, detection, and control for even small quantities. The exposure means the quantity of ionization results in dry air with a unit known as a Roentgen (R), which is equal to the radiation quantity that will release an electrical charge equivalents to 2.58×10^{-4} c/kg of air [4]. The energy deposition of radiation in all kinds of body cells represents the beginning of health effects caused by exposure to radiation. The deposition of energy from radiation arises from the interaction of radiation with material, which is subject to pass through of radiation in it [5]. The biological structure of tissues may be damaged because of bad health effects of ionizing radiation, which may happen when it is absorbed in cells of tissues [6] when the volume of air substitutes by any other material in the path of a photon beam, that means it will be subject to similar to the fluency of energy that will be passed into the volume of air. The transfer

coefficients of mass-energy for the new material will not be equivalent to air. Knowing that the mass absorption coefficient is a function of Z number and E of a photon in mass Δm of a material the deposited energy can be calculated as [7].

$$\Delta E = \varphi \frac{\mu_{en}}{\rho} \cdot \Delta m \quad (1)$$

Where (μ_{en}/ρ) represents a coefficient of mass absorption and φ is the fluence of energy. The absorbed dose can be classified as an amount of energy transported to the mass element of material by radiation that causes ionization [8].

$$D = \frac{\Delta E}{\Delta m} \quad (2)$$

The absorbed dose is measured by the rad unit where 1 rad = 0.01 Joule/kilogram or Gray (Gy). Three substantial factors can evaluate the harm of ionizing radiation on living tissue, the quantity of radioactive nuclei that are available, the rate of energy that they emit how much changes are caused by the transfer of energy to the living tissue cells, which means the manner of interaction with that cells of tissue [6].

The fact of high penetrating ability of gamma rays for major materials can be controlled by using thick plates of materials with high atomic numbers (lead for example) that will make an attenuation depending on the thickness of that material, Ultimate limits for acute doses for which response actions are must be regards under any circumstances to avoid or to minimize severe deterministic and possible effects [9].

Chronic radiation syndrome is a clinical syndrome, which develops in men after whole body annual radiation exposures exceeding 0.7–1.0 Gy and cumulative doses greater than 2-3 Gy over 2-3 years. Healthy young men exposed to external gamma radiation at dose rates below 0.25 Gy.y⁻¹ and cumulative doses from 1.0 to 1.5 Gy, showed no evidence of reduced hemopoiesis. Higher annual doses of 0.25-0.5 Gy and total doses of 1.5-2.0 Gy led to cases of thrombocytopenia and unstable leucopenia, "The highest total doses of 2-9 Gy resulted in leucocyte and thrombocyte counts of 50-65% of the baseline level"[3].

Materials and Methods

Different shapes, activity and energy of the six radioactive sources were used in this study ¹⁵²Eu, ²⁴¹Am, ⁶⁰Co, ¹³⁷Cs, ¹⁹²Ir and ²²Na. Some of these sources employed to calibrate devices and measurements of researches in the laboratory. Ludlum Model 19 Micro R Meter, USA was used to measure the gamma dose rates for 5, 30 and 100 cm from the radioactive source and using the shield of the detector probe. The instrument has linear energy responses to gamma radiation between 0.08 and 1.2 MeV. It covered the most gamma ray spectrum lines emissions from radioactive materials. The instrument uses a 2.54 cm x 2.54 cm sodium iodide (NaI). The shown units were in R.h⁻¹ [10]. The exposure rate to 1R in air $\mu\text{R.h}^{-1}$ gives absorbed dose equal to 0.00786 $\mu\text{Gy.h}^{-1}$. The absorbed dose rate of radiation can be calculated in air utilizing the below transformation [4].

$$D_{\text{air}} = \frac{1.27 \text{ E}^{-6} \cdot C \cdot E}{r^2} \quad (3)$$

where C is the activity of gamma source, E is photon energy per disintegration and r represents the distance from the source.

For any other material one can measure absorbed dose by employing the following equation [7].

$$D_{\text{Medium}} = D_{\text{Air}} \frac{\mu_m (\text{Medium})}{\mu_m (\text{Air})} \quad (4)$$

where μ_m represents the coefficient of mass absorption which is :

$$\mu_m = \frac{\mu}{\rho} \quad (5)$$

where ρ , μ are the density and the coefficient of linear absorbed of material, respectively.

Annual Effective Dose Equivalent (AEDE).

In order to evaluate the annual effective dose, the requirement of the conversion coefficient from absorbed dose in air to effective dose and the indoor occupancy factor must be taken into account. Using the dose rate data obtained from the concentration values of used radionuclides in lab, the United Nations Scientific Committee Effects of Atomic Radiation (UNSCEAR) report[11] used 0.7 Sv.Gy.y^{-1} for the conversion coefficient from absorbed dose in air to effective dose received by adults. The annual effective doses were calculated by the following formula:

$$\text{AEDE (mSv.y}^{-1}\text{)} = D(\text{nGy.h}^{-1}\text{)} * 2000\text{h} * 0.7(\text{Sv.Gy.y}^{-1}\text{)} * 10^{-6} \text{ (6)}$$

where D is the absorbed dose rates, 2000 h represents the hours of radiological workers and 10^{-6} is a conversion factor from Nano to milli units.

Results and Discussion

In this paper, the method has been used to evaluate the absorbed dose and Annual Effective Dose Equivalent of gamma rays in the human body. It's a direct measurement of external gamma dose rates; the measuring values were taken at 15 cm from the radioactive sources by using a portable NaI(Tl) gamma detector. Table 1 indicates the external gamma dose rate ranges from 33 to 435 $\mu\text{R.h}^{-1}$. The values of the absorbed dose and corresponding annual effective dose were determined for radiological workers. These data illustrate that the effective dose from radioactive sources of gamma radiation in the lab was less than maximum levels, where the whole body effective dose was 20 mSv.y^{-1} averaged over defined periods of 5 years not exceeding 50 mSv in any single year according to the UNSCEAR report. Then the results for used radioactive sources indicate the safe environment of work in this lab. We can easily distinguish that doses received from sources of ionizing radiation by individuals do not exceed the applicable limit, and so that doses are maintained as low as reasonably achievable (ALARA).

Table 1 Shows the exposure rate, absorbed dose rate and, annual effective dose.

Nuclide	Exposure rate $\mu\text{R.h}^{-1}$	Annual effective dose equivalent mSv.y^{-1}	Absorbs dose $\mu\text{Gy.h}^{-1}$
^{241}Am	435	5.568	4.241
^{192}Ir	152	1.945	1.543
^{137}Cs	412	5.274	4.233
^{60}Co	170	2.176	1.673
^{22}Na	33	0.422	0.319
^{152}Eu	377	4.826	3.654
Average	-----	3.368	2.61

On the other hand, radiological workers with different duties may receive doses from other sources of radiation. In our paper, the accumulated dose per year for workers results from working with calibration radioactive sources and radioactive waste management like waste decontamination and waste characterization which produce exposure to miscellaneous quality and quantity of ionizing radiation. Data in Table 2 indicate the accumulated dose without the dose that received from calibration sources.

Table 2 Average annual dose for workers per year.

workers No.	Accumulated dose for 5 work days μSv	Accumulated Dose per hour $\mu\text{Sv.h}^{-1}$	Annual dose mSv.y^{-1}	Absorbed dose $\mu\text{Gy.h}^{-1}$
W1	16	0.4	0.8	0.3856
W2	12	0.3	0.6	0.2892
W3	17	0.425	0.85	0.4097
W4	13	0.325	0.65	0.3133

W5	26	0.65	1.3	0.6266
W6	7	0.175	0.35	0.1687
W7	37	0.925	1.85	0.8917
W8	35	0.875	1.75	0.8435
W9	11	0.275	0.55	0.2651
W10	12	0.3	0.6	0.2892
W11	16	0.4	0.8	0.3856
W12	83	2.075	4.15	2.0003
W13	50	1.25	2.5	1.205
W14	61	1.525	3.05	1.4701
AVERAGE		0.707	1.41	0.682

An individual radiological worker in concerning facility of our research receives an average effective dose level about 0.97 to 9.7 mSv.y⁻¹ from work environment gamma radiation.

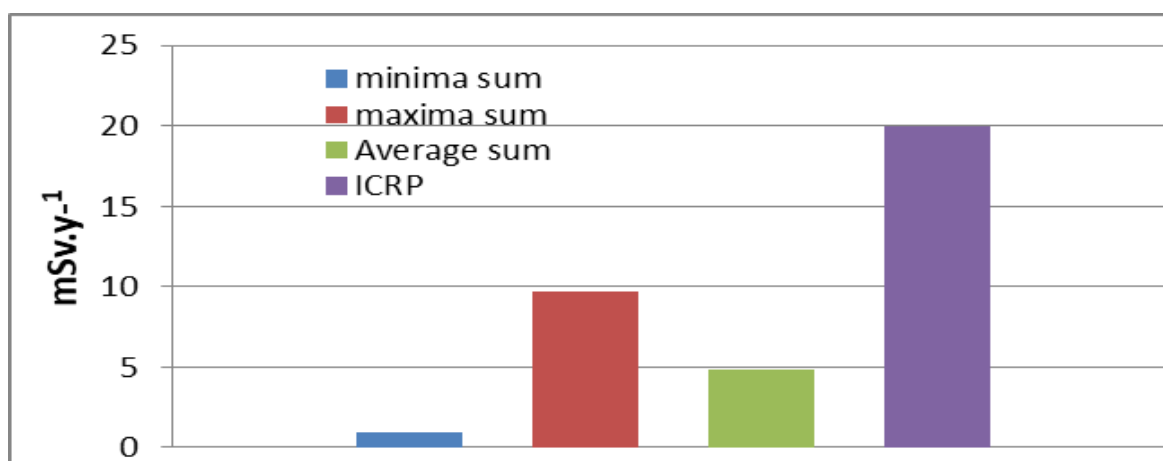


Fig. 1 Average Annual effective dose for minimum and maximum values compared with limits in UNSCEAR report.

In Fig. 1, the minima sums and maxima sums represent the summation of minimum and maximum values of annual effective doses taken from Tables 1. and 2. The average sum represents the summation of the average values of annual effective doses for both tables and the ICRP refers to the limits for worker exposure in radiation field, which equal to 20 mSv.y⁻¹ in the UNSCEAR report.

Conclusions

Comparing threshold exposure and dose for tissue with obtained data concerned with used radioactive sources in this paper one can easily distinguish that workers in the lab are within the safe limit of exposure when they deal with only calibration sources unless adding other sources of doses. Most accumulated dose results from threshold doses for tissue must be less than acceptable levels or else erythematic and cancerous effects will appear within big probability.

References

- [1] Gollnick, Daniel; "Basic Radiation Protection Technology"; 6th edition, Pacific Radiation Press; (2011).
- [2] Nuclear Energy Institute (NEI), Radiation and Human Health, Washington, D.C (2004).
- [3] The International Commission on Radiological Protection (ICRP) draft report for consultation, 20 January (2011).
- [4] James E. Turner : Atoms, Radiation, and Radiation Protection, Wiley-VCH Verlag GmbH & Co. KGaA (2007) 3rd edition.

- [5] Canadian Nuclear Safety Commission (CNSC)," Introduction to Radiation" December (2012).
- [6] Bethesda, MD: National Council on Radiation Protection and Measurements; NCRP Report No. 124 Vol. :21 (1996).
- [7] bJames E. Martin, Physics for Radiation Protection, A Handbook. WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, (2006).
- [8] Radiation Shielding and Radiological Protection, J. Kenneth Shultis · Richard E. Faw, Dan Gabriel Cacuci (ed.), Handbook of Nuclear Engineering, ,© Springer Science+Business Media LLC (2010).
- [9] E. Buglova, T. McKenna, V. Kutkov, Emergency Exposure Situations: IAEA Safety Standards and Guidance, Radioprotection –Vol. 48, no 5, pages S73 à S78– © EDP Sciences, (2013).
- [10] Ludlum Model 19 Micro R Meter, technical manual 2005.
- [11] UNSCEAR, S. Effects of Ionizing Radiation, 2000 Report to the General Assembly, with Scientific Annexes.United Nations, New York. 2000.