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Indoor and Outdoor Gamma Dose Rate Exposure Levels in Major Commercial Building Material Distribution Outlets and Their Radiological Implications to Occupants in Ibadan, Nigeria

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Abstract

The indoor and outdoor gamma exposure levels at commercial distribution stores/shops where different brands of building materials are sold at Iwo road market in Ibadan, Nigeria have been determined. The direct measurements of the gamma exposure levels were made using a calibrated RADEYE G-10 gamma survey meter. Typical mean dose rate obtained in the stores/shops were 0.140 ± 0.01 µSv/h (indoor) and 0.124 ± 0.02 µSv/h(outdoor) for floor Tiles, 0.11± 0.01 µSv/h (indoor) and 0.103 ± 0.020 µSv/h (outdoor) for wall tiles and 0.098 ± 0.010 µSv/h (indoor) and 0.089 ± 0.020 µSv/h(outdoor) for water closet respectively. The calculated annual effective doses for indoor and outdoor were 0.520 ± 0.01 mSv and 0.46 ± 0.02 mSv for floor tiles respectively while it was 0.42 ± 0.01 mSv and 0.37 ± 0.02 mSv and 0.367 ± 0.01 mSv and 0.333 ± 0.02 mSv for wall tiles and water closet respectively. The results showed that the building materials at these stores/shops have slightly increased the natural radiation dose exposure levels in the area and to the occupants. The study also indicated that the occupants at the shops may be subjects for elevated levels of radon exposure due to confined space and poor ventilation.

Keywords: Indoor gamma exposure, Outdoor gamma exposure, Building materials, Building material shop outlets, Annual effective dose

1.0 Introduction

Man is continuously exposed to ionizing radiation from Naturally Occurring Radioactive Materials (NORM). The origin of these materials is the Earth's crust, but they find their way into building materials, air, water, food and the human body itself. The worldwide average indoor effective dose due to gamma rays from building materials is estimated to be about 0.4 mSv per year (UNSCEAR, 2000). In many parts of the world, building materials containing radioactive material have been used for generations. As individuals spend more than 80% of their time indoors, the internal and external radiation exposure from building materials creates prolonged exposure situations (ICRP, 1999). Most building materials of terrestrial origin contain small amounts of NORM, mainly radionuclides from the Uranium-238 (^{238}U) and Thorium-232 (^{232}Th) decay chains and the radioactive isotope of Potassium-40 (^{40}K). The external radiation exposure is caused by the gamma emitting radionuclides, which in the uranium series mainly belong to the decay chain segment starting with Radium-226 (^{226}Ra). The internal (inhalation) radiation exposure is due to Radon-222 (^{222}Rn), and marginally to Radon-220 (^{220}Rn), and their short lived decay products, exhaled from building materials into the room air (Papastefanou *et al*., 2005).

Adequate shelter is a prerequisite for socio-economic development of any society in the today's world. It provides coverage, comfort, protection and security (when indoors), and hence empower mankind to tackle the challenges of everyday life more easily. Adequate shelter is also vital for good governance including regional (space) plans, improvement of health and educational services. However, the fast growing use of recycled industrial by-products containing Technologically Enhanced Natural Occurring Radioactive Materials (TENORM) in the construction industry may extensively increase the levels of natural background radiation exposures in buildings (Papastefanou *et al*., 2005). Coal ash, produced as waste in the combustion of coal, is used as an additive to cement, in concrete and in some countries bricks are made from fly ash. Coal slag is used in floor structures as insulating filling material. Phosphogypsum, a by-product in the production of phosphorous fertilizers is used as building material, and red mud, a waste from primary aluminum production, is used in bricks, ceramics and tiles (Stranden, 1983; Somlai *et al*., 2008). Naturally Occurring Radioactive Materials (NORM) and rapid turn-over in Technologically Enhanced Natural Occurring Radioactive Materials (TENORM) is creating a major concern of elevated levels of public exposures not only in industrialized but also in developing countries like Nigeria. The challenge of public exposure is even of greater concern in developing countries because most of these countries lack the adequate structure and guidelines for measuring the public exposure and assessing the radionuclides contained in the building materials. This leads to the rapid use of these building materials, hence creating health risks to the general public (UNSCEAR, 2000). Radioactivity in building materials has the potential to expose large numbers of people. This exposure rate could result in relatively large additional exposures compared to that due to the natural background of about 2mSv/y. The foregoing indicates that the development of criteria to limit such possibilities should be encouraged.

National and International regulations and guidelines treat radioactivity in building materials as existing exposure situations rather than as planned exposure situations. Controls on the radioactivity concentration of building materials are based on dose criteria and on exemption levels. The dose criterion is established considering the overall national circumstances but it is thoroughly accepted that external doses exceeding 1 mSv/y should be taken into account from the radiation protection point of view. Restricting the use of certain building materials might have significant economical, environmental and social consequences at a local or national level. Such consequences, together with the existing national levels of radioactivity in building materials, should be assessed and considered when establishing binding regulations. But adequate shelter is a prerequisite for socio-economic development of any society in the today's world.

A number of authors have also reported measurements of radioactivity in various building materials used in Nigeria (Ademola, 2008; Ajayi, 1991; Farai and Ademola, 2005), but data are scarce on gamma exposure levels in stores and shops where different brands of building materials are stored and sold. In other words there have not been well established studies to assess the exposure levels, dose and the risk to building material store/shop keepers and the exposure scenario at the building materials shops and their warehouses given the confined space situations which may increase radon concentrations. Consequently, therefore, there is a general lack of awareness and knowledge of radiological hazards and exposure levels by operators (particularly operators of small businesses) and the public (IAEA, 2003; European Commission, 2000). Past research efforts indicate that building materials represent an important natural source of radioactivity, because they come into closest contact with humans (UNSCEAR, 1993). Thus, in this work, the gamma dose exposure levels in shops and store outlets where different brands of building materials are sold at the major market at Iwo road in Ibadan were determined. It was also geared towards determining the particular brand of building materials in these stores/shops that will present elevated levels of gamma dose exposure to the shopkeepers.

2.0 Materials and Methods

2.1 Selection of Sites

The Iwo road building material shops were selected for this study because it is the largest building material distribution outlets in Ibadan. It is beehives of daily activities for customers who come from different towns in the state and also from neighbouring states to buy different building materials for construction purposes. These building materials are usually displayed at the front of their shops while their warehouses filled with materials are located inside the shops. The implication of this system of business which is generally practiced by both small and medium size businesses involves long business hour stay time with these materials. Hence the exposure scenario is of concern given that these materials have elements of natural radioactive materials with their accompanying nuclear particle emissions. Of greater concern is the confine space and poor ventilation that characterize most of these shops and this may lead to high radon build up. The different shops housing different brands of building materials sold at Iwo road market were covered in the measurement. The different shops where measurements were made are presented in Table 1.

Table 1: Different Building Materials and Stores/Shops where measurements were made

S/N	Types of building materials sold at the shops	Number of shops
1	Floor tiles	15
2	Wall tiles	12
3	Water closet	16
4	Wash hand basin	6
5	PVC Ceiling	6
6	Iron rods, rings & binding Wires	5
7	PVC Pipes	6
8	Paints	5
9	Red Cement	3
10	Asbestos Ceiling	5
11	Terrazzo	2
12	Empty shops	6

2.2 Measurement

The instrument used to perform the environmental radiation survey is a RADEYE G-10 by Thermo Scientific with S/no-01524. It is a Geiger Muller base survey meter that is highly sensitive to gamma radiation. The detector was calibrated at National Institute of Radiation Protection and Research, a secondary standard laboratory certified by International Atomic Energy Agency (IAEA) and a division of the Nigerian Nuclear Regulatory Authority (NNRA). The characteristic features of this versatile new pocket meter are the small size, the ease and flexibility of operation and its superior measurement performance which is provided by the use of sophisticated low power technology. When accuracy is needed as required in this type of study, it is of importance to have a very high sensitive and reliable gamma-ray survey meter. Measurements at each sampling location were performed holding the survey meter at 1 m above the ground surface. Each measurement was repeated four times and the average taken to represent the value for the location.

3.0 Results and Discussion

3.1 Effective dose rate levels at the shops

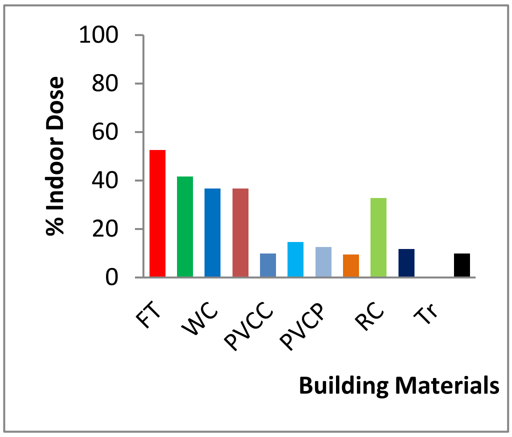
Exposure of persons due to the presence of these building materials in each of the shops was assessed assuming that exposure was uniformly distributed throughout the year based on 12 hours a day, 6 days a week and 52 weeks in a year for salesmen and shopkeepers that stay at their sales point from morning to evening and for six days in a week. This is the typical daily routine peculiar to the traders at the market. The range and mean values of the indoor and outdoor gamma exposure dose rate levels at the various shops are presented in Table 2 while the annual effective dose values are presented in Table 3. The background values in the tables indicate the environmental dose rate outside the building of the shops while the outdoor values are the dose values where the building materials are usually displayed for sales to prospective buyers. From Tables 2 and 3 it could be seen that indoor dose rates were higher than the outdoor and background values. This is a clear indication of the radiation dose contribution due to these building materials that are always in close proximity with the store keeper in their shops. As could be seen from the Table 2, the wall and floor tile shops exhibited higher dose rates compared to other types of shops. The average total annual effective doses due to outdoor and indoor gamma exposures were 0.99 mSv (Floor tiles) and 0.80 mSv (Wall tiles) while for water closest it was 0.70 mSv. The PVC ceiling materials recorded the lowest annual effective dose amongst all the others. The increase in effective dose in Tiles and Water closet could be associated with the presence of TENORM in ceramics and the source of the clay origin. The percentages of the mean doses for both indoor and outdoor exposures were calculated against 1 mSv and the distributions are shown in Figures 1 (a) and 1 (b) respectively for indoor and outdoor. Comparison of annual effective percentage of the indoor and outdoor doses at stores per type of building materials sold is shown in Figure 1(c).

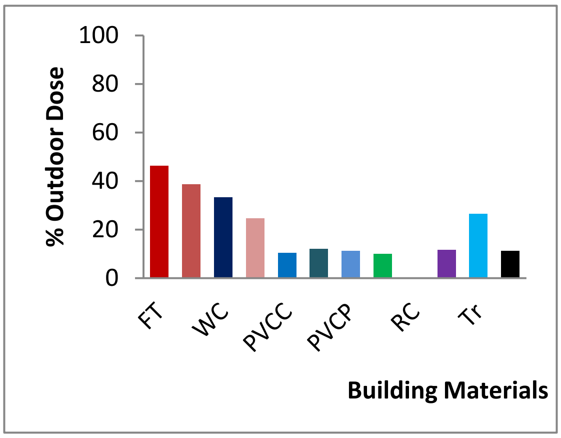
Table 2: The range of indoor and outdoor gamma dose rate levels at the shops and the background dose rate levels

S/N	Type of Building Material	Indoor (μSv/h)		Outdoor (μSv/h)		Background (μSv/h)
		Range	Mean ± SD	Range	Mean ± SD	
1	Floor Tiles	0.127 – 0.153	0.140 ±0.01	0.097 – 0.143	0.124 ±0.02	0.030±0.01
2	Wall Tiles	0.080 – 0.117	0.111 ±0.01	0.063 – 0.113	0.103 ±0.02	0.033±0.01
3	Water Closet	0.080 – 0.120	0.098 ±0.01	0.040 – 0.120	0.089 ±0.02	0.037±0.01
4	Wash Hand Basin	0.097 – 0.100	0.098 ±0.01	0.037 – 0.093	0.066 ±0.02	0.037±0.01
5	PVC Ceiling	0.023 – 0.033	0.026 ±0.01	0.023 – 0.033	0.028 ±0.01	0.027±0.01
6	Rings & Binding	0.033 – 0.047	0.039 ±0.01	0.027 – 0.037	0.032 ±0.01	0.033±0.01
7	PVC Pipes	0.030 – 0.033	0.033 ±0.01	0.027 – 0.033	0.030 ±0.01	0.027±0.01
8	Paints	0.023 – 0.027	0.025 ±0.01	0.026 – 0.027	0.027 ±0.01	0.030±0.01
9	Red Cement	0.037 – 0.137	0.087 ±0.06	No Item Displayed		0.033±0.01
10	Asbestos Ceiling	0.027 – 0.033	0.031 ±0.01	0.027 – 0.033	0.031 ±0.01	0.033±0.01
11	Terrazzo	No Item Displayed		0.070 – 0.072	0.071 ±0.01	0.030±0.01
12	Empty Shops	0.023 – 0.030	0.026 ±0.01	0.027 – 0.033	0.030 ±0.01	0.032±0.01

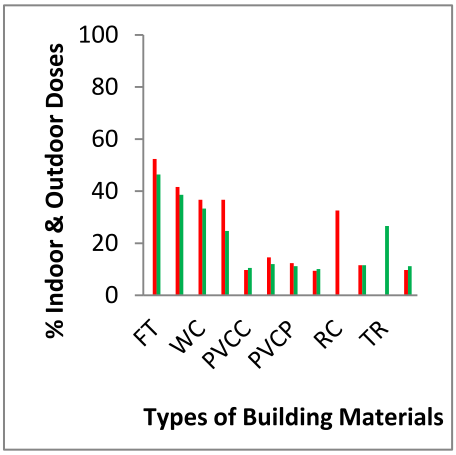
Table 3: Annual Indoor and Outdoor Effective Gamma Dose Levels.

S/N	Building Materials	Indoor Dose (mSv)	Outdoor Dose (mSv)
1	Floor Tiles	0.524 ± 0.01	0.464 ± 0.02
2	Wall Tiles	0.416 ± 0.01	0.386 ± 0.02
3	Water Closet	0.367 ± 0.01	0.333 ± 0.02
4	Wash Hand Basin	0.367 ± 0.01	0.247 ± 0.02
5	PVC Ceiling	0.097 ± 0.01	0.105 ± 0.01
6	Rods, Rings & Binding	0.146 ± 0.01	0.120 ± 0.01
7	PVC Pipes	0.124 ± 0.01	0.112 ± 0.01
8	Paints	0.094 ± 0.01	0.101 ± 0.01
9	Red Cement	0.326 ± 0.06	No Item Displayed
10	Asbestos Ceiling	0.116 ± 0.01	0.116 ± 0.01
11	Terrazzo	No Item Displayed	0.266 ± 0.01
12	Empty Shops	0.097 ± 0.01	0.112 ± 0.01





(a) - Indoor (b) – Outdoor



(c)

. % Indoor Dose, . % Outdoor Dose

Key: FT = Floor Tiles, WT = Wall Tiles, WC = Water Closet, WHB = Wash Hand Basin, PVCC = PVC Ceiling, RRBW = Rods, Rings & Binding Wires, PVCP = PVC Pipes, RC = Red Cement, AC = Asbestos Ceiling, Tr = Terrazzo and ES = Empty Shops

Figure 1: Annual Effective % Indoor and outdoor Dose of Building Materials

3.2 Radiological Consequences of the Effective Dose Rate Level and Regulatory Control

The linear dose response relationship in which the probability of a stochastic effect is proportional to the absorbed dose is assumed in this work. It implies that any radiation exposure, no matter how small, involves some degree of risk. That is, there is a finite probability that the exposed individual will incur some deleterious stochastic effects. The risks of different health effects are mutually exclusive, so that the total risk, R of the different effects on an individual is given by:

$$R = \sum_i P_i \qquad (1)$$

where P_i is the probability that the individual will have an effect i. For a homogeneous group of N persons, the collective health detriment G is given as:

$$G = N \sum_i P_i g_i \qquad (2)$$

where g_i is the severity factor of the effect i. For lung cancer and most severe cancers which are fatal, the value of g = 1, while for skin cancer and other non-lethal cancers, g < 1. Generally, the evaluation of P_i is very complex because exposure to a given type and quantity of radiation can produce effects of varying nature and severity depending on the species of organism and tissue of the system exposed. Other parameters, which must also be considered include age, sex, life style, drugs and diet of the exposed individual which may under certain conditions affect radiosensitivity. The effective dose equivalent H_E due to a radiation exposure of an individual is therefore given by

$$H_E = \sum_T H_T W_T \qquad (3)$$

Since we assumed a direct non-threshold probability between dose equivalent and probability of effects for low level doses, it follows that the collective detriment on the health of a group of N people is proportional to the collective effective dose equivalent resulting from an exposure. That is:

$$G = NR_T H_E \qquad (4)$$

where R_T is the constant of proportionality called the total risk factor.

From equations 1 to 4 it could be seen that even though the dose levels were low since the highest values were far below 1mSv for each exposure scenario, however there could be prolong biological effect from the exposure following the life style of the shop keepers. Also for the floor and wall tiles their dose level exceeded 0.3 mSv recommended by the Israeli's Standard Institute, 2007. Control on the radioactivity of building materials can be based on dose criteria for controls and on exemption levels. The dose criteria used for control should be defined as the excess exposure caused by building materials. That is the background dose from natural radionuclides in the local typical environment need to be subtracted. For the external gamma radiation, the local typical environment can be defined either as the average dose received outdoors, or as the average dose received in a house built from materials with typical activities. The national median exposure level must be taken into account when setting a dose criterion. With a median exposure level of 0.28mSv arising from building materials at Iwo road market, a dose criterion of 0.58mSv may be considered that will not cause economically and socially intolerable situations on the market. When gamma doses are limited to levels below 1 mSv/y, it is recommended that controls could be based on a lower dose criterion if it is judged that this is desirable and will not lead to impractical controls. It is therefore recommended that controls should be based on doses in the range 0.3 – 1 mSv/y. This is the excess gamma dose to that received outdoors. Building materials should be exempted from all restrictions concerning their radioactivity if the excess gamma radiation originating from them increases the annual effective dose of a member of the public by 0.3 mSv at the most. This is the excess gamma dose to that received outdoors. It therefore follows that salesmen and shopkeepers at the major market, Iwo road, Ibadan should spend less time, say, about 10 hours a day for 6 days in a week throughout 50 weeks in a year, in order to limit their levels of exposure.

4.0 Conclusion

The gamma exposure levels in some selected building material stores/shops at the major building material market at Iwo road, Ibadan, Nigeria have been carried out in order to assess their radiological consequences to the storekeepers. The results showed that the radiological hazard parameter values were below the internationally accepted limit of 1 mSv/y for the general public. This is also an indication that the different brands of building materials in the stores/shops may not pose any significant radiation hazard to individual storekeepers who do their daily businesses at those shops. However, because of confined space and very poor ventilation, these sales men may be subjects for high radon inhalation.

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