Nigerian Journal of Theoretical and Environmental Physics (NJTEP)
ISSN Print: 3026-9601
ISSN Online: 1597-9849
DOI: https://doi.org/10.62292/njtep.v4i2.2026.125
Volume 4(2), April 2026

# Measurement Of Ambient Dose Rates In The Near And Far Field Of Selected Cement Stores In Ogun State, South-West, Nigeria

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**ABSTRACT**

The current economic hardship in the nation has resulted in many citizens looking for more jobs that can be done to make ends meet. Sales of cement on small and large scales can be seen everywhere. The young and elderly are involved in the business, which predisposes the workers and the public in the vicinity of the stores to ionizing radiation from the cement stockpiled. The dose rates in the near and far fields of the selected cement store for the study have been investigated. Eight cement stores were selected across the study areas, which include Ilaro, Ayetoro, Sango, Ota, Ibese, Owode, Ifo, and Papalantoro, and the dose rates in the near and far fields of the stores were measured using an FNIRSI GC-01 dosimeter. The radiological parameters associated with exposure to workers and the general public were estimated for 10 years using the URANIUM WISE project software. The mean of the measured dose rates for the near and far fields of the cement stores for the study ranged from (0.07–0.27) µSv/h, which is greater than the world average of 0.059 µSv/h. The estimated radiological parameters for the study exceed the recommended values set by various regulatory bodies. This may have negative health implications for the workers and the public. The study recommends that the cement store owners adopt enclose storage system instead of open storage of cement bags. The ventilation of the cement stores must be improved so as to avoid the accumulation of radon gas and airborne radioactive cement dust. The workers should work on rotation so as to reduce their stay time in the cement store and take personal protective measures, such as the use of face masks, goggles, safety boots, and gloves. The general public in the vicinity of the cement stores should observe the dust suppression system by avoiding dry sweeping and adopting the use of a face mask where necessary.

**Keywords**:
Ambient Dose Rates,
Near Field,
Far Field,
Cement Stores.

## INTRODUCTION

Cement is one of the building industry's most important and expensive materials, and its demand is ever-increasing due to the increase in the number of industries cited across the nation (Uwasu et al. 2014). A myriad of unemployed individuals has ventured into the selling of cement on a large and small scale via cement stores/outlets across the nation. The major composition of cements is silica, alumina, and lime derived from the earth crust, harboring the naturally occurring radionuclides such as Uranium, Thorium, and Potassium that can irradiate the workers and the public in the vicinity of the cement stores. The irradiation can be external and internal contamination via dermal contact with the soil/ cement dust attached to leaves, inadvertent ingestion of soil/cement dust, and inhalation of cement dust. Cement dust permeates the environment where the factory is located, and it is noted to be more prevalent during the dry season. Cement dust has long been connected with respiratory obstruction for workers in the cement industry (Rathebe, 2023; Ali et al.2023; Jahrul et al. 2023). The demand for the establishment of more industries has also resulted in the production of more cements, of which Ewekoro Cement Industry is one of the major suppliers of cements in South-Western Nigeria. Generally, the environment is not devoid of irradiation from other sources of exposure, which include cosmic rays, natural radionuclides in water, air, and artificial radioactivity from fallout in nuclear testing and medical applications. The gamma radiation from natural radionuclides and cosmic rays constitutes external exposure, while that derived from foods and drinking water constitutes internal exposure to humans (Jibiri, 1999). The International Atomic Energy Agency, IAEA (1986), estimates that 85% of doses are derived from the natural radionuclides, while the remaining 15% is from cosmic rays and nuclear processes. There has been a tremendous increase in industrial establishments for socio-economic purposes, which has led to huge releases of various types of materials into the environment, contributing to environmental pollution. The cement outlets/stores around the selected area for the study may also be a source of exposure for the workers and the public in the vicinity of the stores. There are owners and workers in these stores who have worked in the stores/outlets for many years and are the major recipients of irradiation from the stockpiled cements. Their exposure scenarios also include work activities such as loading and offloading bags of cement. The average stay-time of owners and workers at the cement store, where large quantities of blocks of cement are stocked, is between 8 hours per day and since cement is radioactive, the longer the owners of the store stay around the vicinity of the cement store, the more they are exposed to ionizing radiation in the radionuclides in the cement. Secondly, the members of the public in the vicinity of the store, according to the inverse square law, may be getting a lesser dose of exposure, but there is a need to investigate their level of exposure since some of these stores have large numbers of bags of cement stock-pilled and the stay time of the general public in the vicinity of the store is quite significant per day. This may increase the dose rates in the vicinity of these stores, and if the exposure is beyond the permissible limit, the workers and the public in and around the vicinity of the cement store may be at risk of cancer in the future due to long-term exposure to ionizing radiation from the radionuclides in the stockpiled bags of cement (Onwuka et al.2019). There are very few research works on the measurement of dose rates around the vicinity of blocks of cement store, and none have investigated the possible dose that workers of the store and the public may accrue for a long exposure to naturally occurring radionuclides in the blocks of cement stockpiled in such a store. Okeyode et al. *(*2012 in their work on cement stores reported an annual effective dose that ranged from (2.45–4.11) mSv/y in the near field of the cement stores and (1.13-2.41) mSv/y in the far field of the cement store (control area) for a selected cement store in Abeokuta. The present research is aimed at the measurement of dose rates in the near (inside the cement store) and far (the domain of the public) fields of the selected store, and to estimate radiological parameters associated with exposure to radionuclides in the cement stored for the next 10 years, with the aid of dose predictive software.

## MATERIALS AND METHODS

### Description of the Study Area

Ogun West has a land mass of 6,297.64km, which is 37 percent of the total land mass in Ogun State, and a population of 1 109 884 according to the national population census of 2006. The zone is the economic hub of Ogun State, generating 75 percent of the state's internally generated revenue, (Femi, 2019). Ogun West, also known as Yewa/Awori land, is made up of five local governments, namely: Imeko-Afon, Ipokia, Yewa South, Yewa North, and Ado-Odo/Ota local government areas. The sub-ethnic groups in the zone include the Yoruba, Eyo, Anago, Awori, Ketu, Ifonyi and Egun (Afolayan, 2015). The Ogun West, which covers an area of 6,297.64 square kilometers, lies at 7$^{o}$ 00' North and a longitude of 3 ° 35' East. The Ogun West has a tropical wet and dry or savanna climate. The region's yearly average temperature is 29.34 $^{C}$ (84.81 $^{°F}$) and it is -0. 12% lower than Nigeria's averages. Ogun West receives about 141.58 millimeters (5.57 inches) of precipitation and has 224.18 rainy days (61.42% of the time) annually. Harmattan season in Ogun West occurs between the end of November and the middle of March yearly. Ogun West is the industrial hub business area in Ogun State. There are so many industries located in some areas, such as Sango-Ota, Agbara, Ifo, and Ado-Odo-Ota. The people in Ogun West engage in agriculture (production of rice, maize, cassava, yams, plantain, and bananas), while cocoa, kola nuts, rubber, palm oil and palm kernels, tobacco, cotton, and timber are the main cash crops. Figure 1 presents the location map of the study area.

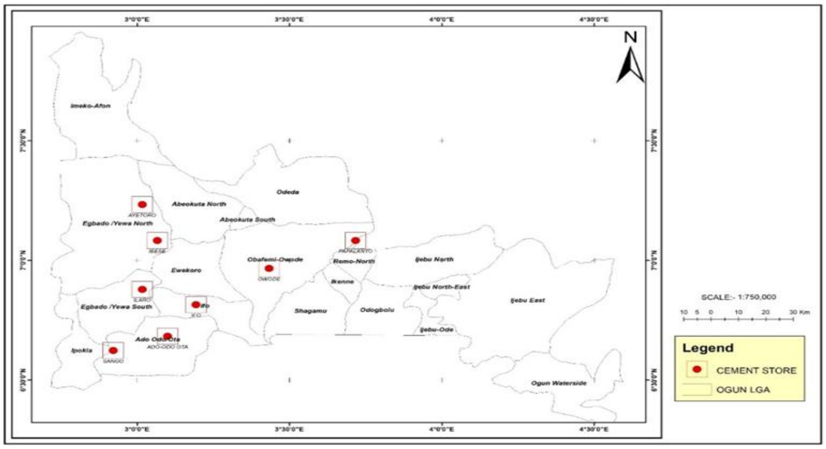


Figure 1: Location Map of the Study Area (Source: Present Study)

**Method of Data Collection**

The dose rate survey meter named FNIRSI GC-01, as shown in Figure 2, is a well-featured compact combination survey meter, sensitive to the three commonest types of ionizing radiation, namely Beta, Gamma, and X-Rays, and was used for the dose rate measurements of dose rates in the near field (in meters) and far field ( in meters) of the selected cement stores as also adopted in Ajetunmobi et al. 2023.The energy range of the dosemeter is from 48 Kev −1.5 Mev ≤ ± 30% ( for 137 Cs). The energy compensation is powered by GM tube (Geiger Conter meter). The sensitivity is 80 count per minutes (CPM) / µSv (for cobalt0). The cumulative dose equivalent for the survey meter ranges from 0.00 µSv − 500.0 mSv. The instrument was placed approximately one meter above the ground level, and dose rates were measured at intervals of 50 meters starting from inside each store to the road network in front of the store. The dose rates were taken every five minutes for each spot of measure ment.


Figure 2: FNIRSI GC-01 Dosimeter (Nuclear radiation Detection Manual and Ajetunmobi et al. 2023)

**Estimation of Radio Logical Parameters Using Uranium Wise Project Software**

A predictive radiological software called Uranium Wise project software (https://www.wise-uranium.org/rdcri.html) was used to predict radiological parameters due to exposure of the dwellers to possible irradiation due to the activities at the cement factory for the next 10 years, assuming the workers and the general public in the vicinity of the cement stores operates for 10 years.

The software determines the health risk from a given radiation dose. The dose can be entered as a dose or as a dose rate plus occupancy information in the interface of the user-friendly software. The software parameters allow the modification of the parameters as needed. The dose rates were entered into the input column in µSv/h, the stay time for the workers at the store is 8 hours/day, and the estimated hours are 2356 hours per year (excluding all the Sundays in the month). The cumulative dose that the owners/workers of the store would have accrued for 10 years was estimated using the software. The same work scenario was assumed for the general public in the vicinity of the store, with a risk factor of 0.05/Sv for the general public. A dose factor for gamma radiation (Sv/Gy) is a conversion factor from absorbed gamma energy in air to an effective dose. UNSCEAR (2000) recommends 0.7 Sv/Gy for adults, 0.8 for children, and 0.9 for infants.

**Statistical Analysis of Data for the Study**

SPSS was used to find the correlation between the dose rates measured, the cumulative dose for 10 years, and the associated cancer risk. A One-Way ANOVA **(**Analysis of Variance**)** was carried out to check for a statistically significant difference in the mean dose rates between the far-field and near-field measurements. This analysis aimed to check if the mean dose rates in the far and near fields of the selected cement store locations are significantly different or if any noticed variations are due to random chance. The null hypothesis ($H_0$) states "that there is no significant difference between the mean dose rates of the Far Field and Near Field," while the alternative hypothesis states that "is a significant difference exists between the dose rates in the far and near fields of the selected cement stores.

## RESULTS AND DISCUSSION

**Table 1: Measures Ambient Dose Rates (µsv/H) From the Near to the Far Fields of the Locations of the Store**

| | | Distance from the store (m) | | | | | | | | | | Coordinates of location of store | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 m | | 50 | | 100 | | 150 | | 200 | | | |
| | | Measured maximum and mean ambient dose rates (µSv/h) | | | | | | | | | | | |
| S/N | Location | Max | Mean | Max | Mean | Max | Mean | Max | Mean | Max | Mean | Latitude | Longitude |
| 1 | Ilaro | 0.36 | 0.24 | 0.34 | 0.21 | 0.31 | 0.20 | 0.30 | 0.18 | 0.28 | 0.17 | 6.87°N | 3.0167°E |
| 2 | Ayetoro | 0.21 | 0.11 | 0.20 | 0.10 | 0.18 | 0.08 | 0.17 | 0.07 | 0.15 | 0.05 | 7.23°N | 3.0167°E |
| 3 | Sango | 0.30 | 0.20 | 0.28 | 0.19 | 0.26 | 0.17 | 0.24 | 0.15 | 0.23 | 0.14 | 6.62°N | 2.9217°E |
| 4 | Ado-Odo Ota | 0.34 | 0.23 | 0.32 | 0.22 | 0.30 | 0.19 | 0.31 | 0.18 | 0.30 | 0.16 | 6.68°N | 3.1000°E |
| 5 | Ibese | 0.42 | 0.27 | 0.40 | 0.24 | 0.38 | 0.23 | 0.35 | 0.21 | 0.33 | 0.20 | 7.08°N | 3.0667°E |
| 6 | Owode | 0.28 | 0.19 | 0.26 | 0.18 | 0.25 | 0.16 | 0.24 | 0.15 | 0.22 | 0.13 | 6.96°N | 3.4333°E |
| 7 | Ifo | 0.23 | 0.14 | 0.21 | 0.12 | 0.20 | 0.11 | 0.18 | 0.10 | 0.15 | 0.07 | 6.81°N | 3.1932°E |
| 8 | Papalantoro | 0.25 | 0.16 | 0.23 | 0.14 | 0.21 | 0.12 | 0.20 | 0.10 | 0.18 | 0.09 | 7.083°N | 3.7167°E |

As indicated in Table 1, the measured dose rates decrease as the distance increases from the store of cement for the selected store in the study. These values justify the inverse square law. The measured dose rates at Ilaro, Ayetoro, Sango, Ado Odo, Ota, Ibese, owode, Ifo, Papalantoro store ranged from (0.36 − 0.28) µSv/h with the mean of 0.24 µSv/h, (0.21−0.05) with the mean of 0.08µSv/h, (0.30 −0.23) µSv/h with the mean of 0.17 µSv/h, 0.34–0.30) µSv/h with the mean of 0.17 µSv/h, (0.42−0.33) µSv/h with the mean of 0.23 µSv/h, 0.28–0.22) µSv/h with the mean of 0.16 µSv/h, 0.23 − 0.25) µSv/h with the mean of 0.10 µSv/h, and 0.25 −0.18) µSv/h with the mean of 0.12 µSv/h respectively. The increasing order of the measured dose rates is Ibese dose rates > Ilaro dose rates > Sango Ado-odo > Owode dose rates > Papalantoro > Ifo >Ayetoro. The increasing order of the measured dose rates may be due to the number of cement stockpiled in the store, environmental background radiation, and any other possible sources of radiation in the environment. Okeyode et al. (2012 reported that dose rates in the far field of a cement store ranged from (0.40−0.74) µSv/h, and the dose rates in the near field of the cement store ranged from (0.74–1.24) µSv/h. The values reported in their study are greater than the range of the dose rates measured in the present study. Figure 3 presents the bar charts for the maximum and mean dose rates measured at the cement stores selected for the study. From the figure, the maximum dose rates were measured at Ibese cement store while Ayetoro cement store recorded the lowest dose rates.

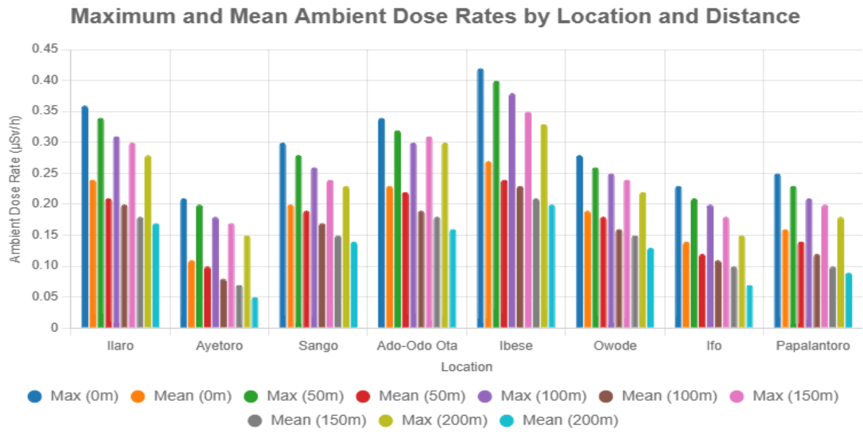


Figure 3: Measured Mean and Maximum Ambient Dose Rates for the Near and Far Fileds of the Cement Stores for the Study

As indicated in Figure 3, the values for the measured maximum dose rates at the near fields (inside the cement stores) of the stores are consistently the highest values for all the selected stores. Similarly, the maximum values for the dose rates at the far fields which are the domain of the general public in the vicinity of the cement stores are consistently lowest for all the stores selected for the study. This deduction follows the inverse square law and suggests that the farther away from the source of radiation, the less radiation dose the general public will receive, and conversely the more radiation dose the workers in the cement stores will receive. The same explanations are applicable to all the estimated mean ambient dose rates for the stores.

**Table 2: Estimated Radiological Parameters for the Near and Far Fields of Ilaro Cement Store**

| S/N | Distance (m) | Mean Dose Rates (µSv/h) | Annual Dose Rate (µSv/y) | Cumulative Dose (mSv) | Excess lifetime Cancer risk × ($10^{-2}$) |
|---|---|---|---|---|---|
| | | **Estimated radiological parameters for the near field for the study** | | | |
| | 0 | 0.24 | 565.4 | 5.654 | 2.3 |
| | 50 | 0.21 | 494.7 | 4.947 | 2.0 |
| | 100 | 0.20 | 471.2 | 4.712 | 1.9 |
| Mean | | 0.22 | 510.4 | 5.104 | 2.1 |
| | | Estimated radiological parameters for the far field for the study | | | |
| | 150 | 0.18 | 424.1 | 4.241 | 2.1 |
| | 200 | 0.17 | 400.5 | 4.005 | 2.0 |
| Mean | | 0.18 | 412.3 | 4.123 | 2.1 |

As seen in Table 2, the measured and estimated radio logical parameters for the near and far fields of the cement store decrease as we move away from the near field to the far field of the store. The measured dose rates in the near and far fields ranged from (0.20–0.24) (µSv/h) with the mean of 0.22 (µSv/h) and (0.1–0.18 (µSv/h) with the mean of 0.18 (µSv/h), respectively. Adewole and Ewumi (2011 reported a dose rate of 10.24 nSv/h for the near field of a cement factory and 4.0 nSv/h for the far field of the cement factory. The reason for such a low value may be due to the period of the year (raining season) that the data was collected. Low doses may be recorded during the wet season and the reverse during dry season. The cement dust is dampened during the wet season, as noticed in the road network of Ewekoro Cement Factory. The annual dose rates in the near and far fields of the cement store ranged from (471.2—565.4) µSv/y, with the mean of 510.4 µSv/y and (400.5.2–424.1) µSv/y) with a mean of 412.3 µSv/y, respectively. These values are greater than 70 µSv/y world average recommended by United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR 2000. Additionally, the cumulative doses that may be accrued by the workers and the public after spending 10 years in the near (workers) and far (general public) fields of the store ranged from (4.712—5.654) mSv with the mean of 5.104 mSv and (4.005–4.242) mSv with the mean of 4.123 mSv respectively. The estimated associated lifetime cancer risk for the study ranged from (1.9–2.3) × $10^{-2}$ for the near field and (2.0–2.1) × $10^{-2}$ for the far field.

The estimated values for the lifetime cancer risk for workers and the public are very close due to the recommended values for the fatal cancer risk per Sievert for stochastic effects, ICRP 60 (1990), with values of 0.04 for workers and 0.05 for the public. These values were adopted when using the software. The estimated values for the lifetime cancer risk for the workers and the general public are greater than the world average of 2.9 × $10^{-4}$ recommended by UNSCEAR, 2000. The health implications for the measured and estimated values for the radiological parameters for the study is that both the workers and the general public may be at risk as a result of prolonged stay in the near and far field of the selected cement store for the next ten years as assumed for the study. These values that are higher than the world average can be due to the number of stockpiled cements in the store and naturally occurring radionuclides (NORMS) in the materials used in the production of cement.

**Table 3: Estimated Radiological Parameters for the Near and Far Fields of Ayetoro Cement Store**

| S/N | Distance (m) | Mean Dose Rates (µSv/h) | Annual Dose Rate (µSv/y) | Cumulative Dose (mSv) | Excess lifetime Cancer risk × ($10^{-2}$) |
|---|---|---|---|---|---|
| 1 | 0 | 0.11 | 259.1 | 2.591 | 1.0 |
| 2 | 50 | 0.10 | 235.6 | 2.356 | 0.9 |
| 3 | 150 | 0.08 | 188.4 | 1.884 | 0.8 |
| Mean | | 0.09 | 227.7 | 2.277 | 0.9 |
| | | Estimated radiological parameters for the far field for the study | | | |
| 4 | 200 | 0.07 | 164.9 | 1.649 | 0.80 |
| 5 | 250 | 0.05 | 117.8 | 1.178 | 0.60 |
| Mean | | 0.06 | 141.3 | 1.413 | 0.7 |

Also, as presented in Table 3, the measured dose rates in the near and far fields ranged from (0.08−0.11) µSv/h with the mean of 0.99 µSv/h and (0.05−0.07) µSv/h with the mean of 0.06 µSv/h) respectively. The measured dose rates is lower than those of the Ilaro cement store. This may be due to the number of cement stockpiled at the Ayetoro cement store, which is lower in quantity. The annual dose rates in the near and far fields of the cement store at Ayetoro ranged from (188.4 ─ 259.1) µSv/y with a mean of 227.7 µSv/y and (117.8−164.9) µSv/y with a mean of 141.3 µSv/y, respectively. These values are greater than the 70 µSv/y world average recommended by UNSCEAR 2000. Also, the cumulative dose that may be accrued by the workers and the public for spending 10 years in the near (workers) and far (general public) fields of the cement store ranged from (1.884−2.591) mSv with the mean of 2.277 mSv and (1.178−1.649) mSv with the mean of 1.413 mSv, respectively. The lifetime cancer risk for the Ayetoro cement store ranged from (0.8−1.0) × $10^{-2}$ for the near field and (0.6−0.8) × $10^{-2}$ for the far field. The estimated values for the lifetime cancer risk for the workers and the general public are greater than the world average of 2.9 × $10^{-4}$ recommended by UNSCEAR, 2000, and 2.7 × $10^{-4}$. The health implication is that both the workers and the general public may be at risk as a result of prolong stay in the cement store and in the vicinity of the cement store, respectively.

**Table 4: Estimated Radiological Parameters for the Near and Far Fields of Sango Cement Store**

| S/N | Distance (m) | Mean Dose Rates (µSv/h) | Annual Dose Rate (µSv/y) | Cumulative Dose (mSv) | Excess lifetime Cancer risk× ($10^{-2}$) |
|---|---|---|---|---|---|
| 1 | 0 | 0.20 | 471.2 | 4.712 | 1.9 |
| 2 | 50 | 0.19 | 447.6 | 4.476 | 1.8 |
| 3 | 150 | 0.17 | 400.5 | 4.005 | 1.6 |
| Mean | | 0.19 | 439.8 | 4.398 | 1.8 |
| | | Estimated radiological parameters for the far field for the study | | | |
| 4 | 200 | 0.15 | 353.4 | 3.534 | 1.8 |
| 5 | 250 | 0.14 | 329.8 | 3.298 | 1.6 |
| Mean | | 0.15 | 341.6 | 3.416 | 1.7 |

Table 4 presents the measured and estimated radiological parameters for the Sango cement store in the near and far fields. The measured dose rates in the near and far fields ranged from (0.17−0.20) µSv/h with the mean of 0.19 µSv/h, and (0.14−0.15) µSv/h with the mean of 0.15 µSv/h, respectively. The annual dose rates in the near and far fields of the Sango cement store ranged from (400.5─4.712) µSv/y) with the mean of 439.8µSv/y and (329.8─353.4) µSv/y) with a mean of 341.6 µSv/y, respectively. These values are lower than the measured dose rates at Ilaro but greater than the measured values at Sango. The value is also greater than the world average value of 70 µSv/y. The estimated cumulative doses for the workers and the public ranged from (4.005─4.712) mSv with a mean of 4.398 mSv, and (3.298── 3.534) mSv with a mean of 3.416 mSv, respectively. The estimated associated lifetime cancer risk for the study ranged from (1.6─1/8) × $10^{-2}$ for the near field and (1.6─1.8) × $10^{-2}$ for the far field. The estimated value for the Sango cement store is lower than that of the Ilaro cement store.

**Table 5: Estimated Radiological Parameters for the Near and Far Fields of Ota Cement Store**

| S/N | Distance (m) | Dose Rates (µSv/h) | Annual Dose Rate (µSv/y) | Cumulative Dose ( mSv) | Excess lifetime Cancer risk × ($10^{-2}$) |
|---|---|---|---|---|---|
| 1 | 0 | 0.23 | 541.9 | 5.419 | 2.2 |
| 2 | 50 | 0.22 | 518.3 | 5.183 | 2.1 |
| 3 | 150 | 0.19 | 447.6 | 4.476 | 1.8 |
| Mean | | 0.21 | 502.5 | 5.026 | 2.0 |
| | | Estimated radiological parameters for the far field for the study | | | |
| 4 | 200 | 0.18 | 424.1 | 4.241 | 2.1 |
| 5 | 250 | 0.16 | 376.9 | 3.769 | 1.9 |
| Mean | | 0.17 | 400.5 | 4.005 | 2.0 |

Table 5 presents the measured and estimated radio logical parameters for the near and far fields of the stores or outlets at Sango. The measured dose rates in the near and far fields ranged from (0.19─0.23) (µSv/h) with the mean of 0.21 (µSv/h) and (0.16─0.18 (µSv/h) with the mean of 0.17 (µSv/h) respectively. The annual dose rates in the near and far fields of the Sango cement store ranged from (447.6─541.9) µSv/y) with the mean of 502.5µSv/y and (375.9─ 353.4) µSv/y) with a mean of 400.5 µSv/y respectively. The value is also greater than the world average value of 70 µSv/y. The estimated cumulative doses for the workers and the public ranged from (4.476── 5.419) mSv with a mean of 5.026 mSv and (3.769─4.241) mSv with a mean of 4.005 mSv, respectively. The estimated associated lifetime cancer risk for the location ranged from (1.8─2.2) × $10^{-2}$ for the near field and (1.9─2.1) × $10^{-2}$ for the far field.

**Table 6: Estimated Radiological Parameters for the Near and Far Fields of Ibese Cement Store**

| S/N | Distance (m) | Mean Dose Rates (µSv/h) | Annual Dose Rate (µSv/y) | Cumulative Dose (mSv) | Excess lifetime Cancer risk × ($10^{-2}$) |
|---|---|---|---|---|---|
| 1 | 0 | 0.27 | 636.1 | 6.361 | 2.5 |
| 2 | 50 | 0.24 | 565.4 | 5.654 | 2.3 |
| 3 | 150 | 0.23 | 541.9 | 5.419 | 2.2 |
| Mean | | 0.25 | 581.1 | 5.811 | 2.3 |
| | | Estimated radiological parameters for the far field for the study | | | |
| 4 | 200 | 0.21 | 494.7 | 4.947 | 2.5 |
| 5 | 250 | 0.20 | 471.2 | 4.712 | 2.4 |
| Mean | | 0.21 | 482.9 | 4.829 | 2.3 |

As seen in Table 6, the measured and estimated radiological parameters for the near and far fields of the cement store at Ibese decrease as we move away from the near field to the far field of the store. The measured dose rates in the near and far fields ranged from (0.23─0.27) µSv/h with the mean of 0.25 (µSv/h) and (0.20─0.21) µSv/h with the mean of 0.21 µSv/h, respectively. The annual dose rates in the near and far fields of the cement store ranged from (541.9─636.1) µSv/y with the mean of 581.1 µSv/y and (471.2─494.7) µSv/y with the mean of 482.9 µSv/y, respectively. These values are greater than 70 µSv/y world average recommended by UNSCEAR 2000. The cumulative doses for the workers and the public ranged from (5.419─6.361) mSv with a mean of 5.811 mSv and (4.712─4.947) mSv with a mean of 4.829 mSv, respectively. The estimated associated lifetime cancer risk for the Ibese cement store ranged from (2.2─2.5) × $10^{-2}$ for the near field and (2.4─2.5) × $10^{-2}$ for the far field. The estimated values for the lifetime cancer risk for the workers and the general public are greater than the world average of 2.9 × $10^{-4}$ recommended by

UNSCEAR, 2000. The health implications for the measured and estimated values for the radiological parameters are the same as the previous cement stores selected for the study.

**Table 7: Estimated Radio Logical Parameters for the Near and Far Fields of Owode Cement Store**

| S/N | Distance (m) | Mean Dose Rates (μSv/h) | Annual Dose Rate (μSv/y) | Cumulative Dose (mSv) | Excess lifetime Cancer risk × ($10^{-2}$) |
|---|---|---|---|---|---|
| 1 | 0 | 0.19 | 447.5 | 4.476 | 1.9 |
| 2 | 50 | 0.18 | 424.1 | 4.241 | 1.0 |
| 3 | 150 | 0.16 | 376.9 | 3.769 | 1.5 |
| Mean | | 0.18 | 416.2 | 4.162 | 1.5 |
| | | Estimated radiological parameters for the far field for the study | | | |
| 4 | 200 | 0.15 | 353.4 | 3.534 | 1.8 |
| 5 | 250 | 0.13 | 306.2 | 3.062 | 1.5 |
| Mean | | 0.14 | 329.8 | 3.298 | 1.7 |

As presented in Table 7, the measured dose rates in the near and far fields ranged from (0.16−0.19) μSv/h with the mean of 0.18 (μSv/h) and (0.13−0.15) μSv/h with the mean of 0.14 μSv/h, respectively. The annual dose rates in the near and far fields of the cement stores at owode ranged from (376.9−447.5) μSv/y with the mean of 416.2 μSv/y and (306.2−353.4) μSv/y with a mean of 329.8 μSv/y, respectively. These values are greater than the 70 μSv/y world average recommended by UNSCEAR 2000. The cumulative doses for the workers and the public ranged from (3.769−4.476) mSv with a mean of 4.162 mSv and (3.769−4.476) mSv with a mean of 4.162 mSv, respectively. The estimated associated lifetime cancer risk for the study ranged from (1.5−1.9) × $10^{-2}$ for the near field and (1.5−1.8) × $10^{-2}$ for the far field. Again, the estimated values for the lifetime cancer risk for the workers and the general public are greater than the world average of 2.9 × $10^{-4}$ recommended by UNSCEAR, 2000. The health implications for the measured and estimated values for the radiological parameters is the same as the previous cement stores selected for the study.

**Table 8: Estimated Radio Logical Parameters for the Near and Far Fields of Ifo Cement Store**

| S/N | Distance (m) | Mean Dose Rates (μSv/h) | Annual Dose Rate (μSv/y) | Cumulative Dose (mSv) | Excess lifetime Cancer risk ×($10^{-2}$) |
|---|---|---|---|---|---|
| 1 | 0 | 0.14 | 329.8 | 3.298 | 1.3 |
| 2 | 50 | 0.12 | 282.7 | 2.827 | 1.1 |
| 3 | 150 | 0.11 | 259.1 | 2.591 | 1.0 |
| Mean | | 0.12 | 290.5 | 2.905 | 1.1 |
| | | Estimated radiological parameters for the far field for the study | | | |
| 4 | 200 | 0.10 | 235.6 | 2.356 | 1.2 |
| 5 | 250 | 0.07 | 164.9 | 1.649 | 0.8 |
| Mean | | 0.09 | 200.3 | 2.003 | 1.0 |

The measured dose rates at Ifo near and far fields ranged from (0.11−0.14) (μSv/h) with the mean of 0.12 μSv/h and (0.07−0.10) μSv/h with the mean of 0.09 μSv/h as shown in Table 8, respectively. The annual dose rates in the near and far fields of the cement store ranged from (259.1−329.8) μSv/y with the mean of 290.5 μSv/y and (164.9− 235.6) μSv/y with a mean of 200.3 μSv/y, respectively. Again, these values are greater than the 70 μSv/y world average recommended by UNSCEAR 2000. Also, the cumulative doses that may be accrued by the workers and the public after spending 10 years in the near (workers) and far (general public) fields of the Ifo cement store ranged from (2.591−3.298) mSv with the mean of 2.905 mSv and (1.649− 2.356) mSv with the mean of 2.003 mSv, respectively. The estimated associated lifetime cancer risk for the sore ranged from (1.0−1.3) × $10^{-2}$ for the near field and (0.8−1.2) × $10^{-2}$ for the far field. The estimated values for the lifetime cancer risk for the workers and the general public are greater than the world average of 2.9 × $10^{-4}$ recommended by UNSCEAR, 2000. These values imply that both the workers and the public in the vicinity of the cement store where cements are sold are likely to have health issues for prolong exposure.

**Table 9: Estimated Radiological Parameters for the Near and Far Fields of Papa Lantoro Cement Store**

| S/N | Distance (m) | Mean Dose Rates (µSv/h) | Annual Dose Rate (µSv/y) | Cumulative Dose (mSv) | Excess lifetime Cancer risk × ($10^{-2}$) |
|---|---|---|---|---|---|
| 1 | 0 | 0.16 | 376.9 | 3.769 | 1.5 |
| 2 | 50 | 0.14 | 329.8 | 3.298 | 1.3 |
| 3 | 150 | 0.12 | 282.7 | 2.827 | 1.1 |
| Mean | | 0.14 | 329.8 | 3.298 | 1.3 |
| | | Estimated radiological parameters for the far field for the study | | | |
| 4 | 200 | 0.10 | 235.6 | 2.356 | 1.2 |
| 5 | 250 | 0.09 | 212.0 | 2.120 | 1.1 |
| Mean | | 0.10 | 223.8 | 2.238 | 1.2 |

The measured dose rates at the cement store at Papa Lantoro's near and far fields ranged from (0.12−0.16) µSv/h with the mean of 0.14 µSv/h and (0.09−0.10) µSv/h with the mean of 0.10 (µSv/h) as shown in Table 9 respectively. The annual dose rates in the near and far fields of the cement store ranged from (282.7.−376.9) µSv/y) with the mean of 329.8 µSv/y and (212.0−235.6) µSv/y) with a mean of 223.8 µSv/y respectively. Again, these values are greater than the 70 µSv/y world average recommended by UNSCEAR 2000. Also, the cumulative doses that may be accrued by the workers and the public for spending 10 years in the near (workers) and far (general public) fields of the store ranged from (2.827−3.769) mSv with the mean of 3.298 mSv and (2.120−2.356) mSv with the mean of 2.238 mSv, respectively. The estimated associated lifetime cancer risk for the store ranged from (1.1−1.5) × $10^{-2}$ for the near field and (1.1−1.2) × $10^{-2}$ for the far field. The estimated values for the lifetime cancer risk for the workers and the general public are greater than the world average of 2.9 × $10^{-4}$ recommended by UNSCEAR, 2000. These values imply that both the workers and the public in the vicinity of the cement store where blocks of cement are sold are likely to have health issues both in the long-term periods of exposure.

Table 10 presents the result of the correlation analysis of the radio logical parameters estimated for the study. All the parameters are strongly correlated. This implies that an increase in one of the parameters will lead to an increase in other parameters, hence increase in dose rates at the near field of the cement stores will result to increase in annual dose rates, estimated cumulative dose for ten years and finally increase in estimated excess lifetime cancer risk for the workers working at the cement outlets. This implies that the longer the number of years the workers stay at the outlets, the more they get exposed to ionizing radiation in the radionuclides found in the materials used in the manufacturing of cement. The owners of the store can run a shift duty for their workers to reduce their stay time at the stores and thereby reduce their exposures.

**Table 10: Correlation Analysis for Radiological Variables in the Near Field of the Cement Store for the Study**

| Variables | Mean dose rates (µSv/h) | Annual Dose rate (µSv/h) | Cumulative Dose (mSv) | Excess lifetime cancer risk 10-2 |
|---|---|---|---|---|
| Dose Rates | 1 | 1.000** | 1.000** | 0.959** |
| Annual Dose Rates | 1.000** | 1 | 1.000 | 0.959** |
| Cumulative Dose | 1.000** | 1.000** | 1 | 0.959** |
| Excess lifetime cancer risk | 0.959** | 0.959** | 0.959** | 1 |

** Correlation is significant at the 0.01 level (2-tailed)

Similarly, in Table 11, all estimated radio logical parameters in the domain of the public are strongly correlated. This is of serious radio logical concern. Advance research work should be carried out at the public domain for detailed assessment of the radio logical safety of the public working and living close to the cement close to the stores where cements are stock-pilled for sales. The longer their stay time in such vicinity, the more their exposure.

**Table 11: Correlation Analysis for Radiological Variables in the Far Field of the Cement Store for the Study**

| Variables | Mean Dose Rates (μSv/h) | Annual Dose rate (μSv/h) | Cumulative Dose (mSv) | Excess Lifetime Cancer Risk 10-2 |
|---|---|---|---|---|
| Dose Rates | 1 | 1.000** | 1.000** | 0.999** |
| Annual Dose Rates | 1.000** | 1 | 1.000 | 0.999** |
| Cumulative Dose | 1.000** | 1.000** | 1 | 0.999** |
| Excess lifetime cancer risk | 0.999** | 0.999** | 0.999** | 1 |

As presented in Table 12, the value (0.0951) of sum of squares within group (error terms) represents the total variability in dose rates that *cannot* be explained by whether the measurement was taken in the near field or far field. It is the "error" or "unexplained" variance arising from differences *within* each group (e.g., natural variation among individual measurements taken within the near field, or within the far field). A relatively small within-groups SS compared to the between-groups SS (0.0131) would suggest group differences are meaningful. Here, the error SS is about 7 times larger than the between-groups SS, indicating substantial natural scatter within each field type. Degrees of freedom (37) indicates a reasonably sized sample for estimating error.

The F-statistic table value is 5.10, which suggests an appreciable variance between the two groups, that is, far field and near field values for dose rates. Additionally, the p-value (0.030) is below 0.05, which implies that the null hypothesis is rejected. The implication of this is that the observed difference in the mean dose rates between the far field and near field is statistically significant and very much unlikely to be an occurrence of chance.

The significant difference in the mean dose rates in the near and far fields of the ionizing radiation from the cement stores has safety implications for the workers working in the stores, since they are more exposed to radiation than those in the far fields. This further affirms the need for stricter safety guidelines in the near-fields where there are likely to be elevated radiation doses that may be above permissible or recommended levels. Also, such guidelines can be extended for the general public residing or working close to cement stores where cement is stockpiled for sale. The study considered the exposure level and associated health risks for a long time (the assumed 10 years) to ionizing radiation from the radionuclides in cement stockpiled in the cement store, unlike the scope of other studies that only focus on the exposure of the public for a year. Regular monitoring and implementation of protective measures, such as gloves, radiation shielding coats, and shift duties, are strongly recommended. Owners of the cement stores must ensure compliance with occupational safety guidelines to minimize radiation hazards during work activities at the cement stores.

**Table 12: One-Way ANOVA Analysis Result for Dose Rates between the Near and Far Field of Selected Cement Stores**

| Source of Variation | Sum of Squares (SS) | Degrees of Freedom (df) | Mean Square (MS) | F-Statistic | p-value | Interpretation |
|---|---|---|---|---|---|---|
| Between Groups (Far field vs Near field) | 0.0131 | 1 | 0.0131 | 5.10 | 0.030 | A significant difference exists |
| Within Groups (Error) | 0.0951 | 37 | 0.00257 | - | - | - |
| Total | 0.1082 | 38 | - | - | - | - |

## CONCLUSION

The measured ambient dose rates and estimated radiological parameters in the near and far fields of the selected cement stores are above permissible limits set by regulatory bodies. This has health implications. The radiation level within and outside the vicinity of the cement stores should be regularly monitored. Appropriate protective materials are needed to alleviate the workers' exposure. Further research can be carried out to investigate factors such as atmospheric conditions, material shielding effects, and long-term exposure risks in these selected cement outlets.

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