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MEAN COUNT RATE MEASUREMENT OF DIFFERENT CONSTRUCTION MATERIALS LOCALLY SOURCED WITHIN THE MAKURDI METROPOLIS, BENUE STATE

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Abstract

Locally construction and building materials were sorted for and obtained within Makurdi metropolis at some construction sites and Timber shade along Naka Road in Makurdi. The materials were collected and taken to the Physics Laboratory of the Benue state University, Makurdi, where they were exposed and the handheld radiation meter was hovered over one sample at a time at some designated distances of 0.5m, 1.0m and 1.5m respectively, above the sample, for 1 min, 5 min and 10 min, respectively for each distance. The background count rate was measured to be 0.0151 μSv/hr and subtracted from each reading to obtain the actual count rate. The count rates which were recorded in microSievert per hour (μSv/hr) showed a particular trend of decrease in the count rates against increase in distance thereby obeying the inverse square law. The results typically illustrate the harmlessness of the measured radioactivity from all the construction materials to man and the environment and perhaps even over a long period of time.

Keywords**:** Mean Count Rate, Building materials, Radiation Meter, Radionuclides, Background radiation.

1. Introduction

Construction materials contain naturally occurring radioactive materials (NORMs) [1 - 3] whose radiation concentrations vary according to the type and origin of the building material [4]. Many of these materials are products derived from rocks and soils [2, 4, 5]. These building/construction materials contain various amount of mainly natural radionuclides of the Uranium (^{238}U) and Thorium (^{232}Th) series, and the radioactive isotope of Potassium (^{40}K) [6 - 12]. These radionuclides are sources of both the external and internal background radiation present in our everyday environment [2 - 3, 12 - 13, 15]. The specific activities of ^{226}Ra, ^{232}Th and ^{40}K in the building raw materials mainly depend on geological and geographical conditions as well as geochemical characteristics of those materials [2, 10, 13 - 14]. The radiological impact from the natural radioactivity is due to radiation exposure of the body by gamma-rays and irradiation of lung tissues from inhalation of radon and its progeny [2, 5]. From the natural risk perspective, it is necessary to know the dose limits of public exposure and to measure the natural environmental radiation level provided by ground, air, water, foods, building interiors and so on, to estimate human exposure to natural radiation sources [3 - 4]. Low level gamma-ray spectrometry is suitable for both qualitative and quantitative determinations of gamma-ray-emitting nuclides in the environment [6, 8, 16 - 17]. Radiation measurement studies can be useful for the assessment of public radiation dose [2, 11] and performance of epidemiology as well as for keeping reference data records [18], to ascertain changes in the environmental radioactivity due to industrial, nuclear and other human activities [19].

Makurdi, being the state capital of Benue state is developing rapidly in terms of infrastructures, that individuals and government together with other cooperate bodies have put in place, either for office accommodation or residency. Construction of roads and other economic activities of man within the environment have been on a steady rise for over time

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due to the exponential increase in the demand of such facilities. Consequently, the demand for building materials have been on the increase year after year. Hence, it is necessary to investigate the radioactivity level in construction materials, in order to identify, limit and control the use of materials with high amount of radioactive content which could pose risk of excess radiation exposure to human and environment. This work is therefore aimed at measuring the radiation level present in the locally building materials that are commonly used in Makurdi metropolis for the construction of such facilities as mentioned earlier. Although several researchers have engaged in various studies in recent years outside of Nigeria to measure the level of radioactivity in building materials (see [2 - 3, 8 - 9, 12, 17 - 22, 27, 29]). However, little studies on the measurement of radioactivity from building materials have been carried out within Nigeria (see [23 - 24]), with no studies carried out in Benue State particularly. Therefore, our results can be considered as a reference data for the thirteen (13) locally sourced building materials measured in this work.

2. Materials and Method

The natural construction materials used in this work include Brazil zinc, Aluminum zinc, Wood, Asbestos zinc, sharp sand, burnt bricks, zinc nails, concrete blocks, Dangote cement (Portland cement), Gravel aggregate, POP cement, saw dust, clay mud and red sand. These samples were collected directly from the suppliers of the building materials and construction sites within Makurdi metropolis. The collected samples were labelled at the time of collection, transferred to the laboratory and stored for 7 days at room temperature in order to homogenize them before measurement using the hand-held radiation meter (the Inspector EXP model).

2.1. The Operation of the Radiation Detector

The Inspector EXP+ Radiation detector (as shown in Figure 1) is a healthy and safety instrument that is optimized to detect low levels of radiation [25 - 26, 28]. The Inspector Alert uses a Geiger-Mueller tube to detect radiation [25, 26]. The Geiger tube generates a pulse of electrical current each time radiation passes through the tube and causes ionization. Each pulse is electronically detected and registers as a count. The Inspector Alert displays the counts in two mode which are, counts per minute (CPM) and milli-roentgens per hour (mR/hr). The display radiation counts were converted to SI units, counts per second (CPS) and micro-Sieverts per hour ($\mu Sv/hr$). The number of counts detected by the meter (the radiation meter) varies from one reading to another due to the random nature of radioactivity. The mean values of these readings were obtained after several values were recorded for a period of time (for instance, 1 *min*, 5 *min* and 10 *min* in this case).

Figure 1. The Handheld Radiation Detector (Radiation Alert Inspector EXP^{+})

3. Analysis of Count Rate Measurement

A total of 13 samples of raw building materials were collected and brought to the Physics laboratory of the Department of Physics, Benue State University Makurdi, for measurement of radioactivity. The radiation detector was connected to the inspector alert, and was fixed on the retort stand. The mode switch of the inspector alert was placed at mSv/hr mode and the background count rate of the laboratory was measured to be $0.0151\ \mu Sv/hr$. The detector was again placed at a height of 0.5 *m* distance away from the exposed sample, and the count rate was measured for 1 *min*, 5 *min* and 10 *min.* Again, the height of the radiation detector was increase to a distance of $1\ m$ and $1.5\ m$ away from the construction material, and the count rate was obtained for 1 *min*, 5 *min* and 10 *min.* The background count rate was subtracted from the count rate of the radiation of the sample measured after 1 *min*, 5 *min* and 10 *min.* The mean count rate was also obtained so as to reduce the variation in the count rate that arises from the random nature of radiation.

The same procedure was repeated for other samples and the count rates were measured as presented in Table 1 at various times and distances as described above.

4. Experimental Results and Discussions

Following the methods and procedures as clearly illustrated in Section 3, the results for the amount of radiation emitted by natural building materials such as saw dust, brick, pop cement, sharp sand, Dangote cement, gravel aggregate, clay mud, red sand, cement block, zinc nails, wood, asbestos zinc, aluminum zinc are presented both in Table 1 while their 'pictorial' behaviour according to distance and time of exposure for these materials are shown in Figures 2 – 6.

Figure 7 shows the combination of the count rates of the samples at different time intervals and distances to which the radiation meter was placed above the samples. This Figure allows to make comparison in the behavior of these samples as presented.

As presented in Table 1, all the thirteen (13) building materials worked within this project were exposed for measurement in the laboratory of the Department of Physics, Benue State University, Makurdi. Their mean count rates were determined after several repeated readings were measured for different time intervals of 1 min, 5 min and 10 min for distances of 0.5 m, 1.0 m and 1.5 m respectively. Results measured has shown that, for the Aluminum zinc, the lowest mean count rate was 0.0022 $\mu Sv/hr$ for the 1.5 m above the ground where the radiation meter was placed. The highest mean count rate was determined from all the three designated time intervals thereby recording the value 0.0046 $\mu Sv/hr$ for the 0.5 m distance above the ground upon which the radiation meter was placed as shown in Figure 2.

The second entry on Table 1 is the Asbestos zinc with the lowest mean count rate recorded at the 1.5 m above the ground. The highest mean count rate of 0.0032 $\mu Sv/hr$ for this material was recorded at the 0.5 m distance where the radiation meter was placed for the measurement of the actual count rates for both 1.0 min, 5.0 min and 10.0 min time intervals. For the Zinc nails, the lowest mean count rate was measured at the 1.5 m to be 0.0016 $\mu Sv/hr$ with the highest mean count rate recorded at the 0.5 m distance to be 0.0029 $\mu Sv/h$ (see details as presented in Table 1 and Figure 2.

A detailed observation of all the building materials as presented in Table 1 and the Figures 2 – 7 in this work have shown that, the highest mean count rate from the radiation exposure of these samples was recorded at the 0.5 m and an exponential decrease of the mean count rate was recorded at higher distances from which the radiation meter was placed above the exposed samples. This trend of observation is evident in all the thirteen building materials used in this work. This further reveal that the radiation exposure mean count rate varies inversely to the distance at which the radiation meter source was placed. This is an indication also that the effects of radiation to human varies inversely to the distance from the source.

Figures 2 – 6 shows the radiation pattern of the samples which decreased with increase in distance, the more the radiation detector was placed away from the exposed samples the less the radiation it detected which signifies that the more we are away from these materials the less exposed we will be.

Figure 7 is a comparative plot of all the samples, which follows the same pattern of radiation emission with respect to distance of the detector away from the sourced samples, with Brick having the highest count rate of 0.019 $\mu Sv/hr$ at 0.5 m and Sharp sand having the lowest count rate of 0.0020 $\mu Sv/hr$ at 0.5 m away from the detector window.

The mean count rate of bricks at $0.5\,m$, $1.0\,m$ and $1.5\,m$ away from the radiation meter being, $0.019\,\mu Sv/hr$, $0.0024\,\mu Sv/hr$ and $0.0023\,\mu Sv/hr$ respectively, corresponds to the bricks' radiation absorbed dose rate, which are equivalent to $0.16655\,mSv/y$, $0.02104\,mSv/y$ and $0.020162\,mSv/y$ respectively. These values except for $0.16655\,mSv/y$ at $0.5\,m$ are by far lower than the results of all the bricks studied in [18] which ranged from ($0.13 - 0.34\ mSv/y$), [2] and [3] averagely $0.09\,mSv/y$ and $0.83\,mSv/y$ respectively. Our results for the bricks at $0.5\,m$ away from the detector, which is $0.16655\,mSv/y$ compared well with the results of [4] ranged ($0.15 - 0.18\,mSv/y$).

Summarily, in all the samples presented in this study, red sand recorded the lowest mean count rate of 0.0004 $\mu Sv/hr$ corresponding to the radiation absorbed dose rate of $0.00351\,mSv/y$ at the 1.5 m above the ground. Burnt bricks has the highest mean count rate of 0.0190 $\mu Sv/hr$ corresponding to the radiation absorbed dose rate of $0.16655\,mSv/y$ recorded at the 0.5 m vertical distance (see also Figures 2 – 7 for details).

Table 1. Mean count rate at various distance for different building materials using the Radiation meter.

S/N	BUILDING MATERIAL	PARAMETERS	DATA								
1	Aluminum Zinc	Distance (m)	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time (min.)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0201	0.0217	0.0174	0.0171	0.0157	0.0191	0.0154	0.0184	0.0181
		Actual Count Rates ($\mu Sv/hr$)	0.0050	0.0066	0.0023	0.0020	0.0006	0.0040	0.0003	0.0033	0.0030
		Mean Count Rates ($\mu Sv/hr$)	**0.0046**			**0.0022**			**0.0022**		
2	Asbestos Zinc	Distance (m)	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time (min.)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0175	0.0197	0.0178	0.0176	0.0175	0.0176	0.0154	0.0182	0.0173
		Actual Count Rates ($\mu Sv/hr$)	0.0024	0.0046	0.0027	0.0025	0.0024	0.0025	0.0003	0.0031	0.0022
		Mean Count Rates ($\mu Sv/hr$)	**0.0032**			**0.0025**			**0.0019**		
3	Zinc Nails	Distance (m)	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time (min.)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0172	0.0190	0.0179	0.0170	0.0152	0.0183	0.0165	0.0184	0.0153
		Actual Count Rates ($\mu Sv/hr$)	0.0021	0.0039	0.0028	0.0019	0.0001	0.0032	0.0014	0.0033	0.0002
		Mean Count Rates ($\mu Sv/hr$)	**0.0029**			**0.0017**			**0.0016**		
4	Concrete Blocks	Distance (m)	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time (min.)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0231	0.0164	0.0180	0.0169	0.0185	0.0166	0.0159	0.0172	0.0182
		Actual Count Rates ($\mu Sv/hr$)	0.0080	0.0013	0.0029	0.0018	0.0034	0.0015	0.0008	0.0021	0.0031
		Mean Count Rates ($\mu Sv/hr$)	**0.0041**			**0.0022**			**0.0020**		

S/N	BUILDING MATERIAL	PARAMETERS	DATA								
5	Burnt Bricks	Distance (m)	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time (min.)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0194	0.0391	0.0437	0.0191	0.0167	0.0168	0.0154	0.0170	0.0198
		Actual Count Rates ($\mu Sv/hr$)	0.0043	0.0240	0.0286	0.0040	0.0016	0.0017	0.0003	0.0019	0.0047
		Mean Count Rates ($\mu Sv/hr$)		**0.0190**			**0.0024**			**0.0023**	
6	Dangote Cement	Distance (m)	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time (min.)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0175	0.0177	0.0254	0.0182	0.0183	0.0161	0.0174	0.0191	0.0166
		Actual Count Rates ($\mu Sv/hr$)	0.0024	0.0026	0.0103	0.0031	0.0032	0.0010	0.0023	0.0040	0.0015
		Mean Count Rates ($\mu Sv/hr$)		**0.0051**			**0.0024**			**0.0026**	
7	POP Cement	Distance (m)	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time (min.)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0177	0.0208	0.0210	0.0169	0.0169	0.0163	0.0185	0.0154	0.0153
		Actual Count Rates ($\mu Sv/hr$)	0.0026	0.0057	0.0059	0.0018	0.0018	0.0012	0.0034	0.0003	0.0002
		Mean Count Rates ($\mu Sv/hr$)		**0.0047**			**0.0016**			**0.0013**	
8	Gravel Aggregate	Distance (m)	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time (min.)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0215	0.0199	0.0172	0.0165	0.0172	0.0195	0.0170	0.0165	0.0189
		Actual Count Rates ($\mu Sv/hr$)	0.0064	0.0048	0.0021	0.0014	0.0021	0.0044	0.0019	0.0014	0.0038
		Mean Count Rates ($\mu Sv/hr$)		**0.0044**			**0.0026**			**0.0024**	

9	**Sharp Sand**	**Distance (m)**	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time ($min.$)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0167	0.0185	0.0169	0.0154	0.0156	0.0164	0.0156	0.0174	0.0163
		Actual Count Rates ($\mu Sv/hr$)	0.0016	0.0034	0.0018	0.0003	0.0005	0.0013	0.0005	0.0023	0.0012
		Mean Count Rates ($\mu Sv/hr$)		**0.0023**			**0.0007**			**0.0013**	
10	**Red Sand**	**Distance (m)**	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time ($min.$)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0170	0.0220	0.0176	0.0159	0.0172	0.0187	0.0155	0.0155	0.0155
		Actual Count Rates ($\mu Sv/hr$)	0.0019	0.0069	0.0025	0.0008	0.0021	0.0036	0.0004	0.0004	0.0004
		Mean Count Rates ($\mu Sv/hr$)		**0.0038**			**0.0022**			**0.0004**	
11	**Clay Mud**	**Distance (m)**	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time ($min.$)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0212	0.0186	0.0182	0.0157	0.0168	0.0178	0.0166	0.0162	0.0164
		Actual Count Rates ($\mu Sv/hr$)	0.0061	0.0035	0.0031	0.0006	0.0017	0.0027	0.0015	0.0011	0.0013
		Mean Count Rates ($\mu Sv/hr$)		**0.0042**			**0.0017**			**0.0013**	
12	**Saw dust**	**Distance (m)**	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time ($min.$)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0206	0.0183	0.0189	0.0186	0.0155	0.0155	0.0166	0.0156	0.0156
		Actual Count Rates ($\mu Sv/hr$)	0.0055	0.0032	0.0038	0.0035	0.0004	0.0004	0.0015	0.0005	0.0005
		Mean Count Rates ($\mu Sv/hr$)		**0.0042**			**0.0014**			**0.0008**	
13	**Wood**	**Distance (m)**	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
		Time ($min.$)	1.0	5.0	10.0	1.0	5.0	10.0	1.0	5.0	10.0
		Count Rates ($\mu Sv/hr$)	0.0245	0.0180	0.0212	0.0166	0.0199	0.0175	0.0171	0.0165	0.0164
		Actual Count Rates ($\mu Sv/hr$)	0.0094	0.0029	0.0061	0.0015	0.0024	0.0024	0.0021	0.0014	0.0013
		Mean Count Rates ($\mu Sv/hr$)		**0.0061**			**0.0021**			**0.0016**	

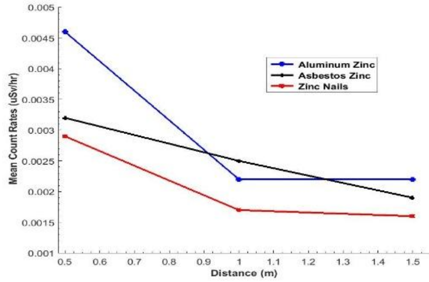

Figure 2. Mean count rate plotted against distance for Aluminum Zinc, Asbestos Zinc and Nails

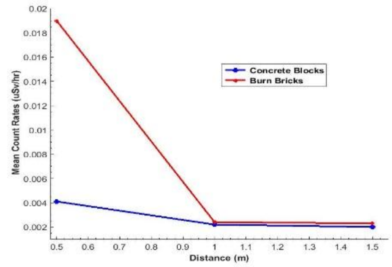

Figure 3. Mean count rate plotted against distance for Concrete Blocks and Burn Bricks

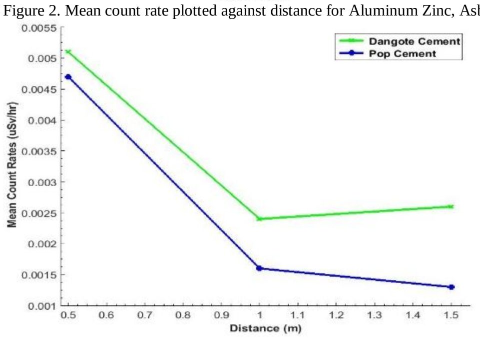

Figure 4. Mean count rate plotted against distance for Dangote Cement and Pop Cement

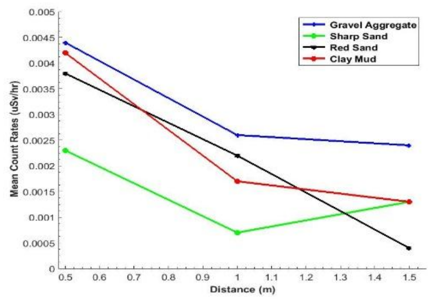

Figure 5. Mean count rate plotted against distance for Gravel Aggregate, Sharp and Red Sand, and Clay Mud

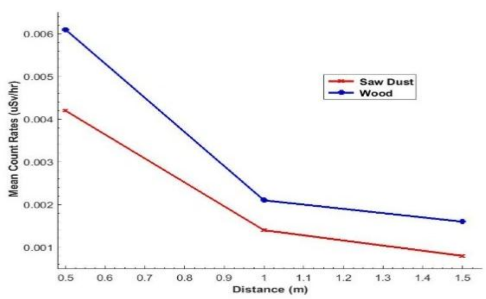

Figure 6. Mean count rate plotted against distance for Saw Dust and Wood.

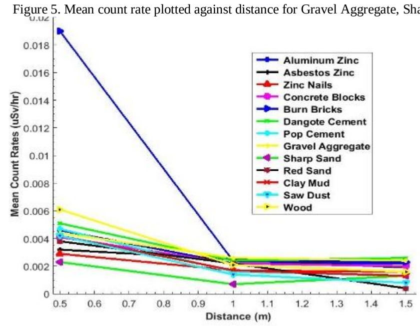

Figure 7. Mean count rate plotted against distance for Selected Samples.

5. Conclusion

In conclusion, the variation in the mean count rates observed to be exponentially linear in this work to the distance above the ground height indicates that the amount of radiation as recorded at the distances of 0.5 m compared to the distances of 1.5 m above the ground reveals how this radiation has no harmful effect on both humans and the animals that are at a reasonable distance from the source. The mean count rate of radioactivity measured in the thirteen (13) sampled building materials as recorded in Table 1 ranged from $(0.0004 - 0.019)\ \mu Sv/hr$. These results converted to radiation absorbed dose rate are equivalent to the range $(0.00351 - 0.16655)\ mSv/y$. Our results are lower than the recommended world average of less than $1\ mSv/y$ [1, 3, 5, 15, 18, 28 - 29]. Our results also varied marginally when compared with results of other radiation related studies in [2, 4, 9, 18].

This work further reveals that the building materials commonly used for construction work in Makurdi and by extension in Benue state are free from radiative elements that could cause serious damage to the artisans working on these sites. In this work, however, it has been established that the mean count rate obeys the inverse square law and that at distances away from the source, the measured count rate indicating the presence of radiation is very minimal and at the distances of 1.5 m from the radiation meter indicating the harmlessness nature of these materials to the human beings. This is to say that, to all the residents of the Makurdi and her environs, the small traces of the amount of radiation recorded here will have no adverse effect to the inhabitants of the town and her environs even in a long run.

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