

The Effect of Harmattan on the Variation of Outdoor Measurement of Background Gamma Radiation with Selected Meteorological Parameters

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Abstract

This paper examines the effect of harmattan on the variation in background gamma radiation with some meteorological parameters in an open field within University of Benin, Ugbowo Campus, Benin City. An in-situ measurement of background gamma radiation was carried out with a Digital Geiger counter GCA-07 model, calibrated with Cesium-137 (^{137}Cs) with a confidence interval of $\pm 5\%$ alongside with a calibrated Digilert-50 nuclear radiation monitor. Four measurements of count per minute (cpm) and dose rate were made daily in the morning, afternoon, evening and mid-night respectively for the months of January (during harmattan) and March (no harmattan). Simultaneously, the ambient temperature and relative humidity were measured by means of an electronic thermo-hygrometer, model THC-20 manufactured by Shenzhen Tonglixing, China. The GCA-07 recorded a maximum mean exposure dose rate of 1.366 mSv/yr and 1.392 mSv/yr while the Digilert-50 recorded maximum dose rates of 1.349 mSv/yr and 1.366 mSv/yr for the months of January and March respectively. These values are lower than the internationally allowed background gamma radiation exposure standard of 5 mSv/yr and the worldwide average background radiation dose to humans which is 2.4 mSv/yr. A positive correlation ($r=0.8979_{\text{GCA-07}}$ and $r=0.8931_{\text{Digilert-50}}$) between cumulative dose and mean temperature was established for the month of March (no harmattan) and a negative correlation ($r=-0.8052_{\text{GCA-07}}$ and $r=-0.8021_{\text{Digilert-50}}$) between cumulative dose and mean relative humidity was established for the month of January (during harmattan). Attempts to obtain correlation between cumulative dose and mean temperature for the month of January (during harmattan), and mean relative humidity for the month of March (no harmattan) were unsuccessful.

Keywords: Background gamma radiation, harmattan, ambient temperature, relative humidity, count per minute, cumulative dose.

1.0 Introduction

Background radiation is the ubiquitous ionising radiation that people on the planet Earth are exposed to, including natural and artificial sources. The three major sources of environmental background radiation are cosmic radiation from the sun and galaxy and radiation from terrestrial sources due to radionuclides in the rocks and soil. Gamma photons are produced by the interaction of cosmic rays in the atmosphere and the rate at which radiation doses from cosmic rays are delivered is fairly constant at any point on the Earth surface, but varies with latitude and to a greater extent with altitude [1 – 4]. The level of radiation in the environment has been a matter of concern for rather long time and has been mapped and surveyed in some part of the World in order to gain knowledge of the variations of radioactivity [1]. As there is growing concern about exposures to natural radioactivities for human beings, this study focuses on the effect of harmattan on the variation of outdoor measurement of background gamma radiation with selected meteorological parameters since it is known [5] that environmental background radiation varies considerably due to local geological features and atmospheric conditions. Some of the meteorological parameters commonly measured are temperature (T), rainfall (R), relative humidity (RH), wind speed (WS) and atmospheric pressure (AP). In this study, only temperature and relative humidity were measured due to non availability of equipment for now to measure the other two parameters (rainfall and atmospheric pressure) and the fact that during the period of this study, there was no serious rain. However, these parameters will be investigated in future studies.

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Just as ambient temperature has time and space variation so also background radiation varies with time and space. However, as ambient temperature is recorded and reported across the World, on a daily basis, background gamma radiation is not so recorded and reported. Moreover, the effect of background gamma radiation is more damaging to the human body than the effect of temperature. The effects of radiation may be divided generally into two types. They include physical effects and biological effects. The physical effects include nuclear, chemical and electrical effects while the biological effects may be grouped into two general categories which are deterministic and stochastic effects. The characteristics of deterministic effects are: damage depends on absorbed dose and threshold exists. Some of these effects are cataract, erythema, infertility etc. Stochastic effects characteristics are: severity is independent of absorbed dose, threshold does not exist and probability of occurrence increases with absorbed dose with examples such as radiation induced cancer and genetic effects [6, 7].

The worldwide average natural background radiation dose to humans is about 2.4 mSv/yr. This is four times the worldwide average artificial radiation exposure, which in 2008 was put at about 0.6 mSv/yr [8]. The biggest source of natural background radiation is air borne radon, a radioactive gas that emanate from the ground. Radon and its isotopes parent radionuclides, and decay products all contribute to an average inhaled background radiation dose of 1.26 mSv/yr. Radon is unevenly distributed and varies with weather such that higher doses apply to many areas of the world, where it represent a significant health hazard. The global average human exposure to artificial radiation is 0.6 mSv/yr, primarily from medical imaging. This medical component can range much higher, with an average of 3 mSv/yr. Other human contributors include smoking, air travel, radioactive building materials, historical nuclear weapon testing, nuclear power accidents and nuclear industry operation. A typical chest x-ray delivers 0.02 mSv of effective dose [9]. A dental x-ray delivers a dose of 5-10 μ Sv [10]. Cigarette contains Polonium – 210, originating from the decay product of radon, which sticks to tobacco leaves [11]. Heavy smoking results in a radiation dose of 160 mSv/yr to localised spots at the bifurcations of segmented bronchi in the lungs from the decay of Polonium – 210. This dose is not readily comparable to the radiation protection limits, since the latter deal with whole body doses, while the dose from smoking is delivered to a very small portion of the body. Air travel causes increased exposure to cosmic radiation. The average extra dose to flight personnel is 2.19 mSv/yr [12].

Radionuclides in natural environment may get into the body unintentionally through inhalation, ingestion or absorption. Subsequently, they are deposited at various sites in the body. The human body cannot sense exposure to radiation directly except at level that are invariably lethal and therefore, it cannot provide defense against it because of the severity of this problem therefore, (acceptable) levels or safe levels of radiation exposure and consequently radiation doses (maximum permissible doses) have been set by various bodies (local, national and international) based on research findings in the field of radiation study [13 – 15]. Maximum permissible dose (MPD) for non-occupationally exposed individual is put at 1mSv/yr. At higher doses, ionising radiation is dangerous. It is therefore necessary to know the level of radiation within our living environment because of the health implications [16,17].

Harmattan is a dry and dusty north easterly trade wind which blows from the Sahara desert over the West Africa subcontinent into the Gulf of Guinea between the end of November and middle of March. It can lead to cold in some places and hot weather in others, according to the circumstances [18]. The harmattan blows during the dry season, which occurs during the lowest- sun months. On its passage over the Sahara, it picks up fine dust and sand particles (between 0.5 and 10 μ m). Harmattan season differs from winter, because it is characterized by cold, dry, dust – laden wind, and also wide fluctuations in the ambient temperatures of the day and night. Temperatures can easily be as low as 9°C all day, but sometimes in the afternoon the temperature can also soar to as high as 30°C, while the relative humidity drops under 10%. Harmattan dissipates cloud cover, prevents rainfall formation and sometimes creates big cloud of dust which can result in dust storms or sand storms. The wind can increase fire risk and cause severe crop damage. The interaction of harmattan with monsoon winds can cause tonadoes.

The air is particularly dry and desiccating when harmattan blows over a place or region. In some Countries in West Africa, the heavy amount of dust in the air during harmattan can severely limit visibility and block the sun for several days, comparable to a heavy fog [19]. During harmattan humidity can drop to as low as 10% or under, which can result in spontaneous nose bleeds for some people. Other health effects on humans may include conditions of the skin, eyes and respiratory system, including aggravation of asthma.

2.0 Materials and Method

The background gamma radiation count per minute and dose rate at the University of Benin, Ugbowo Campus were measured with the aid of two calibrated Geiger Mueller Counters (GCA-07 and Digilert-50).

The Geiger counter GCA-07 with serial number 4134 was calibrated with Cesium-137 source calibrated with an HPGe detector for which the efficiency has been established with an IAEA traceable standard, with a confidence interval of ± 5 %. This equipment was used in the measurement of the background gamma radiation in count per minute and the dose rate in μ Sv/hr. Nuclear radiation monitor, Digilert-50, was also used to measure the background gamma radiation in count per minute. An Electronic thermo-hygrometer model THC-20 was used to determine the ambient temperature and the relative humidity of the study area.

The Geiger counter GCA-07, radiation monitor digilert-50 and the electronic thermo-hygrometer THC-20 were placed on a platform 1.0 metre above the ground in the measurement area. The Geiger counter GCA-07 was set to count per minute and dose rate (in $\mu\text{Sv/hr}$) modes while the radiation monitor digilert-50, was in count per minute mode only. The electronic thermo-hygrometer THC-20 was also placed and set to the mode of temperature and relative humidity measurements. All measurements were made in the morning, afternoon, evening and mid-night respectively during the months of January (during harmattan) and March (no harmattan) 2015.

Conversion of radiation data obtained in count per minute (cpm) to dose rate was done by using the conversion factor in Eqn.(1) [20].

$$1\text{cpm} = 8.3 \times 10^{-3} \text{mSvyear}^{-1} \quad (1)$$

3.0 Results and Discussion

The results obtained in this study are presented as mean count per minute, mean dose rate, mean temperature and mean relative humidity in Tables 1 and 2 for the months of January and March respectively. Table 3 depicts the calculated cumulative doses for the two months of January and March and for the two radiation meters (GCA – 07 and Digilert – 50) employed in this study. In Table 1, the large values of the standard deviation for the mean relative humidity was occasioned by draught that occurred mostly in the afternoon during measurement and no relative humidity value was registered by the electronic thermo-hygrometer THC – 20.

It is known that Radioactivity is a stochastic process, therefore, dose rate is time independent [20, 21]. However, cumulative dose which is the total dose resulting from repeated exposures of ionizing radiation to an occupationally exposed worker to the same portion of the body, or to the whole body over a period of time can be shown to be time dependent. Now electrons, beta particles, and the like are usually grouped into a class of radiation referred to as non-penetrating emissions while x – and γ – rays are called penetrating radiations. A generic equation for the absorbed dose rate D, (rad/hr or Gy/Sec) in the target is

$$D = \frac{KA \sum_i n_i E_i \phi_i}{m} \quad (2)$$

where A is activity (μCi or MBq), n is number of radiations with energy E emitted per nuclear transition, E is energy per radiation (Mev), ϕ is fraction of energy absorbed in the target, m is the mass of target region (g or kg) and K is a proportionality constant (rad – $\text{g}/\mu\text{Ci} - \text{hr} - \text{Mev}$ or $\text{Gy} - \text{Kg}/\text{MBq} - \text{Sec} - (\text{MeV})$. In Eqn.(2), the quantity activity (nuclear transitions per unit time) causes the outcome of the Eqn.(2) to have a time dependence. In order to calculate cumulative dose, the time integral of the activity must be calculated. Regardless of the shape of the time activity curve, its integral, however obtained will have units of transitions. Therefore, the equation for cumulative dose would be

$$CD = \frac{K\bar{A} \sum_i n_i E_i \phi_i}{m} \quad (3)$$

where \bar{A} is cumulated activity. Thus cumulative dose is also time dependence as shown in Table 3 and previous studies [20]. Figures 1 – 4 are plots of cumulative dose against mean temperature and mean relative humidity during harmattan and no harmattan periods for the two radiation meters. Figures 1a and 2a show that there is no good correlation between cumulative dose and mean temperature for the month of January during harmattan while Figures 1b and 2b indicate that there is a good correlation between cumulative dose and mean temperature for the month of March (no harmattan) with positive correlation coefficient as $r = 0.8979_{\text{GCA}-07}$ and $r = 0.8931_{\text{Digilert}-50}$. Thus the effect of harmattan on the relationship between cumulative dose and temperature is to make cumulative dose to be temperature dependent. On the other hand, Figures 3a and 4a show that the effect of harmattan on the relationship between cumulative dose and relative humidity is to bring about decrease in cumulative dose as the relative humidity increases with negative correlation coefficient of $r = 0.8050_{\text{GCA}-07}$ and $r = 0.8020_{\text{Digilert}-50}$. Also Figures 3b and 4b show that there is no correlation between cumulative dose and relative humidity during the month of March (no harmattan). However, the mean dose rate of $1.3683 \pm 0.0154 \text{mSv/year}$ obtained in this study with the two radiation meters and for the period of study is far lower than the internationally set standard of 5mSv/year [22].

4.0 Conclusion

In this study a positive correlation was established between cumulative dose and temperature for the month of March (no harmattan) and a negative correlation between cumulative dose and relative humidity was established for the month of January (during harmattan). Physically, the positive correlation during the month of March (no harmattan) implies there is temperature dependence of cumulative dose as increase in temperature leads to an increase in cumulative dose. On the other hand, the negative correlation between cumulative dose and relative humidity for the month of January (during harmattan) suggests a decrease in cumulative dose as relative humidity increases. Attempts to obtain correlation between cumulative dose and temperature for the month of January (during harmattan), and relative humidity for the month of March (no harmattan) were unsuccessful, as the relationships between cumulative dose and temperature (during harmattan) and relative humidity (no harmattan) can best be described as stochastic.

Table 1: Meancount per minute (cpm), dose rate, mean temperature and mean relative humidity measurements using GCA-07 and Digilert-50 for the month of January (during harmattan)

Time (Minutes)	GCA-07		DIGILERT-50		Mean Temperature (°C)(±SD)	Mean Relative Humidity (%) (±SD)
	Mean cpm (±SD)	Dose Rate (µSv/hr)(±SD)	Mean cpm(±SD)	Dose Rate (µSv/hr) (±SD)		
5.00	17.85±2.61	0.148±0.0038	16.50±3.70	0.137±0.0021	23.92±3.35	36.00±4.01
10.00	18.67±4.40	0.155±0.0049	17.00±3.75	0.141±0.0028	23.63±4.50	31.83±13.19
15.00	17.94±4.51	0.149±0.0038	16.92±2.79	0.140±0.0021	23.50±5.27	32.25±14.59
20.00	17.82±4.06	0.148±0.0038	17.67±2.73	0.147±0.0038	23.49±5.86	32.00±14.81
25.00	18.24±3.45	0.151±0.0015	17.58±2.52	0.146±0.0038	23.32±6.34	32.50±15.43
30.00	17.28±3.39	0.143±0.0040	16.92±1.97	0.140±0.0038	21.61±8.26	32.33±15.73
35.00	17.90±4.00	0.149±0.0042	15.92±3.17	0.132±0.0070	23.12±6.85	32.59±16.18
40.00	17.32±3.21	0.144±0.0032	16.17±4.10	0.134±0.0042	23.13±7.10	27.75±19.80
45.00	18.82±2.98	0.156±0.0060	18.42±3.60	0.153±0.0116	23.22±7.48	28.09±20.37
50.00	17.98±3.37	0.149±0.0060	18.50±3.59	0.154±0.0113	23.19±7.56	28.00±20.47
55.00	16.75±3.80	0.139±0.0085	15.75±2.71	0.131±0.0130	23.28±7.77	25.75±24.01
60.00	18.13±3.24	0.150±0.0061	18.59±4.14	0.154±0.0133	23.29±7.86	26.59±23.97

Table 2: Mean count per minute (cpm), dose rate, mean temperature and mean relative humidity measurements using GCA-07 and Digilert-50 for the month of March (no harmattan)

Time (minutes)	GCA-07		DIGILERT-50		Mean Temperature (°C) (±SD)	Mean Relative Humidity (%) (±SD)
	Mean cpm (±SD)	Dose Rate (µSv/hr) (±SD)	Mean cpm (±SD)	Dose Rate (µSv/hr) (±SD)		
5.00	17.87±3.77	0.148±0.0067	18.58±4.35	0.154±0.0147	28.15±1.63	74.50±3.22
10.00	17.73±4.33	0.147±0.0007	15.92±3.08	0.132±0.0156	28.31±2.23	73.92±5.04
15.00	19.20±3.71	0.159±0.0067	15.17±3.64	0.126±0.0147	28.39±2.64	74.25±5.90
20.00	16.57±3.99	0.138±0.0105	18.83±2.31	0.156±0.0159	28.53±3.07	74.08±6.45
25.00	18.42±3.99	0.153±0.0108	18.42±4.94	0.153±0.0165	28.57±3.23	74.00±6.85
30.00	17.42±4.42	0.145±0.0075	15.33±3.18	0.127±0.0159	28.55±3.36	74.34±7.70
35.00	17.40±3.85	0.144±0.0049	16.83±4.43	0.140±0.0130	28.59±3.49	74.08±8.39
40.00	17.57±3.52	0.146±0.0010	17.25±3.49	0.143±0.0085	28.61±3.69	74.25±8.74
45.00	17.83±3.40	0.148±0.0020	17.58±2.31	0.146±0.0030	28.74±4.00	74.33±9.12
50.00	17.73±3.67	0.147±0.0010	17.50±4.42	0.145±0.0015	28.79±4.13	74.17±9.60
55.00	17.92±3.67	0.149±0.0010	18.58±3.49	0.154±0.0049	28.80±4.22	74.17±9.86
60.00	17.50±3.75	0.145±0.0020	16.92±2.13	0.140±0.0071	28.76±4.23	74.17±10.25

Table 3: Cumulative dose for GCA-07 and Digilert-50 for the months of January and March

TIME(MINS)	CUMULATIVE DOSE FOR GCA-07 (µSv/hr)		CUMULATIVE DOSE FOR DIGILERT-50 (µSv/hr)	
	JANUARY	MARCH	JANUARY	MARCH
5.00	0.148	0.148	0.137	0.154
10.00	0.303	0.295	0.278	0.286
15.00	0.452	0.454	0.418	0.412
20.00	0.600	0.592	0.565	0.568
25.00	0.751	0.745	0.711	0.721
30.00	0.894	0.890	0.851	0.848
35.00	1.043	1.034	0.983	0.988
40.00	1.187	1.180	1.117	1.131
45.00	1.343	1.328	1.270	1.277
50.00	1.492	1.475	1.424	1.422
55.00	1.631	1.624	1.555	1.576
60.00	1.781	1.769	1.709	1.716

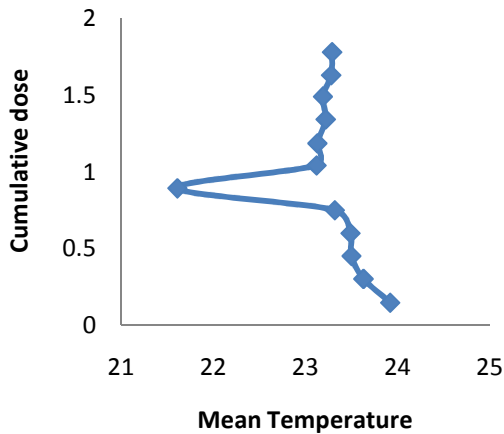


Fig. 1a: Cumulative dose and mean temperature for GCA-07 January (during harmattan)

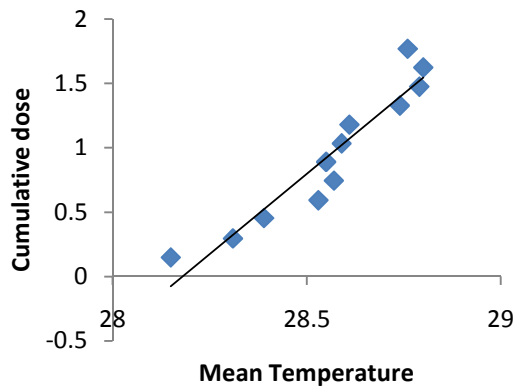


Fig.1b: Cumulative dose and mean temperature for GCA-07 March (no harmattan)

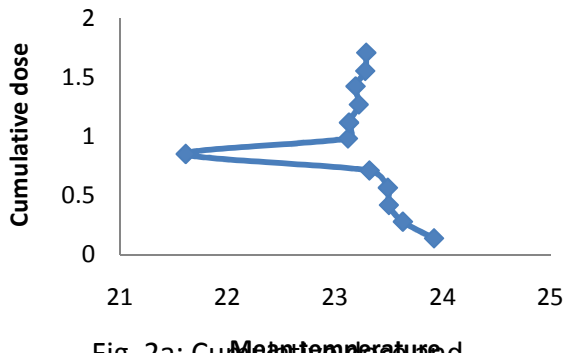


Fig. 2a: Cumulative dose and mean temperature for Digilert-50 January (during harmattan)

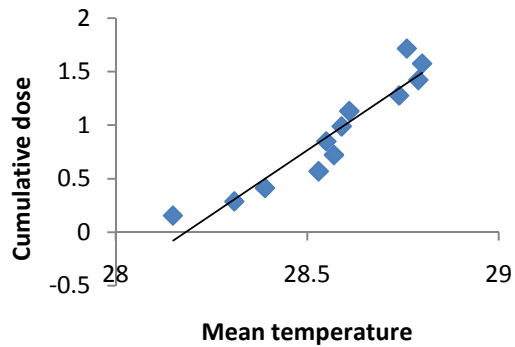


Fig.2b: Cumulative dose and mean temperature for Digilert-50 March (no harmattan)

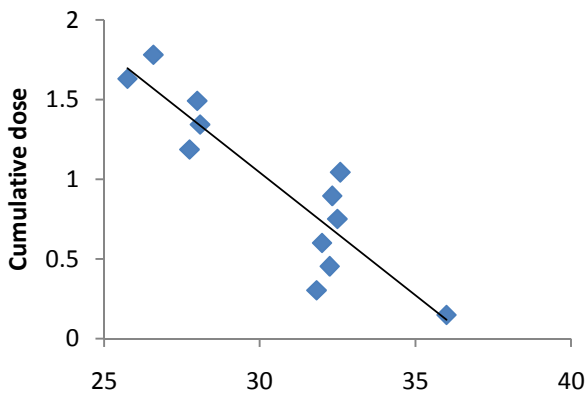


Fig.3a: Cumulative dose and mean relative humidity for GCA-07 January (during harmattan)

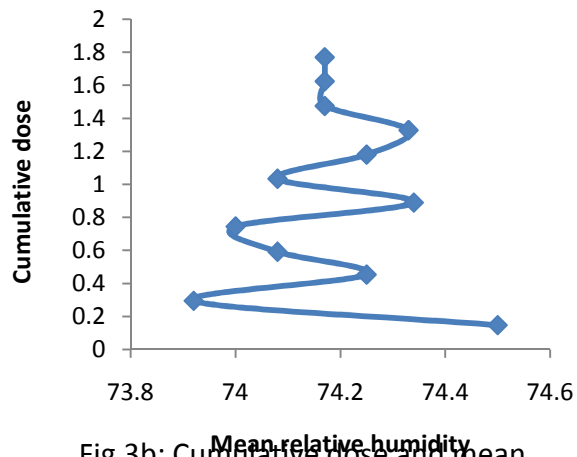


Fig.3b: Cumulative dose and mean relative humidity for GCA-07 March (no harmattan)

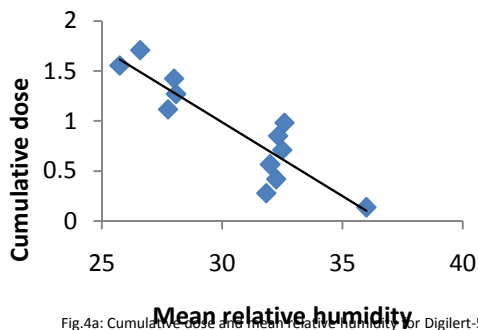


Fig.4a: Cumulative dose and Mean Relative Humidity for Digilert-50 January (during harmattan)

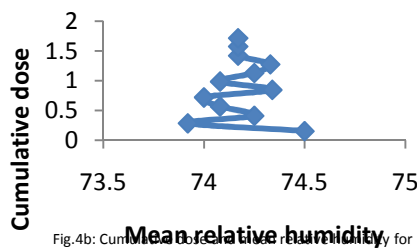


Fig.4b: Cumulative dose and Mean Relative Humidity for Digilert-50 March (no harmattan)

5.0 References

- [1] United States Geological Survey digital data series DDS-9, 1993.
- [2] Finck, R.R., (1992). High resolution field gamma spectrometry and its application to problems in environmental radiology (Doctoral Thesis). Department of Radiation Physics, Malmö and Lund University, Malmö, Sweden.
- [3] Ballinger, P W (1991). National radiation, radiographic position and procedures. Mosby year book. 1:21-32.
- [4] UNSCEAR, 1993. Sources and Effects of ionising radiation. Report to the General Assembly United Nations, New York.
- [5] Miah M.I. (2005). A Study on Seasonal variations of Indoor Gamma Dose in Bangladesh. Radioisotopes 54, 27-33.
- [6] Noz, M.E and Maguire, G.Q. (1979). Radiation Protection in radiological and health sciences. Henry Kimpton publishers, London pp 211.
- [7] United Nations Scientific Committee on Effects of Atomic Radiation (1988). Exposure from natural sources of radiation. UNSCEAR report pp 121-167.
- [8] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2008). Sources and Effects of ionizing radiation. New York: United Nations (published 2010) P. 4 ISBN978-92-1-142274-0.
- [9] Wall, B.F. and Hart, D. (1997). Revised radiation Doses for Typical X-ray Examinations. The British Journal of Radiology 70(833), 437-439.
- [10] Hart, D. and Wall, B.F. (2002). Radiation Exposure of the UK Population from Medical and Dental X-ray Examinations. National Radiological Protection Board. P.9.
- [11] Dade W. Moeller (2013). Doses from Cigarette Smoking. Health Physics Society. Website: everything explained today/Background_radiation/ accessed April, 2016.
- [12] Feng Y.J., Chen W.R., Sun T.P., Duan S.Y., Jia B.S. and Zhang H.L. (2002). Estimated Cosmic radiation doses for flight personnel. Space Med. Eng. 15(4), 265-269.
- [13] Harris, M. J., G. H. Share, and M. D. Leising, Spatial and temporal variability of the gamma radiation from Earth's atmosphere during a solar cycle, J. Geophys. Res., 108(A12), 1435, doi:10.1029/2003JA009958, 2003.
- [14] Afolabi OM, Aboluwoye CO, Ajayi IR (2014) Gamma Ray Spectrometry Analytical Determination of Radiation Levels in Bitumen Deposit Areas of Agbabu and Environment. J Environ Anal Toxicol 4, 211. doi: 10.4172/2161-0525.1000211.
- [15] Arena, V. (1971). Radiation dose and radiation exposure of the human population. In : ionising radiation and life: st. Louis, The C.V. Mosby Co. Publishers, 123-156.
- [16] Washington State department of health. (2002). Background Radiation Natural versus –made. Division of Environmental Health office of radiation protection.
- [17] Lombardi M.H. (2006). Radiation Safety in Nuclear Medicine. Taylor and Francis Group. Boca Raton London, New York.
- [18] Minka N.S. and Ayo J.O. (2013). Influence of cold – dry (harmattan) season on colonic temperature and the development of pulmonary hypertension in broiler chickens, and the modulating effect of ascorbic acid. Dove Press Journal, open access animal physiology Vol. 6 pp 1 – 11.
- [19] Anuforo E. and Chukwu L. (2015). Coping with health hazards of harmattan haze. The Guardian Nigeria, 19th January, 2015.
- [20] Osahon O.D, Abiola J.A (2014). Assessment of Background Gamma Radiation within Geo Works Quarry Site In Igarra Akoko Edo Local Government Area Edo State Nigeria. Journal of the Nigerian Association of Mathematical Physics Vol. 28, No. 1, 213-222.
- [21] Osahon O.D. (2013). Indoor measurement of background gamma radiation with height and ambient temperature within Edo State Secretariat building, Benin City, Nigeria. Journal of the Nigerian Association of Mathematical Physics Vol. 24, 130 – 131.
- [22] ICRP Publication 60 (1990). Recommendations of the International Commission On Radiological Protection. Annal of the ICRP 21