



Assessment of Whole-Body Occupational Radiation Exposure in a Gamma Irradiation Facility (2009-2018) in Abuja, Nigeria,

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ABSTRACT: Individuals working in both radiological and nuclear facilities are often exposed to sources of ionizing radiation resulting in some level of occupational hazards. Appropriate levels of radiation protection of workers are essential for the safe and justified use of radiation, radioactive material and nuclear energy. Occupational exposure to radiation workers in a Gamma Irradiation Facility has been analysed for a 10 year period between 2009 and 2018. The data from 2009-2018 were used to compute the average annual effective dose and the annual collective dose. The results show that the total deep dose, Hp (10), received by the radiation workers for the ten year period ranged between 10.21 mSv to 16.05 mSv with a mean of 13.97 mSv. It also showed that the average annual effective dose ranged between 0.65±0.04 mSv to 1.98±0.30 mSv with a mean of 1.51±0.42 mSv. The Collective dose ranged between 10.92 man.Sv to 33.66 man.Sv with a mean of 23.76±8.32 man.Sv. This shows that the risk due to radiation exposure of the workers is within the recommended and regulatory limits.

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There is a wide variety of situations in which people at work are exposed to ionizing radiation. The conventional definition of occupational exposure to any hazardous agent includes all exposures incurred at work, regardless of source (ILO, 1997). However, to distinguish the exposure that should be subject to control by the operating management from the exposure arising from the general radiation environment, the term 'occupational radiation exposure' is taken to mean those exposures that are incurred by workers in the course of their work and that can reasonably be regarded as the responsibility of the operating management (IAEA, 2014; ICRP, 2007). Such exposures are normally subject to regulatory control. Usually, the exposures are determined by individual monitoring, and an important objective is to provide information on the adequacy of protection measures, as they serve as key inputs to operational decision to the optimization principle. The Gamma Irradiation Facility (GIF) is one of the components of

the Nuclear Technology Centre (NTC) of the Nigeria Atomic Energy Commission, Abuja. It is a multipurpose facility for both industrial and research applications. It was acquired by the Federal Government of Nigeria to contribute to the socio-economic development of the country. It can irradiate a wide spectrum of products. For the purpose of radiation protection, the GIF is classified into different areas such as: controlled areas, supervised areas, surveillance areas and areas outside the facility. Individual dose monitoring is carried out for all radiation workers. All radiation workers are issued Thermos-Luminescent Dosimeter (TLD) badges while working in radiation protection areas. The Nigerian Nuclear Regulatory Authority (NNRA) has in place a strong regulatory framework to ensure occupational exposure for all practices involving the use of ionizing radiation is safe. Exposure is kept As Low As Reasonably Achievable (ALARA Principle) and dose limits specified for individuals does not exceed. To

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ensure the dose limits are not exceeded and in line with IAEA safety standard the NNRA (NiBIRR, 2003; IAEA, 2018) has recommended dose limits for occupational exposure of workers over the age of 18 years: an effective dose of 20 mSv per year averaged over five consecutive years (100 mSv in 5 years) and of 50 mSv in any single year; an equivalent dose to the lens of the eye of 20 mSv per year averaged over five consecutive years (100 mSv in 5 years) and of 50 mSv in any single year; an equivalent dose to the extremities (hands and feet) or to the skin of 500 mSv in a year. For occupational exposure of apprentices of 16 to 18 years of age who are being trained for employment involving radiation and for exposure of students of age 16 to 18 who use sources in the course of their studies, the dose limits recommended are: an effective dose of 6 mSv in a year; an equivalent dose to the lens of the eye of 20 mSv in a year; an equivalent dose to the extremities (hands and feet) or to the skin of 150 mSv in a year (NiBIRR, 2003; IAEA, 2018).

The type of radiological activities conducted in the Gamma Irradiation Facility; however, do not result in exposure to neutrons or uptake of radioactive material. The purpose of occupational radiation dose assessment program has been to provide facts on the capability of protection measures, considered as key input for operative assessments related to principle of optimization and also to validate compliance with relevant recommended national regulations and international standards. In this study, Whole-body was the subject of investigation and Whole-body means the entire body, or a major portion thereof, or the head and trunk, or the active blood forming organs, or the lens of the eyes or the gonads. Whole body does not refer to the skin of the whole body. Therefore, the objective of this paper is to assess the Whole-Body occupational radiation exposure in a gamma irradiation facility (2009-2018) in Abuja, Nigeria

MATERIAL AND METHOD

The monitoring of radiation workers as recommended by ICRP (1991, 2007) requires the assessment of personal dose equivalents to the whole body. Radiation workers at the gamma irradiation facility are issued TLD badges for monitoring personnel dose. The TLD badges are worn for a period of two months and are retrieved by the Radiation protection officer (RPO) and sent to an NNRA accredited Dosimetry Service Provider (DSP) for evaluation. New badges are issued to the radiation workers pending the return of the badges being sent for evaluation. For individual monitoring the operational quantity is the personal

dose equivalent, Hp(d). The personal dose equivalent, Hp(d), is the dose equivalent in ICRU tissue at depth of d mm in human body below the position where an individual dosimeter is worn. For monitoring of the Skin dose d=0.07 mm is recommended and for whole body effective dose d=10 mm (ICRP, 2007). As mentioned earlier, TLDs are used in the facility by all radiation workers for occupational dose monitoring and report issued by the DSP. The TLDs reading represent Hp(10) and Hp(0.07) values. All the radiation workers monitored wear the TLD on the trunk, in the position of likely maximum exposure (Ogundare and Balogun, 2003). Dose data of exposed workers in the Gamma Irradiation Facility for a 10 year period between 2009 and 2018 has been retrieved and analyzed.

RESULTS AND DISCUSSION

The Average Annual Effective Dose, (E): Dose limits have been set for the occupationally exposed worker for all justified practices and this is interpreted mainly in effective doses (E). Effective dose calculations was determined from occupational doses from the Gamma Irradiation Facility from (2009-2018) using the following expressions in equations 1, 2 and 3.

The effective dose is defined as a summation of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor:

$$E = \sum_T H_T W_T \quad (1)$$

Where H_T is the equivalent dose in tissue T and W_T is the tissue weighting factor for tissue.

$$H_T = \sum_R (D_{T,R} \times W_R) \quad (2)$$

Where W_R is the radiation weighting factor for radiation R and $D_{T,R}$ is the average absorbed dose in the organ or tissue T. The unit of effective dose is J/kg, with a special name Sievert (Sv)

$$\text{The mean effective dose, } E_m = \frac{\sum(H_T \times W_T)}{N} \quad (3)$$

N = number of measurement cycles in a year.

The number of monitored radiation worker is presented in Figure 1. The average annual effective dose of the workers at the GIF is presented in Figure 2. A summary of dose data for occupational radiation exposure in a Gamma Irradiation Facility (2009-2018) is presented in Table 1.

Table 1: Summary of Dose Data for Occupational Radiation Exposure in a Gamma Irradiation Facility (2009-2018)

S/N	Personnel	Summary of Dose Data for Occupational Radiation Exposure in a Gamma Irradiation Facility (2009-2018)										
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
		Deep Dose Hp(10) (mSv)	Deep Dose Hp(10) (mSv)	Deep Dose Hp(10) (mSv)	Deep Dose Hp(10) (mSv)	Deep Dose Hp(10) (mSv)	Deep Dose Hp(10) (mSv)	Deep Dose Hp(10) (mSv)	Deep Dose Hp(10) (mSv)	Deep Dose Hp(10) (mSv)	Deep Dose Hp(10) (mSv)	Deep Dose Hp(10) (mSv)
1	PER 1	1.320	1.809	2.164	0.668	2.110	1.560	1.500	1.440	0.980	1.980	15.531
2	PER 2	1.518	1.952	1.731	0.686	2.000	1.450	1.390	1.460	0.920	2.720	15.827
3	PER 3	1.606	1.939	1.871	0.638	2.130	1.690	1.370	1.640	1.070	2.100	16.054
4	PER 4	1.545	2.184	1.758	0.702	2.070	1.560	1.360	1.400	1.120	2.180	15.879
5	PER 5	1.490	1.976	1.804	0.602	2.150	1.600	1.300	1.440	1.100	2.300	15.762
6	PER 6	1.770	1.974	1.729	0.619	1.780	1.450	1.290	1.560	0.830	1.770	14.772
7	PER 7	1.670	1.760	1.967	0.655	1.940	1.610	1.160	1.560	0.980	1.960	15.262
8	PER 8	NA	1.995	1.414	0.621	2.050	1.400	1.310	1.510	1.040	1.650	12.990
9	PER 9	NA	1.686	1.904	0.673	2.020	1.670	1.380	1.720	1.010	2.040	14.103
10	PER 10	NA	1.833	1.904	0.684	1.900	1.330	1.150	2.130	0.930	1.950	13.811
11	PER 11	NA	1.514	1.699	0.637	1.910	1.560	1.330	1.440	0.990	1.740	12.820
12	PER 12	NA	1.467	1.713	0.682	2.040	1.500	1.390	1.590	1.100	2.430	13.912
13	PER 13	NA	1.621	1.819	0.631	1.760	1.510	1.290	1.460	0.990	1.880	12.961
14	PER 14	NA	1.829	1.892	0.615	1.690	1.500	1.280	1.400	0.890	1.680	12.776
15	PER 15	NA	0.988	1.631	0.657	1.830	1.790	1.430	2.270	1.060	1.890	13.546
16	PER 16	NA	NA	1.799	0.646	1.760	1.510	1.250	1.550	0.880	1.830	11.225
17	PER 17	NA	NA	0.943	0.570	1.960	1.410	1.200	1.510	1.060	1.560	10.213
	Average Annual Effective Dose	1.56±0.14	1.77±0.29	1.75±0.26	0.65±0.04	1.95±0.14	1.54±0.12	1.32±0.09	1.59±0.25	0.99±0.09	1.98±0.30	13.967±1.70

The average annual effective dose of exposed workers was computed from the available dose records for all occupationally exposed workers at the Gamma Irradiation Facility from 2009 to 2018 (10 year dose record). The average annual effective dose ranged between 0.65±0.04 mSv (2012) to 1.98±0.30 mSv (2018) with a mean of 1.51±0.42. The total deep dose (10 Years) of Monitored personnel at the GIF is presented in Figure 3. The total deep dose Hp(10) received by the radiation workers for the 10 year period ranged between 10.21 mSv (Per 17) to 16.05 mSv (Per 3) with a mean of 13.97 mSv. The average annual effective dose ranged between 0.65±0.04 mSv (2012) to 1.98±0.30 mSv (2018) with a mean of 1.51±0.42. The total deep dose (10 Years) of Monitored personnel at the GIF is presented in Figure 3. The total deep dose Hp(10) received by the radiation workers for the 10 year period ranged between 10.21 mSv (Per 17) to 16.05 mSv (Per 3) with a mean of 13.97 mSv.

The Annual Collective Dose: The annual collective effective dose, S , is given by

$$S = \sum_{j=1}^r (N_j E_{ji}) \quad (4)$$

Where E_{ji} is the annual effective dose calculated for the j^{th} reading of the i^{th} worker and N is the number of workers in a facility and r is the number of measurement cycles in a year.

A summary of the collective dose for the gamma irradiation facility is presented in table 2. The collective dose for occupationally exposed workers is shown in Figure 4. The Collective dose ranged between 10.92 man.Sv in 2009 to 33.66 man.Sv in 2018 with a mean of 23.76±8.32 man.Sv. The average dose per person ranged between 0.65 mSv to 1.98 mSv with a mean of 1.51±0.42 mSv.

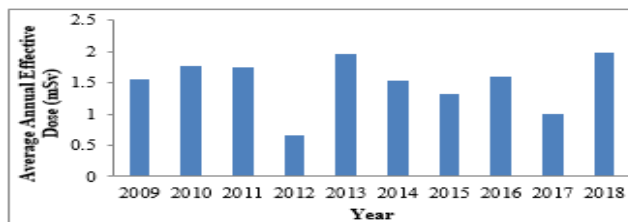


Fig 2: Average Annual Effective Dose for occupationally expose worker at the GIF

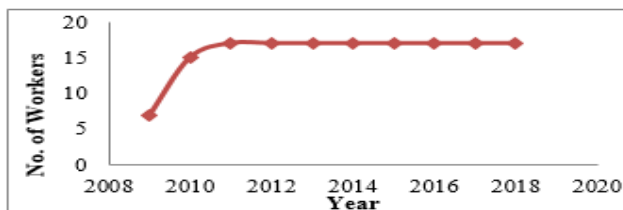


Fig 1: Number of workers occupationally exposed at the GIF

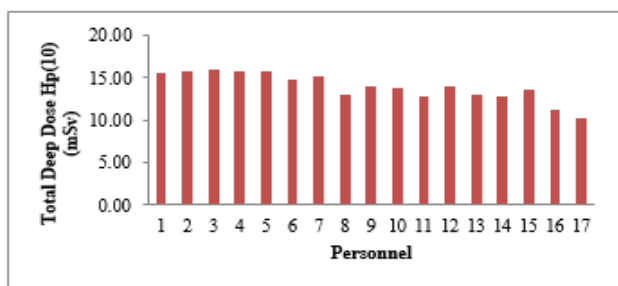


Fig 3: Total Deep Dose (10 Years) of Monitored personnel at the GIF

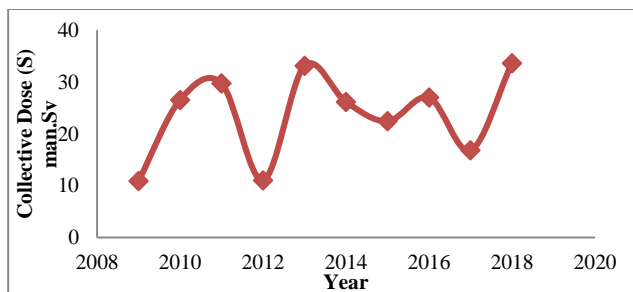


Fig 4: Collective Dose for occupationally expose workers at the GIF

Table 2: Summary of Collective Dose for the Gamma Irradiation Facility (2009-2018)

A	B	C	D	E
2009	7	1.56±0.14	10.92	1.56
2010	15	1.77±0.29	26.55	1.77
2011	17	1.75±0.26	29.75	1.75
2012	17	0.65±0.04	11.05	0.65
2013	17	1.95±0.14	33.15	1.95
2014	17	1.54±0.12	26.18	1.54
2015	17	1.32±0.09	22.44	1.32
2016	17	1.59±0.25	27.03	1.59
2017	17	0.99±0.09	16.83	0.99
2018	17	1.98±0.30	33.66	1.98

A= Year; B= No. of Monitored Workers; C = Average Annual Effective Dose (E) (mSv); D = Collective Dose (S) (Man.Sv); E = Average dose per person (mSv)

Conclusion: Occupational radiation dose to radiation workers of a Gamma Irradiation Facility using the data from the dose record from 2009 to 2018 has been analyzed. The average total dose for all

occupationally exposed workers and the average effective dose were 13.967 ± 1.70 mSv and 1.51 ± 0.42 mSv respectively. The annual collective doses in the GIF did not follow a particular trend. The overall collective dose of all occupationally exposed workers for the study period was 237.56 man.Sv

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