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Occupational Hazards from Outdoor and Indoor Radiation in Oil Field Facilities in Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author GOA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JE and YECU managed the analyses of the study. Author JE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study is to determine the occupational hazards due to exposure to gamma radiations from oil and gas facilities. In-situ measurement of radiation exposure rate of some Oil Field Facilities in Rivers State, Nigeria carried out using Digilert 200 and Radalert 100 nuclear radiation monitor and a geographical positioning system (Garmin GPSMAP 76S). The average exposure rates of the facilities range from 0.010±0.002 to 0.015±0.001$\mathrm{mRhr^{-1}}$, for indoor and 0.014±0.003 to 0.027±0.003 $\mathrm{mRhr^{-1}}$ for outdoor. The mean absorbed dose rates for indoor varied from 92.1 to 121.1 $nGyh^{-1}$ while the mean outdoor absorbed dose varied from 120.4 to 234.2 $nGyh^{-1}$. The estimated indoor annual effective dose varied from 0.14 to 0.19 $mSvy^{-1}$ while the outdoor annual effective dose varied from 0.23 to 0.36 m Svy^{-1}.The estimated indoor excess lifetime cancer risk (ELCR) range from 0.56×10^{-3} to $0.65\text{x}10^{-3}$ and outdoor ranged from $0.65\times10^{-3}5$ to 1.26×10^{-3}. The respective mean values of absorbed dose, AEDE and ELCR for indoor and outdoor measurements at the different locations exceeded the world permissible values of 60 $\mathrm{nGyh^{-1}}$, 70 $\mathrm{mSvy^{-1}}$ and 0.29×10^{-3}

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respectively. The result of this work indicated that used oilfield pipe market recorded the highest exposure rate. This could be due to radiations from scales on the pipes and may pose health challenged for long term exposure.

Keywords: Absorbed dose; annual effective dose; exposure rate; digilert-200; oil field.

1. INTRODUCTION

Naturally Occurring Radioactive Material (NORM) was first reported as being associated with mineral oil and natural gases by McLennan in 1904. Later reports described the occurrence of ^{226}Ra in reservoir water from oil and gas fields [1]. In 1970s to 1980s several observations prompted renewed interest [2,3].

Reported elevated concentrations of NORM found on oil and gas mining equipment [4] generated concern in the United States and Europe, as elevated NORM concentrations may subject oil and gas workers to unnecessary radiation exposure. During the production of oil and gas, NORM in the earth crust flows with the oil, gas and water mixture and accumulates in scale, sludge and scrapings. It can also form a thin film on the interior surfaces of gas processing equipment and vessels. NORM may accumulate, at wellheads in the form of scale; at Gas/Oil Separation Plants (GOSP) in the form of sludge; and at gas plants the formation of thin films as the result of radon gas decay (Babatunde et al., 2019).

IOGP [5] explains the various routes through which radioactive pollution occur during oil and gas production. ^{228}Ra, ^{228}Ra and ^{224}Ra leached from reservoir source rocks are transported in produced water that are disposed into water bodies while ^{222}Rn through emanation/dissolution are emitted through gas flaring into the atmosphere. ^{210}Pb and ^{210}Pb are transported as carriers in condensates and sludge drained into waste pits which leach into the soil contaminating ground water and farm products from uptake. NORM wastes such as Sludge are composed of dissolved solid and contains radium isotopes and their progenies which are strong gamma emitters, the external radiation dose in the vicinity of separation tanks increases as sludge builds up. Other radionuclides such as Lead-210 (beta and gamma emitter) and Polonium-210 (Alpha emitter) can also be found in drilling rig's waste pits, evaporation ponds, mud tanks, mud pumps, drill pipes. As well as in downstream equipment such as pipelines, tank bottoms, gas/oil/water separators, dehydration vessels, liquid natural gas (LNG) storage tanks, slops tanks of oil production facilities [6].

Azionu et al. [7] studied the Occupational Hazards from BIR in Selected Crude Oil Production Pipes Storage Locations in Niger Delta Region of Nigeria. The radiation hazard parameters evaluated exceeded their respective world safe values. This indicates that the crude oil production pipes scales may have impacted the storage locations radiologically.

The workers working on flow line construction and maintenance, drilling rigs and work-over units are more exposed to radiations from scales due to their daily task [6]. The more radiation dose a person receives, the greater the chance of developing cancer, leukaemia, eye cataracts, Erythema, haematological depression and incidence of chromosome aberrations [8].

The Niger Delta complex is one of the 10 major sedimentary basins of Nigeria [9]. Niger Delta is the third largest wetlands of the world with large fresh water swamp forest rich in bio-diversity (UNDP, 2006). This signifies the vastness in diversity of the ecosystem in need of conservation. The Niger Delta geological complex consists of the Akata, Agbada and Benin subsurface sedimentary formations [10]. It has a lot of mineral deposits including oil and gas deposit. This has attracted many oil exploration and exploitation companies in the area.

NORM in the earth's crust are brought to the surface during oil drilling activities and other production activities. Humans within these production facilities are exposed to some levels of radiation. Hence this study seeks to assess the occupational indoor and outdoor radiation in oil field facilities through the estimation of the radiological health risk parameters using radiation models.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in oil facilities in the Niger Delta which extends from the Bight of Bonny on longitude 8.0ºE to the Bight of Benin on longitude 4.1ºE; and overlaying 22 km offshore [11] as well as 70 km onshore the Atlantic coastline.

Radiation exposure rate were measured at four streams of oil and gas production facilities within the study area using two radiation monitors (Radalert 100 and Digilert 200). A Global Positioning System (Garmin GPSMAP 76S) GPS monitor was also used to record the coordinates of the sample sites. The in-situ measurement of exposure rate was done using two calibrated radiation meters (Radalert 100 and Digilert 200) which is capable of measuring alpha, beta, gamma and x-ray radiation. They were set to read in milli Roentgen per hour within the temperature range of 10ºC to 50ºC.

The tube of the radiation monitoring meter was held at a standard height of 1.0 m above the ground and 6m away from any building or wall, with its window facing the suspected source while the GPS reading was taken at that spot. Readings were obtained between the hours of 13:00 and 16:00 since the exposure rate meter has a maximum response to environmental radiation within these hours. The radiation exposure reading in all the locations were converted to absorbed dose using the conversion factor shown in equation 1 (Agbalagba et al. 2016).

$$1\mu\ \mathrm{R/h} = 8.7\,\mathrm{nGy/h} = 8.7 \times 10^{-3}\,\mu\mathrm{Gy}/(\tfrac{1}{8760\mathrm{y}}) = 76.212\ \mu\mathrm{Gyy}^{-1} \qquad (1)$$

Absorbed dose is a measure of the energy absorbed by the human body from ionizing radiation within a given time period.

Annual effective dose is the measure that assesses the radiation detriment to the whole human body within a given time period due to the radiation absorbed. The maximum permissible limit was recommended to be 1.0 $mSvy^{-1}$(ICRP, 1999), to evade any associated health side effects to non-industrial worker and the public. For the calculation of the AEDE, dose conversion factor of 0.7Sv/Gy and occupancy factor for outdoor of 0.25 (6/24) was used.

The annual effective dose (AED) was calculated using equation 2

$$\mathrm{AED}\ (\mathrm{mSvy^{-1}}) = \mathrm{D}\ (\mathrm{nGyh^{-1}}) \times 0.7 \times 8760\ (\mathrm{hy^{-1}}) \times 0.25 \times (10^{3}\mathrm{mSv}/10^{9}) \qquad (2)$$

Excess lifetime cancer risk is the risk of death of cancer in the excess of the natural background risk, resulting from a lifetime exposure to carcinogens. It is estimated using equation 3.

$$\mathrm{ELCR} \times 10^{-3}(\mathrm{mSvy^{-1}}) = \mathrm{AEDE}\ (\mathrm{mSvy^{-1}}) \times 70(\mathrm{y}) \times 0.05\ \mathrm{Sv^{-1}} \qquad (3)$$

Where 0.05 is the Risk Factor recommended by ICRP.

3. RESULTS AND DISCUSSION

The results of the measured BIR level at the pipe inspection facility X showed a mean value of 0.012 mRhr^{-1} for indoor and a mean outdoor value of 0.015 mRhr^{-1}. The mean indoor and outdoor exposure rate measured at drill cutting treatment facility V are 0.015 mRhr^{-1} and 0.017 mRhr^{-1} respectively. The mean exposure rate measured at used oilfield pipe market W are 0.014 mRhr^{-1} for indoor and 0.027 mRhr^{-1} for the outdoor. The mean radiation exposure rate at oil flow station Z are 0.010 mRhr^{-1} for indoor and 0.014 mRhr^{-1} outdoor.

The obtained results showed that only indoor values from pipeline inspection facility and oil flow station were below ICRP recommended level of 0.013 mRhr^{-1} for general public while other values from the measured locations both indoor and outdoor exceeded the permissible value. In spite of higher values obtained in most sampling points, the result of this study is consistent with some results in literatures [7].

The results also showed the mean site radiation levels for the Pipe Inspection Facility; Drill Cutting Treatment Facility and Oil Flow Station were within the range of 0.014±0.001 mRhr^{-1} and 0.018±0.002 mRhr^{-1} obtained by Ononugbo et al. [11] within industrial areas of ONELGA local government area of Rivers state and mean value of 0.015±0.002 mRhr^{-1} obtained at Emene industrial layout of Enugu state by Ugbede and Benson (2013). The mean value of 0.019±0.006 mRhr^{-1} obtained by Anekwe et al. [12] for the selected oil spill areas in Rivers state was slightly higher than the exposure rate at the pipe inspection, drill cutting treatment and oil flow station facilities, but lower than the mean BIR level for used oilfield pipe market, 0.027±0.003 mRhr^{-1}.

The measured high exposure rates of some facilities could be attributed to the radionuclides enhancement in the oil and gas wastes stream generated or processed within those facilities. The results also showed consistency in the elevated outdoor exposure levels above the indoor exposure levels. This can be attributed to effect of cosmic rays as well as waste disposal effect more prevalent outdoor. The values of all the radiological health risk parameters computed from the exposure rate showed consistently elevated values when compared with their reference values as shown in Figs. 1-4.

The radiological health hazard indicators (Figs. 1 to 4) varied significantly for the four facilities studied in this research. The absorbed dose values estimated at the pipe inspection facility X ranged from 74.0 to 126.2 nGy/h with mean value of 103.7 nGy/h (indoor survey) and 78.3 to 169.7 nGy/h with mean value of 126.9 nGy/h (outdoor survey), while absorbed dose values for drill cuttings treatment facility indoor survey ranged from 65.3 to 134.9 nGy/h with mean value of 111.0 nGy/h and for outdoor survey ranged from 117.5 to 169.7 nGy/h with mean value of 147.2 nGy/h. The assessed absorbed values for used oilfield pipe market ranged from 47.9 to 239.3 nGy/h with mean value of 121.1 nGy/h for indoor survey and 69.6 to 704.7 nGy/h with mean value of 234.2 nGy/h for outdoor survey. For the Oil flow station indoor survey, the values ranged from 52.2 to 134.9 nGy/h with mean value of 92.1 nGy/h and outdoor survey ranged from 100.1 to 134.9 nGy/h with a mean value 120.4 nGy/h.

This range of values in the study for indoor and outdoor survey were higher than the weighted world average of 59 nGy/h and the UNSCEAR recommended safe limit of 84 nGy/h respectively The average absorbed dose rate for outdoor survey in the current the locations falls within the range 166.7 nGy/h of value selected crude oil production pipe storage locations in Niger Delta region of Nigeria [7]. Apart from the recorded outdoor survey value recorded at used oilfield pipe market which was higher.

The calculated AEDE values from pipe inspection facility varied from 0.11 to 0.19 mSv/yr with a mean value of 0.16 mSv/yr for indoor survey and 0.12 to 0.26 mSv/yr with mean 0.19 mSv/yr for the outdoor survey. Estimated AEDE values at drill cuttings treatment facility ranged from 0.10 to 0.21 mSv/yr with an average value of 0.17 mSv/yr (indoor survey) and 0.18 to 0.26 mSv/yr with mean value of 0.23 mSv/yr (outdoor survey) while results obtained from used oilfield pipe market indoor survey ranged from 0.07 to 0.37 mSv/yr with mean value 0.19 mSv/yr and outdoor survey values varied 0.11 to 1.08 mSv/yr with an average value of 0.36 mSv/yr. The average AEDE values recorded from the oil flow station indoor survey ranged from 0.08 to 0.21 mSv/yr with mean value of 0.14 mSv/yr and outdoor results ranged from 0.15 to 0.21 mSv/yr with average value of 0.18 mSv/yr. Obtained Average AEDE results are significantly higher when compared to the world average value of 0.70 mSv/y.

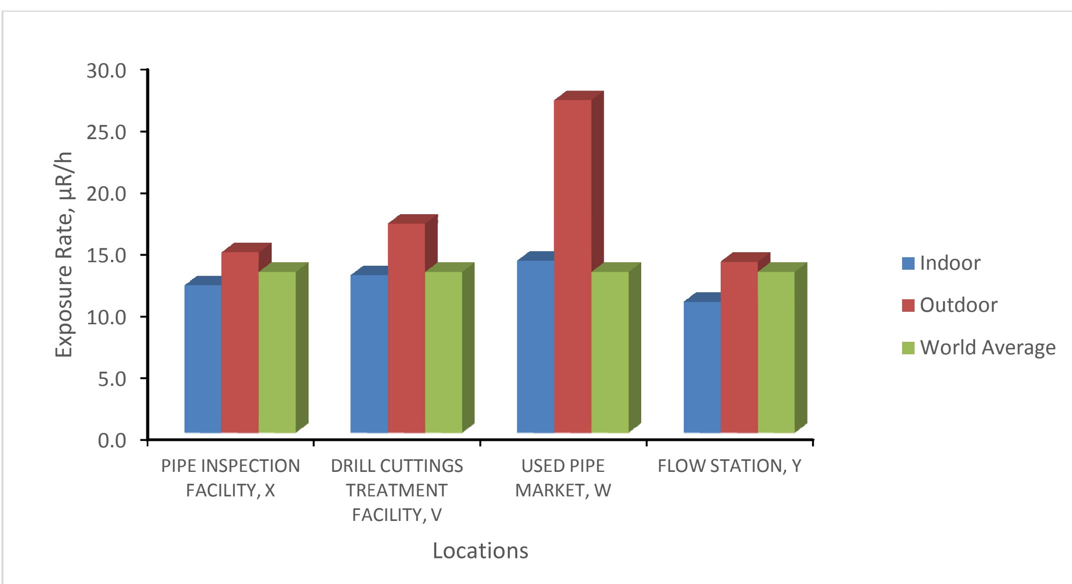

Fig. 1. Exposure rate in four oil and gas waste processing facilities

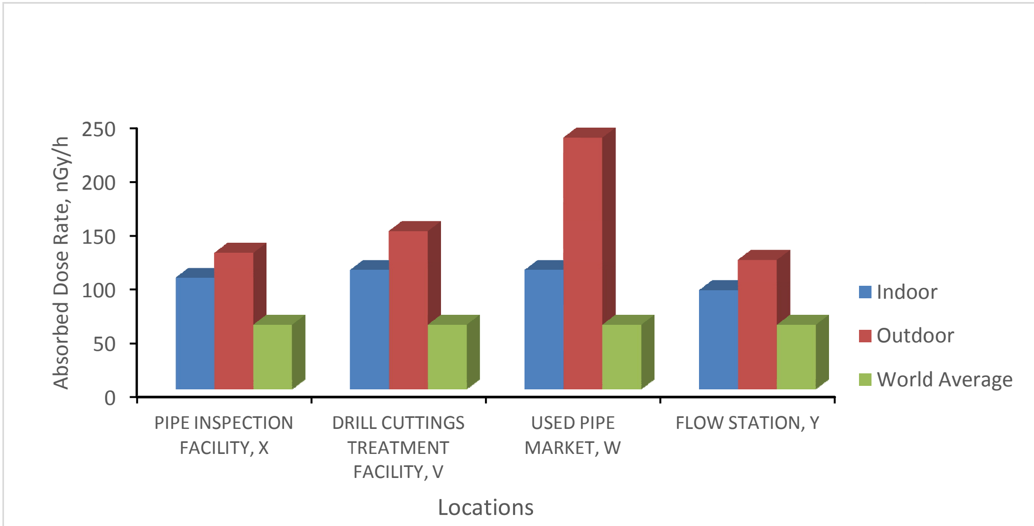

Fig. 2. Absorbed dose rate in four oil and gas waste processing facilities

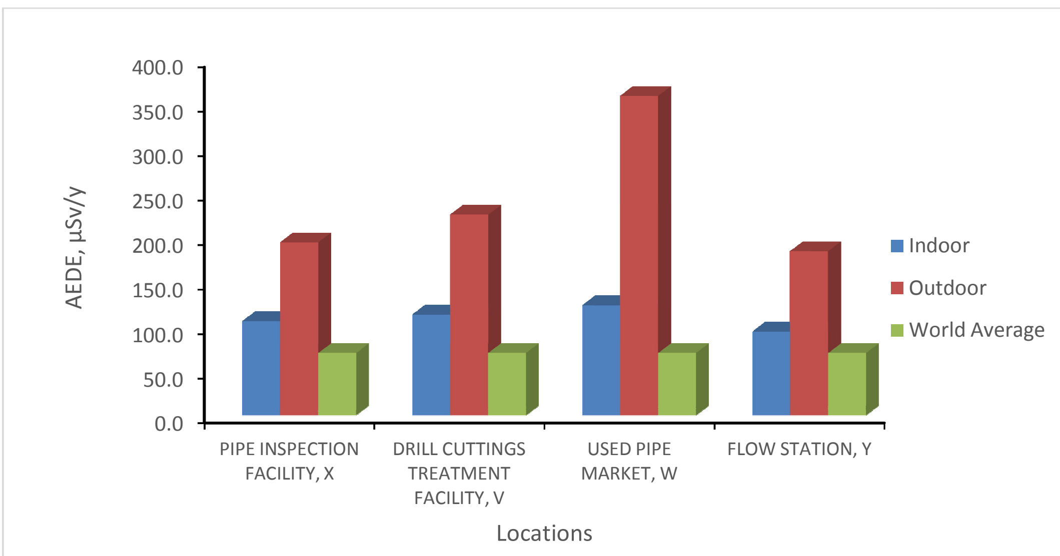

Fig. 3. AED in four oil and gas waste generating and processing facilities

The ELCR values varied from (0.40 to 0.68) x 10^{-3} with a mean value of 0.56 x 10^{-3} for indoor survey and (0.42 to 0.91) x 10^{-3} with mean of 0.68 x 10^{-3} for outdoor survey at pipe inspection facility while at the dill cuttings treatment facility, the indoor survey values ranged from (0.35 to 0.72) x 10^{-3} with an average of 0.60 x 10^{-3} and outdoor survey values varied from (0.63 to 0.91) x 10^{-3} with mean value of 0.79 x 10^{-3} for outdoor survey values. Estimated ELCR values at used oilfield pipe market indoor survey ranged from (0.26 to 1.28) x 10^{-3} with mean of 0.65 x 10^{-3} and (0.37 to 3.7) x 10^{-3} with average value of 1.26 x 10^{-3} and the outdoor survey. Oil flow station ELCR values varied from (0.28 to 0.72) x 10^{-3} with mean of 0.49 x 10^{-3} for indoor survey and (0.54 to 0.72) x 10^{-3} with mean value of 0.65 x 10^{-3} for the outdoor survey.

The high values of all the radiological parameters at used oilfield pipe market is an indication that the pipe sellers and the buyers may be exposed to slightly high radiation. The elevated ELCR values within the oilfield locations shows that there are possibility of workers and residents around these locations developing cancer for long term exposure if not monitored.

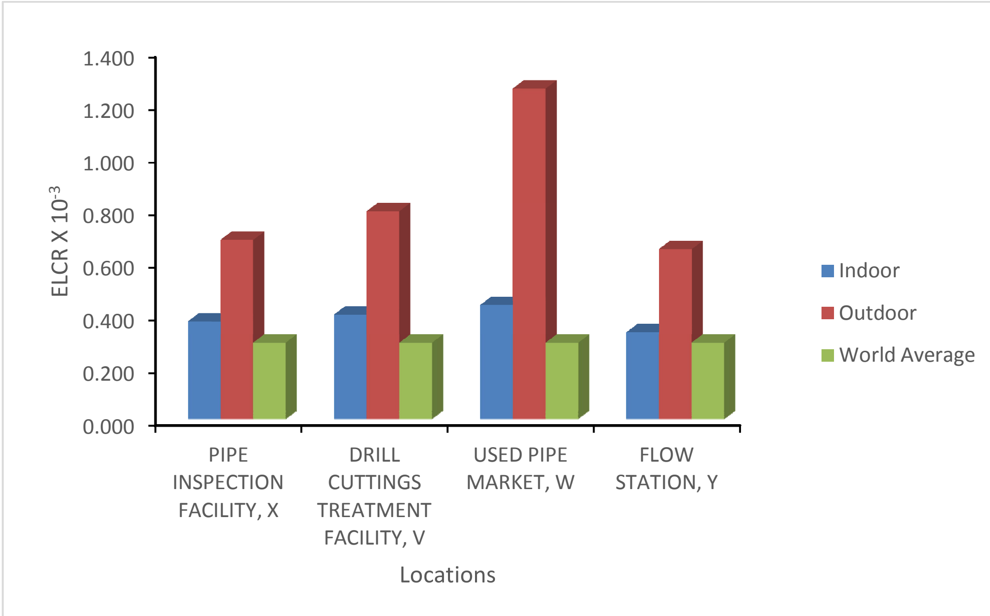

Fig. 4. ELCR in four oil and gas waste generating and processing facilities

4. CONCLUSION

The occupational hazards from outdoor and indoor radiation in oil field facilities in Rivers State, Nigeria carried out using radiation. The exposure rate measured in all the oil facilities were higher than the permissible value of 0.013 mRh^{-1}. The absorbed dose, annual effective dose and excess lifetime cancer risk estimated showed slightly elevated values in most of the facilities and its environment.

These reported values according to EPA (2009) could constitute long-term health hazards to both oilfield workers and host community residents. From the results of this study, oilfield pipe is not suitable for construction of tank stands in residential homes because it could act as a source of radiation exposure.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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