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Evaluation of approximation methods of conversion from Microsieverts Per Hour (µSv/hr) to Counts Per Minute (CPM) of background gamma radiation measurements

O. D. Osahon*[1], G. E. Okungbowa[2] and G. O. Igomah[3]

[1]*Department of Physics, Faculty of Physical Sciences, University of Benin, Benin City, Edo State, Nigeria.*
[2]*Department of Radiography, School of Basic Medical Sciences, University of Benin, Benin City, Edo State, Nigeria.*
[3]*Department of Physics, University of Calabar, Calabar, Cross River State, Nigeria.*

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Abstract

There is no direct method of conversion from Microsieverts Per Hour (µSv/hr) to Counts Per Minute (CPM). This study presents an evaluation of approximation methods of going about this conversion. In this study, indoor and outdoor background gamma radiation measurements are carried out using Fluke Biomedical 451 ion Chamber Survey Meter. A cogitate look at the survey Meter's manual shows that the specifications are: Radiation Detected – Alpha above 7.5 MeV, Beta above 100 keV and Gamma above 7 keV; Operating Ranges – 0 to 50 µSv/hr, 0 to 500 µSv/hr, 0 to 5 mSv/hr, 0 to 50 mSv/hr, 0 to 500 mSv/hr and Accuracy – ± 10 % of reading between 10 % and 100 % of full – scale indication on any range, exclusive of energy response (calibration source is Cs–137). Relevant literatures have shown that for radiation survey meters whose calibration source is Cs–137, the conversion factor from µSv/hr to CPM is around 1 µSv/hr per 120 CPM while those whose calibration source is Co–60, the conversion factor from µSv/hr to CPM is around 1 µSv/hr per 108 CPM. In this study, the calculated Annual Effective Dose (AED) of background gamma radiation levels ranges from 0.925 to 2.943 mSv/yr for the indoor measurement and from 0.289 to 0.560 mSv/yr for the outdoor measurement. The ratio of indoor to outdoor dose rate values in µSv/hr is computed for each corresponding reading from which the mean indoor – to – outdoor ratio for the readings is computed for comparison with the 1.5 set by UNSCEAR (UNSCEAR, 2008). The use of CPM in radiation monitoring, environmental monitoring, health physics, quality control and the health implications of the results obtained in this study are discussed.

***Keywords**: Background gamma radiation, indoor, outdoor, dose rate, annual effective dose.*
*Corresponding author, e-mail: **okhuomaruyi.osahon@uniben.**edu

1 Introduction

Radiation is the energy in motion in the form of waves or streams of particles from a source that travels through space or other mediums. Radiation has always been present and is all around us in many forms. One of the inescapable features of life on planet Earth is exposure to ionising radiation. Ionising radiation of the environment is the most ubiquitous form of exposure, therefore, determination of the health risk of background gamma radiation is of great importance in biophysics and health physics. Life has evolved in a world with significant levels of ionising and non – ionising radiations and our bodies have adapted to them. This study focuses on the evaluation of approximation method of conversion from Microsieverts Per Hour (µSv/hr) to Counts Per Minute (CPM) via background gamma radiation measurements. Background radiation is a constant source of ionising radiation present in the environment and emitted from a variety of sources. According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR,2008) there are four major sources of natural radiation; cosmic radiation, terrestrial radiation and intakes of naturally occurring radionuclides through inhalation and ingestion.

Usually, cosmic radiation originates from a variety of sources, including the sun and other celestial events in the universe due to the fact that the earth's outer atmosphere is continually bombarded by it. Some ionising radiation will penetrate the earth's atmosphere and become absorbed by humans which results in natural radiation exposure. Terrestrial radiation which is the next major source of natural radiation is as a result of the composition of the earth's crust. The main contributors are natural deposits of uranium, potassium and thorium which, in the process of natural decay, will release small amounts of ionising radiation. Uranium and thorium are found essentially everywhere. Traces of these minerals are also found in building materials so exposure to natural radiation can occur from indoors as well as outdoors. Inhalation of radioactive gases that are produced by radioactive minerals found in soil and bedrock is responsible for most of the variation in exposure to natural radiation. Radon is an odourless and colourless radioactive gas that is produced by the decay of uranium. Thoron is a radioactive gas produced by the decay of thorium. Radon and thoron levels vary considerably by location depending on the composition of soil and bedrock. Once released into the air, these gases will normally dilute to harmless levels in the atmosphere but sometimes they become trapped and accumulate inside buildings and are inhaled by occupants. Radon gas poses a health risk not only to uranium miners, but also to people living in their homes if it is left to collect in the home. On the average, it is the largest source of natural radiation exposure. Now, trace amounts of radioactive minerals are naturally found in the contents of food and drinking water. For instance, vegetables are typically cultivated in soil and ground water which contains radioactive minerals. Once ingested, these minerals result in internal exposure to natural radiation. Some of the essential elements that make up the human body, mainly potassium and carbon, have radioactive isotopes that add significantly to our background radiation dose.

Effective dose is a general term that is used to refer to the amount of energy absorbed by tissue from ionising radiation. The effective dose is measured in Sieverts (Sv) and is more commonly expressed in units of millisieverts (mSv) or microsieverts (μSv). The total worldwide average effective dose from natural radiation is approximately 2.4 mSv per year, however, doses can vary greatly from place to place (UNSCEAR, 2008, NCRP160, 2009).

Man's exposure to natural radiation exceeds that from all technologies put together (UNSCEAR, 2010); and the International Atomic Energy Agency (IAEA) estimate of the dose contribution to the environment shows that, over 85% of background radiation received by man is derived from natural radionuclides, while the remaining 15% is from cosmic rays and nuclear process (Agba *et al*., 2006).

Previous studies have shown that areas with high background radiation are found in Kerala Coast, India; Yangjiang, China; and Ramsar, Iran (Ghiassi – nejad *et al*., 2002); and in Asia, maximum outdoor measurement was recorded in Malaysia and maximum indoor measurement was recorded in Hong Kong and Iran (Gholami *et al*., 2011). In Nigeria, studies have been conducted in different parts of the country to determine the natural radiation levels (Farai and Vincent, 2000; Farai and Jibri, 2000; Mokobia and Balogun, 2004; Sadiq *et al*., 2010; Usman *et al*., 2021; Samaila *et al*., 2022 and Samaila *et al*., 2024).

2 Material and method

In this study, all measurements indoor and outdoor were made using Victoreen 451B- De – SI ion chamber radiation survey Meter within and around the Department of Physics, Faculty of Physical Sciences, University of Benin, Benin City, Edo State, Nigeria. In order to avoid effects of ground on indoor and outdoor measurements, the Meter was placed one metre height above the ground level. Also, during the outdoor measurement, the Meter was used at least six metres distance away from the walls of any building nearby to avoid unwanted effects of the materials used in the buildings on the measurements. To account for errors in the measurements, twenty – four (24) different readings were taken for both indoor and outdoor measurement. To convert Microsieverts Per Hour (μSv/hr) to Counts Per Minute (CPM) equation (2) of the following approximation equations was utilised:

$$1\ \mu\text{Sv/hr} \cong 108\ \text{CPM, for Co} - 60. \tag{1}$$

$$1\ \mu\text{Sv/hr} \cong 120\ \text{CPM, for Cs} - 137. \tag{2}$$

$$1\ \mu\text{Sv/hr} \cong 1\text{CPM} \times \text{Conversion Factor}. \tag{3}$$

$$1\ \mu\text{Sv/hr} \cong 1\text{CPM} \times \frac{\text{Gamma Sensitivity}}{\text{Calibration or Conversion Factor}}. \tag{4}$$

It has been shown that, in a pure gamma field, the detector has gamma sensitivity of the order of 10^{-7} to 10^{-6} for Co – 60 and 10^{-9} to 10^{-8} for Cs – 137, as a result of detector geometry, fibre coding and signal processing. Gamma sensitivity is unchanged to any statistical significance in a mixed neutron gamma field (Sykora *et al.*, 2012).

3 Results and discussion

The results obtained in this study are presented in Tables 1, 2, 3 and 4, and Figures 1, 2, 3 and 4 respectively.

Table 1: *Indoor dose rate measurements analysis*

Indoor Dose Rate D_i (μSv/hr)	$\Delta D_i = (D_i - \bar{D}_i)$ (μSv/hr)	ΔD_i%	Dose Equivalent D_E (mSv/yr)	ΔD_E (mSv/yr)	ΔD_E%
O	0.21	50.00	3.679	1.814	49.31
0.41	0.20	48.78	3.592	1.727	48.08
0.35	0.14	40.00	3.066	1.201	39.17
0.29	0.08	27.59	2.540	0.675	26.57
0.31	0.10	32.26	2.716	0.851	31.33
0.28	0.07	25.00	2.453	0.588	23.97
0.24	0.04	16.67	2.102	0.237	11.28
0.27	0.06	22.22	2.365	0.500	21.14
0.19	-0.02	10.53	1.664	-0.201	12.08
0.16	-0.05	31.25	1.402	-0.463	33.02
0.17	-0.04	23.53	1.489	-0.376	25.25
0.20	-0.01	5.00	1.752	-0.113	6.45
0.20	-0.01	5.00	1.752	-0.113	6.45
0.15	-0.06	40.00	1.314	-0.551	41.93
0.22	0.01	4.55	1.927	0.062	3.22
0.14	-0.07	50.00	1.226	-0.639	52.12
0.14	-0.07	50.00	1.226	-0.639	52.12
0.14	-0.07	50.00	1.226	-0.639	52.12
0.14	-0.07	50.00	1.226	-0.639	52.12
0.13	-0.08	61.54	1.139	-0.726	63.74
0,14	-0.07	50.00	1.226	-0.639	52.12
0.14	-0.07	50.00	1.226	-0.639	52.12
0.14	-0.07	50.00	1.226	-0.639	52.12
0.14	-0.07	50.00	1.226	-0.639	52.12

Mean Dose Rate, $\bar{D}_i$ = 0.21 μSv/hr and Mean Dose Equivalent, $\bar{D}_E$ = 1.865 mSv/yr

The annual effective doses for both the indoor and outdoor data were computed using equations (5) and (6) (UNSCEAR, 2008).

$$E_i = D_i(\mu Sv/hr) \times 8760 \ hr/yr \times 0.8, \quad (5)$$

$$E_o = D_o(\mu Sv/hr) \times 8760 \ hr/yr \times 0.2, \quad (6)$$

where E_i is the indoor annual effective dose (mSv/yr), E_o is the outdoor annual effective dose (mSv/yr), D_i is the indoor meter reading (μSv/hr) ≡ indoor absorbed dose rate, D_o is outdoor meter reading (μSv/hr) ≡ outdoor absorbed dose rate, 0.8 and 0.2 are the indoor and outdoor occupancy factors respectively. The computed values of E_i and E_o are displayed in Table 3.

Table 2: *Outdoor dose rate measurements analysis*

Outdoor Dose Rate, D_O (μSv/hr)	$\Delta D_O = (D_O - \bar{D}_O)$ (μSv/hr)	ΔD_O%	Dose Equivalent D_E (mSv/yr)	ΔD_E (mSv/yr)	ΔD_E %
0.32	0.12	37.50	2.803	1.073	38.28
0.31	0.11	35.48	2.716	0.986	36.30
0.30	0.10	33.33	2.628	0.898	34.17
0.25	0.05	20.00	2.190	0.460	21.01
0.22	0.02	9.09	1.927	0.197	10.22
0.20	0.00	0.00	1.752	0.022	1.26
0.19	-0.01	5.26	1.664	-0.066	3.97
0.17	-0.03	17.65	1.489	-0.241	16.19
0.18	-0.02	11.11	1.577	-0.153	9.70
0.18	-0.02	11.11	1.577	-0.153	9.70
0.17	-0.03	17.65	1.489	-0.241	16.19
0.17	-0.03	17.65	1.489	-0.241	16.19
0.17	-0.03	17.65	1.489	-0.241	16.19
0.17	-0.03	17.65	1.489	-0.241	16.19
0.17	-0.03	17.65	1.489	-0.241	16.19
0.17	-0.03	17.65	1.489	-0.241	16.19
0.17	-0.03	17.65	1.489	-0.241	16.19
0.18	-0.02	11.11	1.577	-0.153	9.70
0.17	-0.03	17.65	1.489	-0.241	16.19
0.17	-0.03	17.65	1.489	-0.241	16.19
0.17	-0.03	17.65	1.489	-0.241	16.19
0.18	-0.02	11.11	1.577	-0.153	9.70
0.18	-0.02	11.11	1.577	-0.153	9.70

Mean Dose Rate, $\bar{D}_o$ = 0.20 μSv/hr and Mean Dose Equivalent, $\bar{D}_E$ = 1.730 mSv/yr

The indoor dose rate – to – outdoor dose rate ratio was computed for each of the datum from which the mean indoor dose rate – to – outdoor dose rate ratio was calculated for comparison with the 1.5 value set by UNSCEAR (UNSCEAR, 1993). In this study a value of 1.05 was obtained as the mean indoor dose rate – to – outdoor dose rate ratio. Also, in this study, it was observed that the indoor meter readings (μSv/hr) were higher than the outdoor meter readings (μSv/hr) in agreement with previous studies carried out in some Nigerian cities reported in (Ramli et al., 2014; Sadiq and Agba, 2011; Oladele and Arogunjo, 2018; Archibong and Chiaghanam, 2020 and Mgbeokwere *et al*., 2021). In this study, statistical analysis using T – test was carried out in order to determine if there is any significant difference between the indoor and outdoor annual effective dose values. The result of the test combined with the R – Square values from Figs. (3) and (4) show that there was no significant difference between the indoor and outdoor annual effective dose values.

Using one of the approximation equations (Equ.2), the indoor and outdoor dose rate values in μSv/hr were converted to CPM. Now, CPM indicates the number of radiation events (or counts) that is detected by a radiation detector within a one minute time frame. Table 4 depicts the values obtained for the conversion from μSv/hr to CPM.

Table 3*:* *Indoor and outdoor dose rates conversion to indoor and outdoor annual effective doses*

D_i (μSv/hr)	D_o (μSv/hr)	E_i (mSv/yr)	E_o(mSv/yr)	($R=D_i/D_o$)
0.42	0.32	2.943	0.561	1.31
0.41	0.31	2.873	0.543	1.32
0.35	0.30	2.435	0.526	1.17
0.29	0.25	2.032	0.438	1.16
0.31	0.22	2.172	0.385	1.41
0.28	0.20	1.962	0.350	1.40
0.24	0.19	1.681	0.333	1.26
0.27	0.17	1.892	0.298	1.59
0.19	0.18	1.332	0.315	1.06
0.16	0.18	1.121	0.315	0.89
0.17	0.17	1.191	0.298	1.00
0.20	0.17	1.402	0.298	1.18
0.20	0.17	1.402	0.298	1.18
0.15	0.17	1.051	0.298	0.88
0.22	0.17	1.542	0.298	1.29
0.14	0.17	0.981	0.298	0.82
0.14	0.17	0.981	0.298	0.82
0.14	0.18	0.981	0.315	0.78
0.13	0.17	0.911	0.298	0.77
0.14	0.17	0.981	0.298	0.82
0.14	0.17	0.981	0.298	0.82
0.14	0.18	0.981	0.315	0.78
0.14	0.18	0.981	0.315	0.78

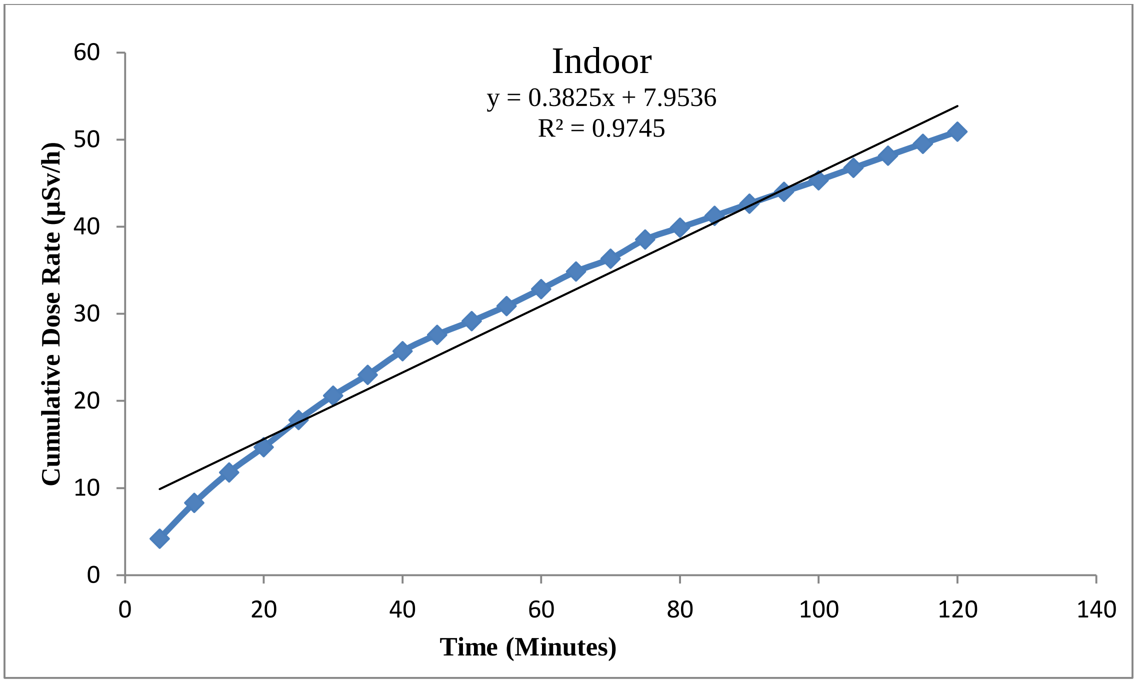

Figure 1: *Plot of cumulative dose rate against time for indoor measurements*.

Table 4: *Conversion from Microsieverts Per Hour (µSv/hr) to Counts Per Minute (CPM) of indoor and outdoor measurements*

Indoor Dose rate (µSv/hr)	Outdoor Dose rate (µSv/hr)	Indoor CPM	Outdoor CPM
0.42	0.32	50.4	38.4
0.41	0.31	49.2	37.2
0.35	0.30	42.0	36.0
0.29	0.25	34.8	30.0
0.31	0.22	37.2	26.4
0.28	0.20	33.6	24.0
0.24	0.19	28.8	22.8
0.27	0.17	32.4	20.4
0.19	0.18	22.8	21.6
0.16	0.18	19.2	22.8
0.17	0.17	32.4	20.4
0.20	0.17	24.0	20.4
0.20	0.17	24.0	20.4
0.15	0.17	18.0	20.4
0.22	0.17	26.4	20.4
0.14	0.17	16.8	20.4
0.14	0.17	16.8	20.4
0.14	0.18	16.8	21.6
0.13	0.17	15.6	20.4
0.14	0.17	16.8	20.4
0.14	0.17	16.8	20.4
0.14	0.18	16.8	21.6
0.14	0.18	16.8	21.6

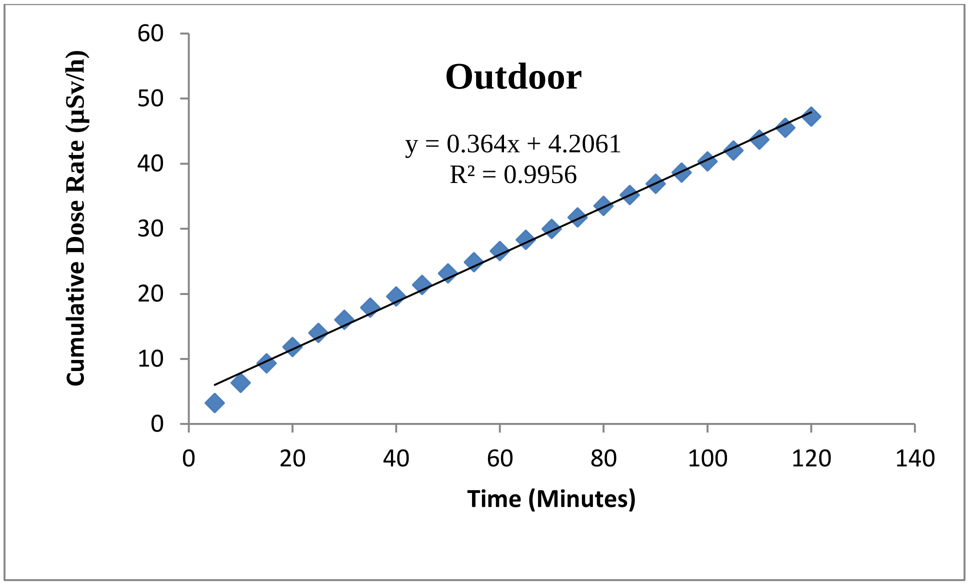

Figure 2: *Plot of cumulative dose rate against time for outdoor measurements*.

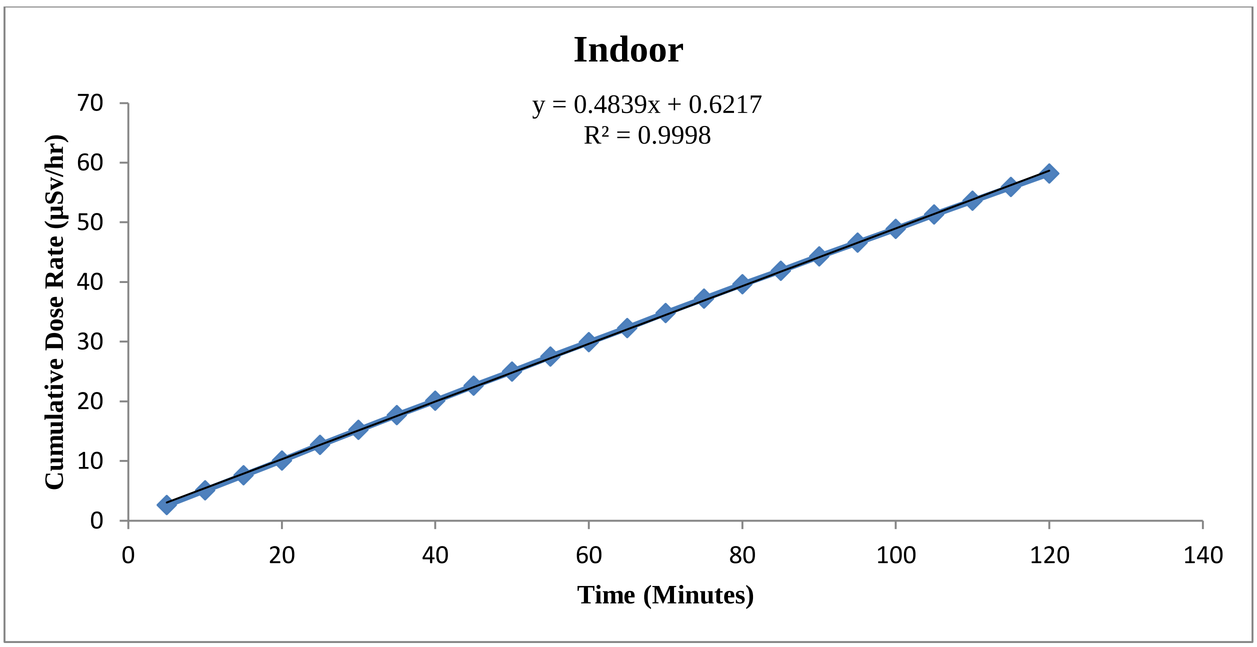

Figure 3: *Plot of cumulative dose rate against time for indoor measurements for calibration of the radiation meter*.

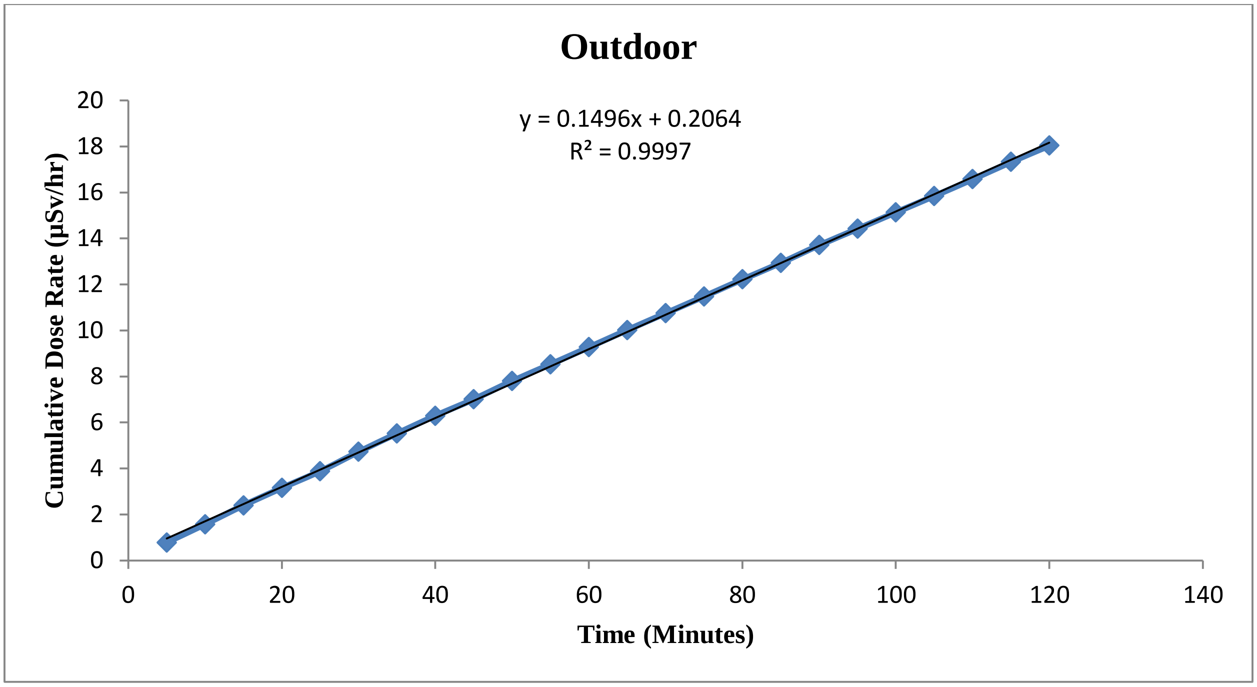

Figure 4: *Plot of cumulative dose rate against time for indoor measurements for calibration of the radiation meter*

4 Conclusion

The natural background gamma radiations (indoor and outdoor) within and around the Department of Physics, Faculty of Physical Sciences, University of Benin, Benin City, have been measured and the results obtained were in good agreement with those determined in previous studies within and outside Nigeria. The conversion from µSv/hr to CPM shows that the indoor values range from 15.6 to 50.4 CPM while the outdoor values range from 20.4 to 38.4 CPM. It is normal to find range of 7 to 30 CPM in surroundings. However, anything below 150 CPM is considered safe, but if the value overshoots this limit, the substance or environment is considered to be dangerously radioactive.

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