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Investigation on the Background Radiation of Abakaliki Rice Mill in Ebonyi State, Nigeria

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ABSTRACT

This study investigated the background ionizing radiation of Abakaliki rice mills. The requirement to monitor this site is because the prevalent activities in the site suggest that it is a source of ionizing radiation. The activities include fuel stations and excavation sites. Other sources are various chemicals and agrochemicals (like Phosphate, Uranium, Thorium, and Radium) used during the planting of the different rice species. There is, therefore, an urgent need to investigate the radiation level of Abakaliki rice mills in Ebonyi state, Nigeria to ascertain if it has passed the safety standards. The investigation was carried out using the Radalert 100 radiation monitor and a geographical positioning system (Garmin GPSMAP 765). The studied site was split into different points with each representing a mill that houses different grinding plants. This study included all the sections of the mill. The mean background radiation exposure rate ranges from 0.014 $mRhr^{-1}$ to 0.0204 $mRhr^{-1}$. The obtained values are higher than the world standard limit of 0.013 $mRhr^{-1}$ recommended by ICRP except point 7 which corresponds to the top of the rice husk dumpsite. The calculated absorbed dose rates for the various sections of the mill ranged from 99.18 nGh^{-1} to 177.48 $nGyh^{-1}$. These values of absorbed dose rates were observed to be far higher than the world permissible value of 89 $nGyh^{-1}$. The annual effective dose equivalent (AEDE) for the exposure values ranged from 0.122 $mSvy^{-1}$ to 0.218 $mSvy^{-1}$ which are far lower than the ICRP permissible limits of 1.00 mSvlyr for the public and therefore implies absence of any immediate radiological risk. The excess lifetime cancer risk for the mill users were all above the 0.29×10^{-3} world recommended value. This suggests a possibility of the rice mill workers developing radiation-related illnesses over time.

INTRODUCTION

Radiation can be generally described as the emission, transmission and the absorption of waves and particles from a source through space or material medium [1]. Background radiation is defined by the International Atomic Energy Agency as "Dose or dose rate (or an observed measure related to the dose or dose rate) attributable to all sources other than the one(s) specified. It is, therefore, a measure of the level of ionizing radiation present in the environment at a particular location which is not due to the deliberate introduction of radiation sources [2]. It originates from a variety of sources, which can either be natural or artificial and consisting danger both to human health and to the environment [2].

Gooniband *et al.* [3] reported that approximately 85 % of human-absorbed radiation doses come from naturally radioactive materials. Most of these materials which are present in the earth's crusts arise from natural sources such as outer space (cosmic), terrestrial and exposure from inhaled and exhaled radiation sources. These radioactive nuclei can be found in the water we drink, the food we eat, soil, rock, and even our building materials. The accumulation of this radiation impacts on humans, plants, and animals [3].

Dobrzyński *et al.* [4] reported that there was no place on earth without natural background radiation. Life in these areas of natural radiations comes with its adaptive features which allow for survival and evolution. Dobrzyński *et al.* [4] also reported that background radiation has not been proved to be the cause of acute diseases such as cancer. This was corroborated by the findings of Demoury *et al.* [5].

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In spite the above reports, several studies have been carried out both globally and locally to ascertain the level of ionizing radiation on human health and the environment.

Global studies include the research done on the atomic bomb survivors of the popular Hiroshima and Nagasaki in Japan which showed that there was a remarkable increase in acute leukemia risks and striking effects of radiation exposure seen among the survivors [6]. However, the research revealed that both the leukemia risks and exposure rate generally dropped at certain age [7].

Sahoo *et al.* [8] while studying the natural radioactivity level and elemental composition of soil samples of High Background Natural Radiation (HBNR) area of Odisha, the eastern coast of India found out that the level of activity concentration for ^{228}Ra, ^{228}Th and ^{40}K were 130 ± 97, 1110 ± 890 and 360 ± 140 BqKg^{-1} respectively. They also calculated the effective dose rate and found that its values ranged from 0.14 ± 0.02 to 2.15 ± 0.26 mSv. This was higher compared to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) annual worldwide average value of 0.01 mSv.

Furthermore, the research conducted on very high background radiation areas of Ramsar in Iran showed that Ramsar received annual radiation absorbed dose from background radiation whose level was 260 mSvy^{-1}[9]. This value is substantially very high.

Computed data of the sources of exposures to the Indian population has been assessed and it was discovered that India has a total natural radiation contribution to be 2.3 mSvy^{-1} against the global value of 2.4 mSvy^{-1}. This was because there were activities such as the mining of heavy metals, mining of phosphate rocks, use of phosphate rocks as fertilizers, uses of coal-fired plants, production of natural gases, atmospheric weapon tests, medical exposure due to medical applications of radiation, air travel contributions, and lastly exposures due to nuclear power productions [10]. Every living organism is in the midst of a radiation environment and we need to be conscious of these facts and make constant efforts to control the man-made radiations to be at levels as low as reasonable [10].

Among the local studies is an evaluation of radiation indices and excess life cancer risk within Uyo, Unity Park, Uyo, Nigeria with a reported average dose rate of 0.116 μSvhr^{-1} [11]; measurements of surface dose rate of nuclear radiation in coastal areas of Akwa Ibom State, Nigeria where average dose rate of 0.12 μSvhr^{-1} (0.012 μRhr^{-1}) was reported and which is below International Commission on Radiological Protection (ICRP) set standard of 1.0 mSvyr^{-1} [12]; the measurement of BIR from some selected refuse dumpsites in Yola Metropolis, Nigeria with the mean BIR values in all the five dumpsites as 0.132 ± 0.021 μSvhr^{-1} (0.015 ± 0.002 mRhr^{-1}) [13]. The results showed that the average dose equivalent obtained for most locations within the study areas were above the standard background radiation of 0.013 mRhr^{-1} as recommended by ICRP.

Ayua *et al*. [14] reported that mining workers and the neighboring inhabitants of the mining sites have been for a long time exposed to ionizing radiation with or without their consent. Sadiq *et al.* [15] found the effective dose equivalent at Maloney Hill Quarry in Keffi to be 1.75 mSvy^{-1}. They also measured the background radiations in the mines area of Nasarawa state (Alizaga Quarry) and observed that the area had a maximum reading of 2.60 mSvy^{-1}. They noted that the Alizaga stone quarry in Nasarawa Egon had the highest background radiation equivalent dose rate at the excavation point while Oleishi barite mine had a quite low radiation level measured at some other locations [15]. They concluded that the levels of the radiation were within the healthy range of the Nigerian Basic Ionizing Radiation Regulation standards [16].

Assessment of the Indoor and Outdoor BIR of Sheda Science and Technology Complex, Abuja revealed both the Annual Effective Dose Equivalents (AEDE) and Effective Doses are below the dose limit of 1.0 mSv as recommended by ICRP [17]. Ife-Adediran and Uwadiae [18] evaluated background ionizing radiation from different buildings in Lagos and Ibadan, Nigeria and found the indoor dose rates to be within the world average values while the AED for most of the buildings were above the world average for indoor gamma exposure from building materials. A baseline study of terrestrial outdoor gamma dose rate levels in Nigeria revealed that the mean annual effective dose equivalent in Nigeria is 0.27 mSvy^{-1} [19].

Milling of rice is an important activity in the food chain of the world economies. Shrestha *et al*. [20] reported that rice feeds more than half of the world's population and according to Nasrin *et al*. [21] it is the major staple food in African countries including Nigeria. About 85 % of the total production of rice is meant for human consumption [22]. Rice is reported as the most consumed food in Nigeria and this cut across all economic classes where it is eaten in different recipes [23]. The rice milling industry in Nigeria is capable of contributing significantly to employment generation, economy-boosting, and food security [24].

Today rice milling has emerged as one of the major industrial activities in various scales to cater to the increasing population of large number of millers engaged in processing due to industrialization and global competitiveness. Milling of rice has spread over in some states across the country and it has high pollution in some of its processes.

The process of cleaning the paddy, parboiling of paddy and milling of rice causes a high level of pollution. Primary and secondary cleaning of paddy causes solid waste and fugitive emissions in the work environment [25]. The coal and husk generate fly, smoke, suspended particulate matter and oxides of carbon. Dey and Mistri [26] reported that effluent elements of rice mills create water, air, and land pollution and if left unchecked may present significant environmental problems both on-site and the surrounding locality.

Globally, the industrial sector has been responsible for a "significant percentage" of all environmental damage and pollution among which background ionizing radiation has been at the front burner. Abakaliki has the largest indigenous rice mill in Nigeria. The Abakaliki Rice Mills Company Ltd has above 5,000 workforce, 2,500 rice milling machines plus a production capacity of more than 11,000 metric tons per month [27]. Several tonnes of rice husks are produced every year as a by-product of rice processing at Abakaliki rice mills. This calls for the need to investigate the radiation emanating from Abakiliki rice mills and its environment and to provide data as part of environmental monitoring research for proper assessment of radiation exposure rate of the population of the Abakaliki rice mill in Ebonyi State, Nigeria.

The aim of this work was to ascertain if the background radiation of Abakaliki rice mills constitutes any radiological risk. To do this effectively, the underlisted radiation indices were obtained and compared with the International Commission on Radiological Protection (ICRP) standards:

- The Background Ionization Radiation (BIR) level of the rice mills
- The radiation absorbed dose rate (ADR) of the various mills
- The annual effective dose equivalent (AEDE) of the rice mills and its environment and
- The excess life time cancer risk (ELCR) of the study area.

MATERIALS AND METHODS

This study was carried out in eight different mill stations of the Abakaliki rice mills (Fig. 1) using radiation meter, a Geographical Positioning System (GPS), and a constructed stand of 1m above the ground. The radiation meters used in this work for measurement of background ionizing radiation was the Radalert-100. The choice of this meter was based on its portability, sensitivity and response which are appropriate for radiation measurement of low radiation field [28]. The Radalert 100 uses a Geiger-Muller tube to detect α, β, γ, and x-rays. A pulse of electrical current is produced by the Geiger tube any time radiation passes through it and results in ionization which the CPU registers as counts and is displayed on the screen. The Radalert 100 displays the counts in the mode you choose: counts per minute (CPM), mill roentgen per hour ($mRhr^{-1}$), or total counts for a timed period. In SI units, counts per second (CPS) and micro Sieverts per hour ($\mu Svhr^{-1}$) are used. The procedure for calibration is as reported in the monitors' operating manual [29]. Measurements from the Radalert-100 monitor were acquired in units of $mRhr^{-1}$.

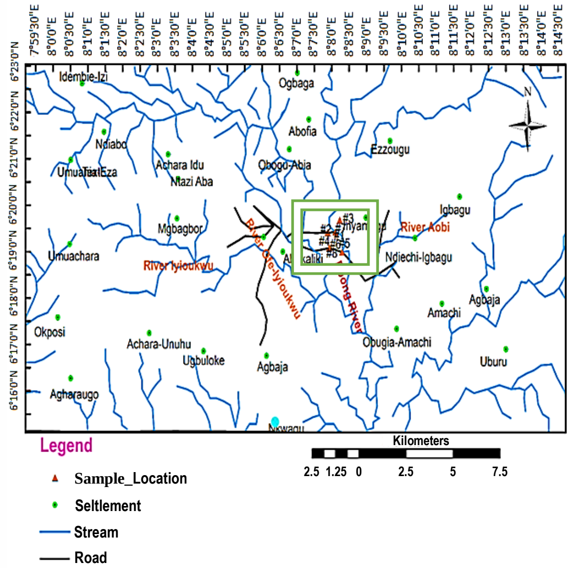

Fig. 1. Map of Abakaliki Metropolis, indicating the studied points of the rice mills.

The method of radiation measurement employed in this work was direct observation and measurement of radiation levels from the rice mill area visited with the above-mentioned detector. The detector was held one meter above the ground surface for the entire rice mill selected areas visited and readings were taken. Each reading was repeated ten times at four-minute intervals to account for any error due to fluctuation in the environment parameters [30]. For each of the selected rice mill sections, the mean Background Ionizing Radiation (BIR) reading of each set of ten measurements was obtained and denoted as mean BIR exposure rates for each point. The mean BIR exposure rates obtained were quantitatively used to assess the radiation health impact to workers within the immediate environment of the rice mill by performing several radiological health indices calculations such as absorbed dose rate, annual effective dose equivalent and excess lifetime cancer risk using the necessary relations given by Rafique *et al*. [31] and Ezekiel [30].

The radiation absorbed dose rates were evaluated using Eq. (1).

$$1\ \mu Rh^{-1} = 8.7\ \eta Gyh^{-1} \quad (1)$$

The computed absorbed dose rates were used to calculate the annual effective dose equivalent (AEDE) using Eq. (2).

$$AEDE = ADR\ (\eta Gyh^{-1})\ x\ 8760\ h\ x\ 0.7\ (SvGy^{-1})\ x\ 0.2 \quad (2)$$

ADR equals the absorbed dose rate in ηGyh^{-1}, 8760 equals the total hours in a year, 0.7 Sv/Gy equals the dose conversion factor from absorbed dose in the air to the effective dose using an occupancy factor of 0.2 for outdoor exposure as recommended by UNSCEAR (2008).

The excess lifetime cancer risks were evaluated using the annual effective dose values by employing Eq. (3).

$$ELCR = AEDE\ (mSvy^{-1})\ x\ DL\ x\ RF \quad (3)$$

where AEDE is the annual effective dose equivalent, DL is average duration of life (70 years) and RF is the fatal cancer risk factor per sievert (Sv^{-1}). For low-dose background radiation, which is considered to produce stochastic effects, ICRP 103 uses a fatal cancer risk factor value of 0.05 for public exposure [32].

The position of each location at which radiation dose rate measurement took place was recorded with the help of global positioning system (GPS). The global positioning system (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the earth. It is maintained by the United States Government and is freely accessible to anyone with a GPS receiver.

RESULTS AND DISCUSSION

These results of the BIR exposure level measurements and the associated radiological health parameters for the Abakaliki rice mill are given in Tables 1 and 2 below. Figure 2 represents a comparison of the background ionizing radiations (BIRs) in the mills with recommended ICRP limits.

The BIR levels for the rice mill range from 0.005 to 0.033 mRh^{-1} with a total mean value which ranges from 0.0114 mRh^{-1} to 0.204 mRh^{-1} (Table 1). The BIR of those at point 1 ranges from 0.009 mRh^{-1} to 0.033 mRh^{-1} with a mean value of 0.0204 mRh^{-1}. Points 2 and 4 have minimum values of 0.009 mRh^{-1} and maximums as 0.021 mRh^{-1} and 0.019 mRh^{-1} respectively. They both share the same mean BIR value of 0.0162. Points 3 and 5 have BIR values which ranged from 0.008 mRh^{-1} to 0.022 mRh^{-1} and 0.011 mRh^{-1} to 0.017 mRh^{-1} respectively. They have the same mean values of 0.015 mRh^{-1}. Those of point 6 has values that range from 0.012 mRh^{-1} to 0.022 mRh^{-1} with its mean value as 0.0178 mRh^{-1}. The BIR values at Point 7 range from 0.009 mRh^{-1} and 0.014 mRh^{-1} with a mean value of 0.0114 mRh^{-1}. Similarly, Point 8 has BIR values which range from 0.011 mRh^{-1} to 0.021 mRh^{-1} with an average of 0.163 mRh^{-1}.

Table 1. Result of background ionizing radiation of the different sections of the mill

S/N	Point 1 (mRh^{-1})	Point 2 (mRh^{-1})	Point 3 (mRh^{-1})	Point 4 (mRh^{-1})	Point 5 (mRh^{-1})	Point 6 (mRh^{-1})	Point 7 (mRh^{-1})	Point 8 (mRh^{-1})
1	0.009	0.019	0.009	0.009	0.017	0.018	0.012	0.013
2	0.020	0.021	0.017	0.020	0.013	0.017	0.011	0.018
3	0.022	0.018	0.017	0.018	0.017	0.012	0.010	0.016
4	0.017	0.016	0.017	0.020	0.011	0.021	0.009	0.019
5	0.016	0.018	0.019	0.014	0.013	0.016	0.013	0.021
6	0.019	0.018	0.008	0.017	0.014	0.018	0.020	0.011
7	0.025	0.015	0.022	0.019	0.016	0.019	0.005	0.016
8	0.033	0.018	0.017	0.015	0.017	0.022	0.009	0.015
9	0.019	0.010	0.016	0.014	0.020	0.013	0.014	0.014
10	0.024	0.009	0.015	0.016	0.013	0.022	0.011	0.02
Mean	**0.0204**	**0.0162**	**0.015**	**0.0162**	**0.0151**	**0.0178**	**0.0114**	**0.0163**

Table 2. Radiation health indices associated with BIR in various sections of the mill.

			Radiation health indices		
Points	**Geographical Location**	**Mean BIR**	**ADR ($nGyh^{-1}$)**	**AEDE ($mSvy^{-1}$)**	**ELCR ×10^{-3}**
1	N06°19'22.4" E008 °08'01.5"	0.0204	177.48	0.218	0.763
2	N06°19'16.7" E008 °08'03.1"	0.0162	140.94	0.173	0.606
3	N06°19'44.0" E008 °08'08.2"	0.0157	136.59	0.167	0.585
4	N06°19'09.5" E008 °08'06.4"	0.0162	140.94	0.173	0.606
5	N06°19'03.1" E008 °08'02.3"	0.0151	133.37	0.161	0.564
6	N06°19'10.1" E008 °08'00.4"	0.0178	154.86	0.190	0.665
7	N06°19'22.8" E008 °08'00.9"	0.0114	99.18	0.122	0.427
8	N06°19'12.9" E008 °08'03.0"	0.0163	141.81	0.174	0.609
Mean		**0.01691**	**147.38875**	**0.1805**	**0.657**

Points 1 and 7 have the highest and the lowest mean values of BIR respectively. As can be observed in Fig. 1, all the points except point 7 exceed the 0.013 mRh^{-1} recommended ambient BIR exposure level [32]. The variations in BIR can be attributed to the various agrochemicals and fertilizers used during the planting of the different rice species. The high values of BIR can further be attributed to the presence of fuel stations and excavation sites around the mills. Different geological and geophysical characterization of the environments can also contribute to these variations in BIR [33].

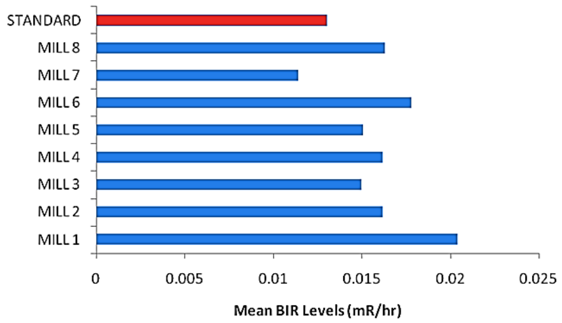

Fig. 2. Comparison of BIRS in the mills with recommended ICRP limits

The radiation health indices associated with BIR in the mills with its corresponding mean absorbed doses and annual effective dose equivalent are shown in Table 2. The mean absorbed dose of BIR exposure is 147.3887 $nGyh^{-1}$ while the mean annual effective dose equivalent of the mill is 0.1804 $mSvy^{-1}$. The absorbed doses in the entire rice mills are far higher than those reported in literature [8-15,19] and also above the recommended safe limit of 84.0 $nGyh^{-1}$ [34,35]. Radiation levels increase as one gets closer to the source, so the high amount of absorbed radiation recorded in this work may have come from the rice grain and husks which the workers are always in contact with. The radiation may be attributed to their radioactive mineral content and the geological, geochemical and geographical origins of the raw materials used in rice production. Another reason for high absorbed doses is the absence of shielding materials like trees.

The annual effective dose is a radiation protection index that quantifies the whole-body absorbed dose per year [33]. The values for the annual effective dose for all the mills' section in this study are lower than the ICRP permissible limits of 1.00 $mSvyr^{-1}$ for the general public [32]. This indicates that the studied areas are in good agreement with the permissible limit. The absorbed dose rates arising from the BIR levels in the mills and the annual effective radiation doses at these rates do not constitute any immediate radiological health effect on the rice mill workers and the general public. The values of the absorbed doses obtained in this present work are higher when compared with world recommended values.

The values for the cancer risks obtained in this work are far higher than the average value of 0.29 x 10^{-3} as recommended by UNSCEAR [34,36]. The implication of this is that workers and members of the public who visit the mill on daily basis to either buy, sell or get the husk of the different rice species and end up spending long hours within the milling industry are likely to develop cancer at ages of 65 to 70 years or above of their lifetime. The radiation levels in the compound and environs of the rice mill must be monitored against any further increase.

CONCLUSION

The study has revealed that the background ionizing radiation of most of the different sections of the Abakaliki rice mill is higher than the ICRP recommended values except at the rice husk dump section. This can be attributed to the presence of petrol stations within and around the site, the geological and geographical settings of the areas. Other reasons for high background radiations may include contributions of fertilizers and agrochemicals used during the rice planting. Though the mean absorbed dose rate of BIR radiation of each of the mills is higher than the standard limit, it does not pose any immediate radiological risk. This is because the calculated values for the annual effective dose of the mills are all lower than the ICRP permissible limits. The calculated excess lifetime cancer risk values are all far above the recommended average value – which implies that people who live or work close to the rice mills and who spend long time there have the potential of developing cancer from the ages of 65 years and above. In spite of that the result shows that Abakaliki rice mills do not constitute immediate radiological risk both to human health and the environment; there is no guarantee, however, that they will not pose threat even in the nearest future. Consequently, regular radiological monitoring of Abakaliki rice mills is recommended, and the data are considered as a radiological baseline for all the rice mills in Ebonyi State. This should also be extended to the unmonitored rice mills especially those located within public facilities and residential areas like the ones studied in this work.

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AUTHOR CONTRIBUTION

A.N. Nwachukwu, C.F Ikeagwuani and A.O. Adeboje equally contributed as the main contributors of this paper. All authors read and approved the final version of the paper.

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