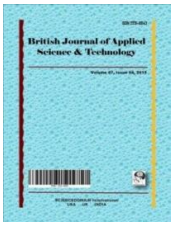

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Characterization of Radiation Exposure Dose Rate from Waste Dumpsites within Owerri, Nigeria: An Atmospheric Concern

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Authors' contributions

This work was carried out in collaboration between all authors. Author UKO designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed literature searches. Authors ID, C. Chineke, CG and C. Chukwunyere managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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Short Communication

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ABSTRACT

This work evaluated the exposure dose rates emanating from five (5) selected waste dumpsites within the Owerri metropolis, Nigeria. The objectives are to measure the dose rates emanating from the selected dumpsites, evaluate the rates at which the radiation exposures diminished with distance at each dumpsite, show the relationship between the emissions emanating from each dumpsite within the metropolis and identify "Safety Zone", which defined safe regions that can mitigate increased exposure dose rates. The data were acquired by a portable radiation survey meter (Radalert-100) and analyzed using descriptive statistics. The results show that all the waste dumpsites emit radiation that exceeds the ICRP recommended maximum permissible limit of 11.4 μR hr^{-1} for members of the public. However the radiation exposure dose rate obeying the inverse

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square law were observed to diminish with varying distance from the linear regression equation of the trends having rate values of -0.398 μR hr^{-1} m^{-1}, -0.266 μ R hr^{-1} m^{-1}, -0.348 μR hr^{-1} m^{-1}, -0.369 μR hr^{-1} m^{-1}, -0.237 μR hr^{-1} m^{-1} and -0.323 μR hr^{-1} m^{-1} for dumpsites 1 to 5 and the areal average respectively. The exposure dose rate at each of the dumpsites significantly correlated to one another and to the areal average at 95% confidence level, then the attributes of one waste dumpsite stands for the other. The "Safety Zone" from all waste dumpsites was computed from the linear regression equation of the trends. This study is imperative as it point at a way in mitigating radiation exposure dose rates from waste dumpsites in developing cities around the world with similar attributes to Owerri metropolis, Nigeria.

Keywords: Radiation; exposure dose rate; waste dumpsite; Owerri metropolis; safety zone.

1. INTRODUCTION

Synonymous with every growing city within the developing world is its inability to manage the waste it generates. The constituents of these wastes, which are usually complex blends of biodegradable and non-biodegradable substances, are compositions of both the domestic and industrial wastes that are indiscriminately dumped around these cities [1]. These waste dumpsites pose serious threat to the environment through their odor, presence of disease causing micro-organism, as well as the radiation emanating from them [1-3]. An example is the threat from electronic wastes (e-waste) generation. Its trans-boundary movement and disposal has been of utmost concern globally due to its rapid and uncontrollable growing rate [4-7]. The e-waste has been identified as the major source of Lead (Pb) in waste dumpsites, which contaminates the environment [6,8,9].

The measurement and characterization of the radiation exposure dose rates emanating from waste dumpsites are imperative as it shows the level of risk and possible long term effects on people, if not adequately managed. Radiation is the emission of energy in the form of particles or waves [10-12]. Ionizing radiation is produced by radioactive materials that decay spontaneously whereas it damages any living tissue in the human body in a unique way [7,13]. Radioactive pollution, which is the release of these radioactive materials into the environment, mutates DNA thereby causing abnormal growth and possibly cancer since it remains in the atmosphere for years, slowly diminishing over time [14]. Estimates of dose contribution of ionizing radiation in the environment showed that 85% are derived from natural radionuclides while 15% are from cosmic rays and nuclear processes [2,10,14]. A number of studies have measured the activity concentration of natural radionuclides in soil in order to determine level of contamination [2,15-26]. Recent science proposed existence of some threat from any exposure to radiation as effects from small or even moderate exposures may not be noticeable since the damage occurs at the cellular level [10,12]. The probability that cancer will result from radiation exposure increases as the dose increases [7,13]. The likelihood of developing cancer, not the gravity of the cancer, will be on the increase with increasing radiation dose. Cancer risk does not materialize until years after the exposure such as 50 years after exposure for breast cancer [10,12].

Studies have shown that the stochastic health effects (i.e. the probability of occurrence regarded as a function of dose without threshold) are associated with long term, low level (chronic) exposure to radiation [7,27]. The International Commission on Radiation Protection (ICRP) recommends a maximum permissible limit of 11.4 μR hr^{-1} for members of the public, which quantifies radiation dose limit based on the latest scientific findings [13,27,28]. In view of the above, this work characterized the radiation exposure dose rates emanating from selected waste dumpsites within Owerri metropolis, Nigeria as it contributes to atmospheric pollution. The objectives of this study are to present the dose rates emanating from the dumpsites, evaluate the rates of change of concentration with distance from each dumpsite, show the relationship between the emissions emanating from each dumpsite within the Metropolis and identify safe zone, which is a tool in mitigating radiation exposure dose rates from waste dumpsites. It is noteworthy that the scope of this work does not include the nature of the radiation from the dumpsites.

2. SITE AND DATA ACQUISITION

Fig. 1 shows the map of Owerri metropolis, which is one of the major cities in the Niger Delta region of Nigeria, and comprising of three administrative Local Government Areas of Owerri North, Owerri

West and Owerri Municipal respectively [29,30]. It extends over 100 km^2 and has an estimated population of about 400,000 [31]. There are Rivers Nwaorie and Otamiri, which serves as major sources of water to the metropolis. The metropolis has rain forest vegetation and shows trend of increasing monthly rainfall variability with mean annual rainfall and global solar power of about 2400 mm/yr and 4.82 kW h respectively [32-35]. The metropolis does not have any legislative or laws that regulate the position of dumpsites with respect to populated area. The five waste dumpsites selected for this study duly represent the three Local Government Areas of the metropolis as shown on Table 1. The choices of these dumpsites were due to heavy human activities (both residential and commercial) around them. Although the constituent of these waste dumpsites and the nature of emitted radiation is not the scope of the study, analysis to show the linear relationship of the radiation exposure dose rates from them was investigated. Fig. 2 shows a typical scene around any of the waste dumpsites within the metropolis with scavengers all over it as well as commercial activities.

The data of radiation emissions from the waste dumpsites were acquired using a portable radiation survey meter (Radalert-100), which measures the dose rate or exposure in mixed field [1]. The Radalert-100 uses a Geiger-Muller tube (GM) to detect radiation, which generates a pulse of electrical current each time radiation passes through the tube and causes ionization. The working range for the measurements are obtained for subdivisions of mR hr^{-1}, mSv hr^{-1} or Counts per minute (CPM) depending on the level of radiation. Data were obtained for the daily peak radiation emissions from the waste dumpsites for a period of seven (7) days at distances of 0 m (right on top of the dumpsite), 1 m, 5 m and 10 m respectively. The choice of these distances is to investigate the exposure dose rate on scavengers (0 m), pedestrians (1 m), passengers on vehicles (5 m) and residents (10 m) found around the various waste dumpsites.

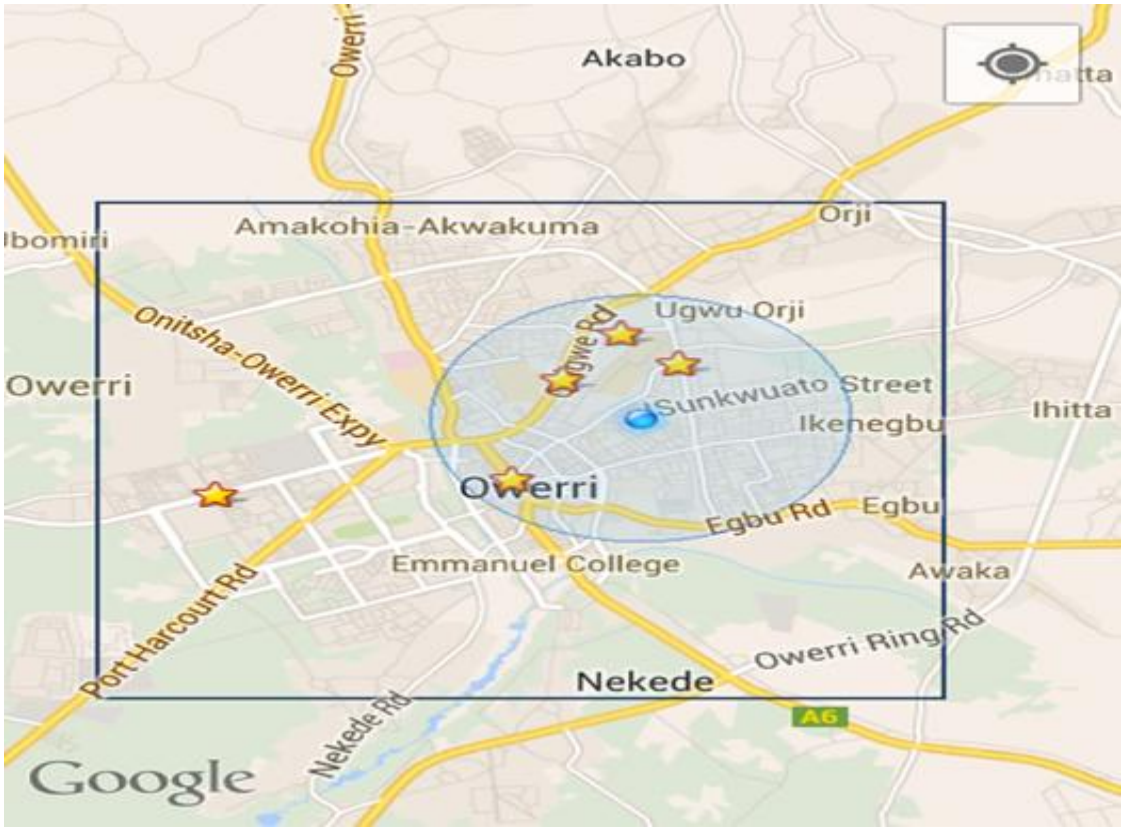

Fig. 1. Map of Owerri metropolis (in box) with the five selected waste dumpsites indicated by the star signs (https://www.google.com.ng/maps/place/Owerri/)

Table 1. The selected waste dumpsites and locations, their coordinate and associated wastes

Dumpsite number	Waste dumpsites and Local Government area	Coordinates	Associated wastes
1	World Bank Housing Estate Market (Owerri West)	5˚28′3.59″N, 7˚ 0 6.88″E	i. Domestic wastes from residential areas ii. Electronic wastes from the market and homes iii. Animal wastes from abattoirs iv. Decomposing vegetables v. Ceramics, glass, wood, paper, tins and polythene vi. Unidentified burnt materials
2	Ekeukwu main market (Owerri Municipal)	5˚28′57.34″N, 7˚ 1 5′7.69″E	i. Domestic wastes from residential areas ii. Electronic wastes from the market and homes iii. Animal wastes from abattoirs iv. Decomposing vegetables v. Ceramics, glass, wood, paper, tins and polythene vi. Unidentified burnt materials vii. Chemical wastes from manufacturing companies
3	Imo State University Front Gate (Owerri North)	5˚28′57.34″N, 7˚ 1 5′7.69″E	i. Domestic wastes from residential areas ii. Electronic wastes from homes iii. Decomposing vegetables iv. Ceramics, glass, wood, paper, tins and polythene v. Unidentified burnt materials
4	Owerri Club (Owerri North)	5˚30′9.42″N, 7˚2′49.02″E	i. Domestic wastes from residential areas ii. Electronic wastes from homes iii. Decomposing vegetables iv. Ceramics, glass, wood, paper, tins and polythene v. Unidentified burnt materials
5	Federal Government Girls College (Owerri Municipal)	5˚30′2.76″N, 7˚2′10.16″E	i. Domestic wastes from residential areas ii. Electronic wastes from homes iii. Decomposing vegetables iv. Ceramics, glass, wood, paper, tins and polythene v. Unidentified burnt materials vi. Chemical wastes from manufacturing companies

Fig. 2. A typical scene of a waste dumpsite within Owerri metropolis with scavengers, residential and commercial activities around them

3. METHODOLOGY

The Radalert-100 measurements of the radiation exposure dose rates at 0 m, 1 m, 5 m and 10 m distances from the waste dumpsite were obtained. The data were in μR hr^{-1} [36] with uncertainty of ±0.15 μR hr^{-1} (from the manufacturer) for each dumpsite. The average of the seven (7) days is shown on Table 2. The radiation exposure dose rates diminished with distance, which obeys the inverse square law. Linear regression analysis was carried out in order to investigate the rate at which the diminishing radiation exposure dose rates varied with the corresponding distances at the dumpsites [37].

The linear relationship between the diminishing radiation exposure dose rates and the corresponding distances is determined using the coefficient of correlation (r) of each dumpsite to one another and to the areal average of the Owerri metropolis using the equation

$$r = \frac{\sum_{i=1}^{n}[(x_i-\bar{x})(y_i-\bar{y})]}{(n-1)(s_x s_y)} \quad (1)$$

where x and y are the corresponding values from the dumpsites, s is the standard deviation and n is the number of dumpsites plus the areal average [37].

T-test was carried out to determine the percentages of the dependency and the underlying uncertainty between the associated dumpsites using the equation,

$$t = \frac{(\bar{\Delta}-\beta_{\Delta})}{\left(\frac{s_{\Delta}^2}{n}\right)^{\frac{1}{2}}} \quad (2)$$

where $\bar{\Delta} = \bar{x} - \bar{y}$, whereas the population mean $\beta_{\Delta} = \beta_x - \beta_y = 0$ under H_0 hypothesis [37].

Table 2. Average exposure dose rate at each of the waste dumpsites and for the areal average of Owerri metropolis, measured at the varying distances

Dumpsite number	Average exposure dose rate (μR hr^{-1} ±0.15 μR hr^{-1})			
	0 m	1 m	5 m	10 m
1	15.5	14.9	12.4	11.6
2	14.3	13.3	12.8	11.3
3	13.9	13.0	11.2	10.3
4	14.9	12.9	11.8	10.6
5	12.6	12.0	11.1	10.1
Areal average	14.24	13.22	11.86	10.78

4. RESULTS AND DISCUSSION

Table 2 shows the average exposure dose rate at each of the waste dumpsites as well as the areal average for the Owerri metropolis, measured at the varying distances of 0 m, 1 m, 5 m and 10 m respectively. It is also noteworthy that the scope of this study does not include identifying the link between waste composition of the dumpsites and the nature of the radiation emanating from them. However, the values indicate that there is enormous radiation emission from the waste dumpsites as represented by the exposure dose rates but diminishes with varying distance. Fig. 3 shows the scatter plot of the average exposure dose rates (μR hr^{-1}) at the corresponding distances (m) from the various dumpsites as well as the areal average of Owerri metropolis. From the linear regression equations of the trends, it is seen that the exposure dose rates diminished with varying distance at the rates of -0.398 μR hr^{-1} m^{-1}, -0.266 μR hr^{-1} m^{-1}, -0.348 μR hr^{-1} m^{-1}, -0.369 μR hr^{-1} m^{-1}, -0.237 μR hr^{-1} m^{-1} and -0.323 μR hr^{-1} m^{-1} for dumpsites 1 to 5 and the areal average respectively.

Since the contents of the waste dumpsites vary, it is expected that the nature of the emitted radiation will also vary hence the need to establish the linear relationship between the dumpsites is imperative. Table 3 shows the coefficient of correlation values (r) of each dumpsite to another as well as to the areal average of Owerri metropolis. The values were significant at 95% confidence level from the T-test analysis. This shows that irrespective of the associated waste contents of the individual dumpsites, there is similarity in the trends of the respective radiation exposure dose rates. Hence the exposure dose rate attributes of each waste dumpsites is synonymous with the other waste dumpsites within the Owerri metropolis.

Therefore with reference to the ICRP recommended maximum permissible limit of 11.4 μR hr^{-1} for members of the public as the benchmark [13,27,28], a "SAFETY ZONE" has been computed from each of the waste dumpsite as well as on the areal average of Owerri metropolis. This was achieved using the linear regression equation of the trends of the diminishing exposure dose rates against distance. The "SAFETY ZONES" are at distances not less than 9.52 m, 9.74 m, 6.01 m, 7.10 m, 4.18 m and 7.49 m for dumpsites 1, 2, 3, 4, 5 and the areal average respectively.

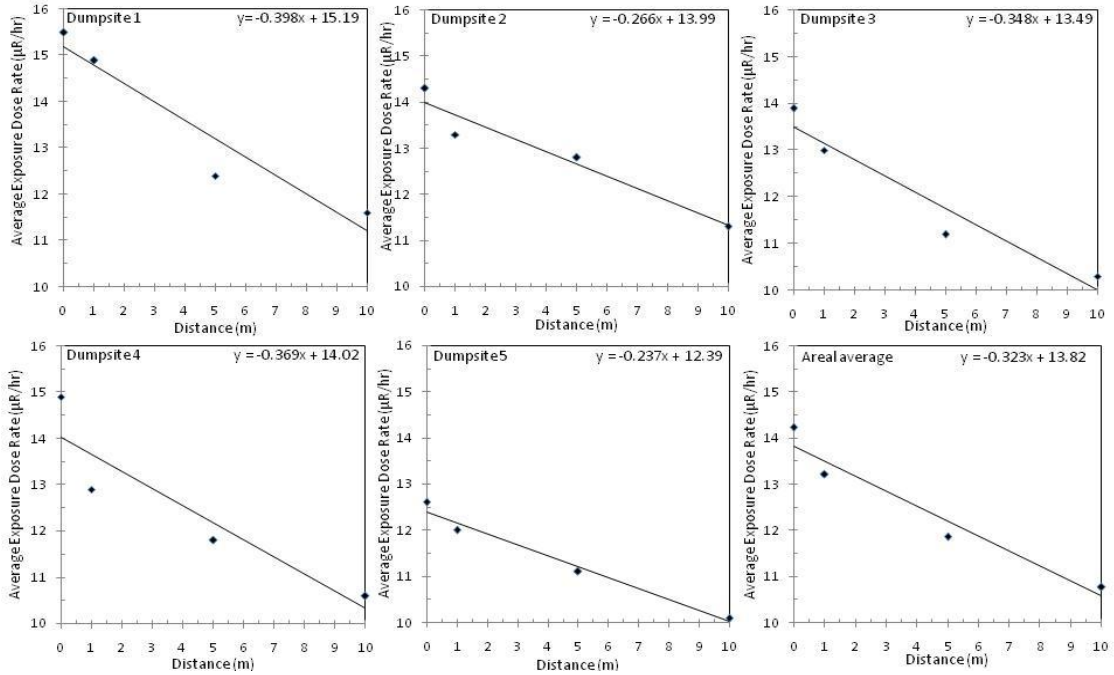

Fig. 3. Scatter plot showing the average exposure rate (μR hr^{-1}) with uncertainty of ±0.15 μR hr^{-1} at the corresponding distances (m) from the various dumpsites and the areal average of Owerri metropolis. The linear regression equations of the trends are inserted on each panel

Table 3. Coefficient of correlation values (r) of each dumpsite to another and to the areal average of Owerri metropolis

Dumpsite number	1	2	3	4	5
1					
2	0.9161				
3	0.9939	0.9494			
4	0.9374	0.9672	0.9695		
5	0.9722	0.9839	0.9875	0.9686	
Areal average	0.9808	0.9729	0.9960	0.9828	0.9951

All coefficient of correlation values are significant at 95% Confidence Level from t-test

5. CONCLUSION

Since it is obvious that for every dose of radiation exposure there is a risk of cancer, then there is every need to mitigate such exposure. The establishment of "SAFETY ZONE" from waste dumpsites within the Owerri metropolis, defined as safe regions that can mitigate increased exposure dose rates, is imperative. From the Table 2, a perimeter at 10 m from the limits of the dumpsite should provide protection for the public. Therefore it is recommended for the local relevant authorities to provide perimeter fencing in order to restrict people from exceeding the "SAFETY ZONE" of the dumpsites within the Metropolis while carrying out their daily activities. Also the authorities can provide conveyor systems at the "SAFETY ZONE" of the dumpsites so that residents who wish to dispose their wastes do not get exposed. The safety authorities should enlighten and provide scavengers protective materials since this study has highlighted on how much exposure dose rate one can absorb. This study points at a way in mitigating radiation exposure dose rates from waste dumpsites in developing cities around the world with similar attributes to Owerri metropolis, Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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