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Determination of Dose Rate Levels around Nuclear Installations in Ghana

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ABSTRACT

As part of a national survey to estimate ambient or background dose rate within the country, background dose rate evaluation was carried out around the only Nuclear Research Reactor, the Gamma Irradiation Facility and their environs on the premises of the Ghana Atomic Energy Commission. The work was performed using an AT6101C Spectrometer normally known as Backpack. It was identified at the end of work that the dose rate varied from 0.1410 ± 0.042μSv/h to 0.2730 ± 0.101μSv/h with an average value of 0.1979 ± 0.056 μSv/h. The work also revealed that the background dose at the Ghana Atomic Energy Commission is primarily from natural background implying that there is adequate shielding for all the radioactive sources present on its premises and there has possibly never been any significant contamination from the activities of the commission on its premises.

Keywords: *Doserate, Annual Effective Dose, Cancer Risks, Hereditary Effects, Gamma Radiation*

1. INTRODUCTION

Background

Radioactivity exists everywhere in the radioactive world. Ionizing radiation exposure may come from either natural or man-made radioactivity. As stated in Radioactivity in Nature [1], natural radioactivity is present in most materials of the Earth. Cosmic, Cosmogenic, Terrestrial External Radiations, Internal exposure, Radon, Thoron among others are examples. The major radionuclides of concern from terrestrial sources of radiation are isotopes of potassium, uranium and thorium. Radon is an important source of natural radiation produced by the decay of Radium-226 which also comes from the decay chain of uranium. Since radon is a gas, it continually seeps out of uranium-containing soils (found across the world) or bedrocks due to its high density, accumulating in poorly ventilated houses. It is often the single largest contributor to background radiation dose and is certainly the most variable from location to location.

Ionizing radiation has many practical uses in medicine, research, construction among others but also presents a health hazard if adequate safety measures are not put in place. Exposure to ionizing radiation can be chronic as with natural background exposures or acute as with accidental exposures. Studies carried out by Florou and Kritidis [2] shows that with natural background radiation, normal level is difficult to determine. This is due to variations in soil type and features in different geographic locations. It has been confirmed by Jaworowski [3] that exposure to radiation causes damage to living tissue resulting in skin burns, radiation sickness, cancer, tumors, and genetic damage at low doses and death at high doses.

The Human body cannot sense radiation, but several types of radiation measuring instruments or dosimeters have been developed to serve a wide range of purposes as mentioned by Cember [4]. Dosimeters measure an absolute dose received over a period of time. The ion-chamber is one of the portable instruments or dosimeters commonly used for individual dose assessment. Film-badge dosimeters enclose a piece of photographic film, which responds to radiation as it passes through it. Another type of dosimeter is the TLD (Thermoluminescent Dosimeter) which contain crystals that emit visible light when heated, in direct proportion to their total radiation exposure. Scintillation detectors in the form of sodium Iodide (NaI) are also used for environmental monitoring. A newly developed detector working under the scintillation principle is the backpack monitoring kit.

Justification

Long term radiation health detriments are of concern to the nuclear industry and the general public, hence environmental monitoring in high risk areas and densely human populated areas is encouraged; first to establish the baseline radiation dose which could be used to assess the impact of the introduction of practices involving nuclear or radioactive materials. GAEC promotes the peaceful use of radiation and possesses several sources on its premises including a Cs-137 source used in the Secondary Standard Dosimetry Laboratory (SSDL) of RPI, Co-60 and Ir-192 for non-destructive testing, Co-60 for radiation processing and many others at the waste management facility for temporary storage. There is also the Ghana Research Reactor-1 (GHARR-) for research and training which releases inert gases regularly into the atmosphere to avoid reactor “poisoning”. The use of radioactive sources in the past and those currently in use may or may not have influenced the background radiation dose rate. Hence this study became necessary to determine the background levels due to NORMs, type and extent of radionuclide contamination if any on the premises of GAEC and their possible radiation health hazards.

Objectives

Leon and Caplan [5] identified that naturally occurring radioactive materials (NORMs) have existed since creation and we are all immersed in naturally occurring radiations. Man or human activities can raise the levels of NORMs in a particular area, through mining and radioactive contamination. The geological formation of the earth crust could also give rise to high levels in air as radioactive gases like radon is released as a final decay product of uranium. The aim of this work is to use the backpack monitoring kit to measure the environmental radiation dose rate levels on the premises of GAEC and also identify the presence of NORMs within the stated vicinity. The data collected would be compared with acceptable levels based on recommendations of the International Commission on Radiological Protection (ICRP) [6].

This study will inform Staff and Management of GAEC of the extent of radiation exposure and their health implications and provide guidance where necessary in improving on health and safety or reducing their risk to radiation exposure.

Dose and Risk Estimation

The effective dose was calculated from the absorbed dose rate multiplied by the dose conversion factor of 0.7 Sv/Gy and a occupancy factor of 2000hrs/yr for workers.

Risk can be defined as 'the probability of an event occurring multiplied by the severity if it does occur'. Radiation workers (occupationally exposed) are normally exposed to chronic risk of somatic or hereditary damage of human tissues, thus much emphasis is always placed on the reduction of chronic risks. The nominal lifetime risk coefficients of fatal cancer recommended in the 2007 Recommendations of the ICRP are 5.5×10^{-2} Sv^{-1} for members of the public and 4.1×10^{-2} Sv^{-1} for occupationally exposed workers. For heritable effects, the detriment- adjusted nominal risk coefficient is estimated at 0.2×10^{-2} Sv^{-1} for the whole population and 0.1×10^{-2} Sv^{-1} for adult workers as stated in ICRP [6] for stochastic effects after exposure at low dose rates.

The risk to workers of GAEC was then estimated using the 2007 recommended risk coefficients in ICRP [6] report and an assumed 70 years lifetime of continuous exposure of the population to low level radiation.

According to the ICRP methodology:

- Cancer Risk = Total Annual Effective Dose (Sv) x Cancer Risk Factor (1)
- Hereditary Effects = Total Annual Effective Dose (Sv) x Hereditary Effect Factor (2)

2. MATERIALS AND METHOD

Description of Sampling Area

The Ghana Atomic Energy Commission (GAEC) representing Ghana at the International Atomic Energy Agency (IAEA) promotes the peaceful uses of radiation and regulates the utilization of nuclear and radioactive sources in Ghana. It is the home of the only research reactor in the country. The Commission is located north-west of the University of Ghana. It is about 24km from Central Accra and 6 km off the Legon-Madina road towards Kwabenya through the Haatso Township. It has a working population of about 800 comprising research scientists, technicians and technologists, administrative and support Staff.

The Commission is made up of four institutes namely, the National Nuclear Research Institute (NNRI), the Radiation Protection Institute (RPI), the Biotechnology and Nuclear Agriculture Research Institute (BNARI) and the Radiological and Medical Sciences Research Institute (RAMSRI). The data collection was carried out on the premises of GAEC taking into consideration places where there are human activities as well as radioactive sources. For the purposes of this study, GAEC was divided into nine (9) zones as shown in Table 1.

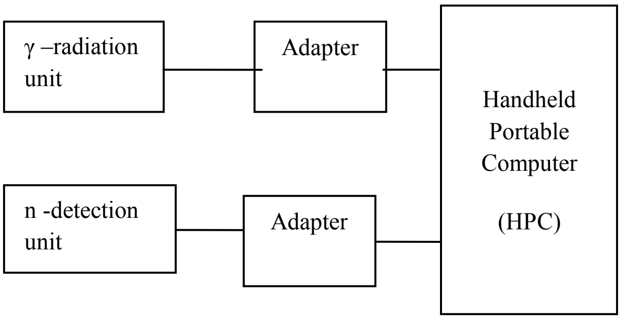
Table 1: The respective descriptions of the zones

Zone	Facility
1	BNARI Farm
2	BNARI Directorate
3	Gamma Irradiation Facility and Offices
4	Car Pack
5	Maintenance Office
6	Administration Block
7	RPI and NNRI Block
8	Chemistry Block
9	Nuclear Accelerator Building and Waste Management Centre

Instrumentation

The equipment used in this study was the AT6101C Spectrometer assembled in a backpack for convenience in carrying about whiles taking measurements. It comprises a spectrometric gamma (γ)-radiation detection unit equipped with a scintillation crystal NaI (Tl) φ 63 X 63, radiometric neutron (n)-radiation detection unit and a portable Computer (TDS Recon serial No. 9875) with an inbuilt ATAS Mobile Scanner software which calculates the dose rate. The

system incorporates a Global Positioning System (GPS) card which is connected to the HPC for identifying a measured dose rate within a given location.
Below is the connection diagram of the Spectrometer Components



Technical Characteristics

The spectrometer measures γ-radiation energy ranging from 20 – 1500 keV and 40 – 3000 keV, the energy distribution being put into channels numbered 0 – 11. It also measures dose rate within 0.01 μSv/h - 100 μSv/h. The spectrometer conversion response is calibrated based on the established γ-radiation energy values against channel numbers.

Data Collection

Considering the location of offices and facilities (laboratories) at the Commission, the area was partitioned into zones and then to smaller grids of 250cm^2. With the backpack and HPC in their positions, every cubicle was covered by walking at regular paces along the edges of the grids to give adequate time for system to respond to the background radiation. All grids within a specified area or zone were covered and the data stored.

Transfer of Data

After the data collection, the stored information was transferred from the GPS-Spectrometer to a computer and with the support of Google Earth software, the work carried out was viewed and the data analysed.

3. RESULTS AND DISCUSSION

The result from the work carried out is tabulated in Tables 2 and 3 below.

In all five hundred and fifty-four (554) measurements were taken. An average background dose rate of 0.113μSv/h was measured before the commencement of the data collection. Table 2 shows the results of the *in-situ* gamma radiation dose rates measured with the Backpack. The results of the measured dose rates varied from an average of 0.1410 ± 0.042μSv/h to 0.2730± 0.101μSv/h. This indicates that within the Commission, an average dose rate of 1.7809 ± 0.509μSv/h was estimated. Zones 1, 2 and 7 can be said to have mean dose rate values less than the set value (i.e. 0.15μSv/h) above. This is to be expected for zone 1 and 2 as no radioactive sources are present there while sources used at zone 7 are adequately shielded. The highest mean dose rate value of 0.2730 ± 0.101μSv/h was recorded at Zone 8, this could be attributed to the temporary storage measures provided for the storage of a decommissioned Cobalt-60 industrial irradiator point source under the Chemistry Block.

Table 2: Mean and Standard Deviation of dose rate values measured at the defined Zones

Zone	Mean Dose Rate* μSv/h	Number of data points
Zone 1	0.1420 ± 0.023	83
Zone 2	0.1442 ± 0.041	192
Zone 3	0.2364 ± 0.083	28
Zone 4	0.2009 ± 0.084	45
Zone 5	0.2627 ± 0.088	33
Zone 6	0.1763 ± 0.007	46
Zone 7	0.1410 ± 0.042	62
Zone 8	0.2730 ± 0.101	40
Zone 9	0.2044 ± 0.040	25
Total	**1.7809± 0.509**	**554**

*Values represented as Mean ± Standard Deviation.

Zone 5 recorded the second highest *in-situ* gamma radiation mean dose rate of 0.2627±0.088 μSv/h. There are no practices in Zone 5 that require the use of radioactive sources or radiation emitting devices. The possible explanation may be attributed to the fact that gaseous releases from the research reactor in zone 7 settles mostly at that location. The third highest *in-situ* gamma radiation mean dose rate on the GAEC premises was found in Zone 3. This could be attributed to the housing of the Cobalt-60 industrial irradiator source for irradiating food samples and certain items in that zone.

Zone 9 recorded the fourth highest dose rate of 0.2044±0.040 μSv/h on the premises due to the construction of the Waste Management Centre which houses all the radioactive materials in the country that have exhausted their useful half-life. Zone 4 recorded the fifth highest *in-situ* gamma radiation mean dose rate of 0.2009±0.084 μSv/h on GAEC premises. This is followed by Zones 6, 2, 1 and 7 in that order with 0.1763±0.007, 0.1442±0.041, 0.1420±0.023 and 0.1410±0.042 μSv/h *in-situ* gamma radiation mean dose rate respectively.

Table 3 illustrates the estimated fatality cancer risk to adult workers per year which ranges from 8.09 x 10^{-6} Sv^{-1} (Zone 7) to 15.67 x 10^{-6} Sv^{-1} (Zone 8) with the associated lifetime fatality cancer risk of 5.66 x 10^{-4} Sv^{-1} (Zone 7) to 10.97 x 10^{-4} Sv^{-1} (Zone 8). The calculated lifetime Hereditary Effect to adult workers ranged from 13.81 x 10^{-6} Sv^{-1} (Zone 7) to 26.75 x 10^{-6} Sv^{-1} (Zone 8). It could also be inferred that the annual effective dose values does compare well with the worldwide average of the annual effective of 0.48 $mSvy^{-1}$ or 480 μSvy^{-1} as stated in ICRP (2007) annals.

Table 3: Estimated Average Annual Effective Dose, Cancer Risks and Hereditary Effects of adult workers

Zone	Average annual effective dose (µSv/yr)	Fatality cancer risk to adult workers per year (x10^{-6})	Lifetime fatality cancer risk to adult workers (x10^{-4})	Severe hereditary effect in adult workers per year (x10^{-6})	Estimated lifetime hereditary effect in adult workers (x10^{-6})
Zone 1	198.87	8.15	5.71	0.20	13.92
Zone 2	201.88	8.28	5.79	0.20	14.13
Zone 3	331.00	13.57	9.50	0.33	23.17
Zone 4	281.24	11.53	8.07	0.28	19.69
Zone 5	367.82	15.08	10.56	0.37	25.75
Zone 6	246.82	10.12	7.08	0.25	17.28
Zone 7	197.35	8.09	5.66	0.20	13.81
Zone 8	382.20	15.67	10.97	0.38	26.75
Zone 9	286.16	11.73	8.21	0.29	20.03

On the average, Zone 8 recorded the highest level of risks to it's workers and it could thus be inferred that the likelihood of a worker within Zone 8 expiring from a radiation-induced cancer and passing on radiation – induced heritable effects to their offspring is high. It could also be deduced that approximately 8 persons out of 10,000 people are likely to suffer cancer related diseases from irradiation due to low background radiation exposure. In the case of lifetime hereditary effect, approximately 2 people out of 100, 000 are likely to pass on radiation-induced hereditary diseases to their offspring.

4. CONCLUSION

In conclusion, the survey carried out on ambient dose rate measurement at the Ghana Atomic Energy Commission revealed that the calculated average annual effective dose is comparable to the worldwide average annual effective dose. This explains the acceptable level of safety culture being practiced in the Commission. It could also be concluded that a smaller percentage of workers are likely to develop fatal cancer, expire from radiation-induced cancer as well as passing on adverse hereditary traits to offspring. Further studies would be required at zones 4, 5 and 6 to better explain the high dose rates recorded.

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