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Occupational Hazards from BIR in Selected Crude Oil Production Pipes Storage Locations in Niger Delta Region of Nigeria

Azionu C. Kingsley[1*], Avwiri O. Gregory[2] and Ononugbo, P. Chinyere[2]

[1]Centre for Occupational Health, Safety and Environment, University of Port Harcourt, Rivers State, Nigeria.
[2]Department of Physics, University of Port Harcourt, Rivers State, Nigeria.

Authors' contributions

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

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ABSTRACT

The study of occupational hazards from BIR in selected crude oil production pipes storage locations in Niger Delta Region of Nigeria has been carried out using two well calibrated radiation monitoring meters (Digilert $_{Tm}$ 100 and Radalert $_{Tm}$ 200). A global positioning system (GPS 76 CSX) was also used to geographically co-ordinate the sampling locations. Measurements were carried out in forty two (42) selected locations in oil producing area of Niger Delta. The following parameters were estimated to determine the level of occupational exposures by crude oil production pipes dealers and customers. The result of the highest exposure rate was observed in Warri Steel Village, Delta State and the lowest value was in Ogunu, Warri, Delta State with respective values of 61.4 and 12.2 μRh^{-1}. The mean exposure rate value for all the test study locations was 19.18 ± 10.25 μRh^{-1}. The absorbed dose values ranged from 106.1 to 533.7$nGyhr^{-1}$ with mean value of 166.73 ± 89.08 $nGyh^{-1}$ while the calculated annual effective dose range from 162.71 to 818.23 μSvy^{-1} with an average value of 255.60 ± 136.57 μSvy^{-1} and the excess lifetime cancer risk ranges from 0.45 to 2.25 × 10^{-3}

**Corresponding author: E-mail: kc.azionu@gmail.com;*

with mean value of 0.70 ± 0.38 × 10^{-3}. All the radiation hazard parameters determined exceeded their respective world safe values. This research work indicated that the crude oil production pipes radioactive scales may have impacted the storage locations radiologically. The elevated radiation hazard parameters observed in this study may pose ill health effects to those working and leaving in the studied locations especially long term ionizing radiation exposure.

Keywords: Occupational hazards; BIR; crude oil production; radiation exposure.

1. INTRODUCTION

In oil and gas exploration and exploitation, contact with both natural and artificial radioactive substances is inevitable. Therefore, this may lead to raised natural background ionization radiation [1,2]. Petroleum production pipes may contain scales from technologically enhanced natural occurring radioactive material (TENORM) [3,4,5]. Some processes in oil and gas fields may require artificially sealed and unsealed radioactive material usage [6]. It is worthwhile to note that improper disposal of these hazardous materials may lead to internal (fine grain distribution, that increases the risk of inhalation or ingestion) and external radiation hazards exposure to workers, general public and the environment [3,4,5].

The Earth's crust contains primordial radionuclides with different concentrations depending on the geology of the area. The geochemistry of each element also plays a role in radionuclides migration. These primordial radionuclides like uranium and thorium undergo natural decay, producing a sequence of radioactive progenies [7].

Scale deposition is the crystalline precipitate of mineral compounds formed in water amongst which include radium, calcium, barium, strontium of sulphate and carbonate. The radionuclides found in petroleum production pipes scales include radioactive radium isotopes (^{224}Ra, ^{226}Ra and ^{228}Ra) and their decay products: radon, lead, polonium and bismuth isotopes [8,9]. Scales by – products can be suspended in aqueous solution or get adhered to the pipe surface. Typically, scales are deposited in the inner walls of production tubulars, valves, wellheads, water treatment plants, gas treatments pumps, separators, oil storage tanks, other types of topside equipment, filters amongst others [6]. Scales can also present as a coating on produced sand grains [10]. Fig. 1 shows petroleum production pipes with scales.

The health, safety and environment challenges are encountered when the scales contaminated pipes are moved from site to site. It can also occur if production pipes and other contaminated equipment are reused or recycled. Some pipes may be discarded and others stock piled in several locations. These radioactive contaminated pipes will continue to emit radiation that may contaminate groundwater, air and land. These may pose negative health risks for workers, public and other organisms in the immediate and remote areas [11,12]. According to the International Labour Organization, occupational exposure to any hazardous agent includes all exposures incurred at work, regardless of source. Prior to 1990s, attention in the area of occupational exposure focused on artificial sources of radiation. However, recent research results have shown that very large number of workers is exposed occupationally to natural sources of radiation as well.

The radioactive exposure limits are designed to protect individual workers, public and the environment. Background ionization radiation when it exceeds safe occupational and public limits, can be considered a form of environmental contamination [13]. However, inasmuch as

Fig. 1. Scale of petroleum production pipes

ionizing radiation exposure can cause adverse health effects, there is strong evidence of cancer preventive effect of low dose ionizing radiation observed in animal and human studies. Radiation hormesis studies have shown that low dose rate ionizing radiation stimulates living system defense mechanisms [14].

The need for precise and accurate information on the background ionizing radiation levels of discarded crude oil production pipes stored locations and the inadequate data on back-ground radiation levels in this environment lay credence to this study. This paper therefore measured the radiation exposure rates and also estimated the radiological hazards indices of the studied locations. This study will be a useful tool for helping decision makers and authorities in charge of radiation exposure rates in the studied locations.

2. MATERIALS AND METHODS

2.1 Study Area

The Niger Delta of Nigeria is situated in the Gulf of Guinea between latitudes 3° and 5° N and longitudes 5° and 8° E. It is an area of about 70,000 km^2, it is rich in biodiversity and maintains the largest drainage system into the Atlantic Ocean in West Africa. It is the largest wetland and maintains the third-largest drainage in Africa [15]. Within wetlands (20,000 km^2), formed primarily by sediment deposition, which houses Nigeria's proven gas reserves, estimated to be 120 trillion cubic feet [16]. The Niger Delta area cuts across nine states in southern Nigeria which include Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo and River States [17,18, 19]. Fig. 2 shows the map of Nigeria and the constituent states and some oil producing fields in the Niger Delta Region. The Niger Delta forms one of the world's major hydrocarbon provinces. Oil and gas exploration and exploitation in the Niger Delta of Nigeria has led to various forms of activities that tend to affect the fragile ecological, biophysical systems and the socio-economic and political structures. Oil and gas industry in the Niger Delta is a multi-faceted industry that includes the construction, exploration, production and marketing sectors. The areas are criss-crossed with network of pipelines carrying either oil or gas to the flow stations from many oil wells. In most of these sectors, radioactive materials and radiation generators are used on a large scale [20]. Incidence of ionizing radiation is further enhanced in the Niger delta widespread gas flaring which contribute to the radon in the atmosphere of the region. Also, re-injected of gas into oil wells to improve oil recovery increases the ionizing radiation level. Large volume of radioactive seawater used in the process of oil recovery contributes significantly to increasing in ionizing radiation level in this region [21].

2.2 Field Measurement

An *in-situ* measurement of the background ionizing radiation level was done using two well calibrated radiation monitoring meters (Digilert $_{Tm}$ 100 and Radalert $_{Tm}$ 200, S. E. International Inc, Summer Town, USA) containing a Geiger-Muller tube capable of detecting alpha, beta gamma and x-rays within the temperature range of 10°C and 50°C. The Geiger Muller tube generates a pulse current each time radiation passes through the tube and causes ionization [22]. Each pulse is electronically detected and registered as a count. The radiation meters were calibrated at and set to measure exposure rate in milli-Roentgen per hour. The readings were taken within the hours of 1300 and 1600 hours because exposure rate meter has a maximum response to environmental radiation within these hours [23,24]. The tube of the radiation meter was raised to a height of 1.0m above the earth surface with its window facing first the earth surface and then vertically downwards [1].

While a global positioning system (GPS 76 CSX) was used to geographically co-ordinates the sampling locations.

Measuring were carried out in forty two (42) selected crude oil production pipes storage locations in Niger Delta Region. These areas were divided into test (21) and control (21) areas. Ten (10) readings were taken in each of the test areas while five (5) readings were taken in each of the control areas making a total of three hundred and fifteen (315).

To estimate the whole body equivalent dose rate over a period of one year, the National Council on Radiation Protection and Measurement [23] recommendation is used:

$$1\text{mRh}^{-1} = \frac{0.98 \times 24 \times 365}{100} = 84.1\ \text{mSvy}^{-1} \quad (1)$$

2.3 Absorbed Dose Rate

Data obtained for outdoor exposure rate in mR/h was converted into absorbed dose rate in nGy/h using the conversion factor.

$$1\ \mu\text{R/h} = 8.7\text{nGy/h} = 8.7 \times 10^{-3}\ \mu\text{Gy/ (1/8760) yr} = 76.212\mu\text{Gyy}^{-1} \quad (2)$$

Fig. 2. Map of the constituent states and oil producing fields of the Niger Delta Region
(Source: studies.aljazeera.net)

2.4 Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent received outdoor by a member of the public is calculated from the absorbed dose rate using dose conversion factor of 0.7Sv/Gy and the occupancy factor for outdoor of 0.2 [25]. AEDE outdoor involves a consideration of the absorbed dose emitted from radionuclides in the environment such as 226Ra, 232Th and 40K [26].

$$\text{AEDE (Outdoor) } (mSvy^{-1}) = \text{Absorbed dose rate } (nGyhr^{-1}) \times 8760hr \times 0.7Sv/Gy \times 0.2 \quad (3)$$

2.5 Excess Lifetime Cancer Risk (ELCR)

Excess Lifetime Cancer Risk is the probability of developing cancer over a lifetime at a given radiation exposure level. It is presented as a value representing the number of extra cancers expected in a given number of people on exposure to a carcinogen at a given dose. It is calculated using the equation (3) [27].

$$\text{Excess lifetime cancer risk (ELCR)} = AEDE \times DL \times RF \quad (4)$$

Where, AEDE is the Annual Effective Dose Equivalent, DL is average Duration of Life (estimated to be 55years) and for low–dose background ionizing radiation, which is considered to produce stochastic effects, ICRP–60 uses a fatal cancer risk factor value 0.05(Svy^{-1}), for the public exposure [27].

3. RESULTS AND DISCUSSION

The result is represented in Table 1, Figs. 2, 3 and 4.

The highest exposure rate was observed in Warri Steel Village, Delta State (61.4 $\mu Rh^{-}1$) and the lowest in Ogunu, Warri, Delta State (12.2 μRh^{-1}). The mean exposure rate value was 19.18 ± 10.25 μRh^{-1}.

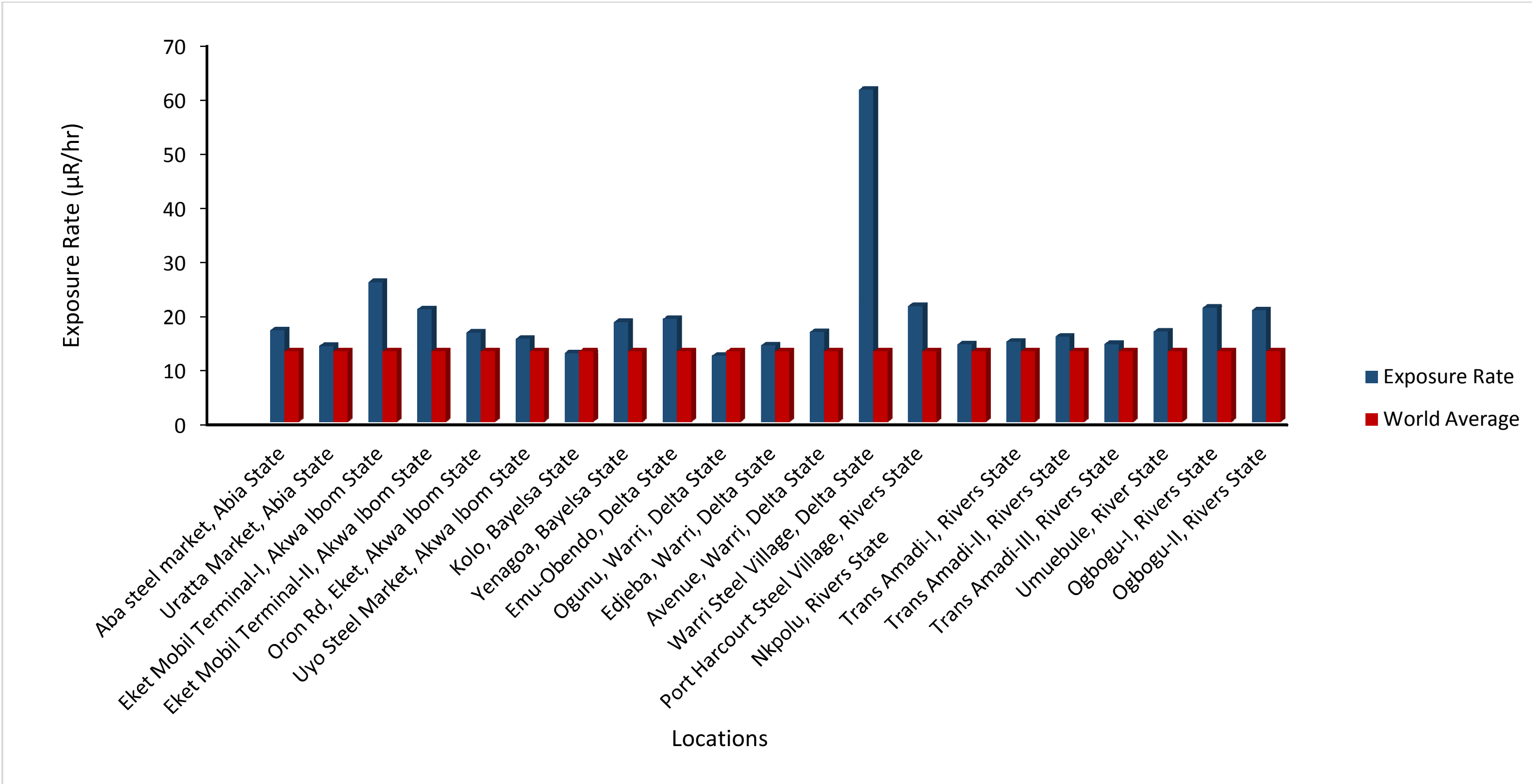

Fig. 3. Comparison of exposure rate with normal background of standard

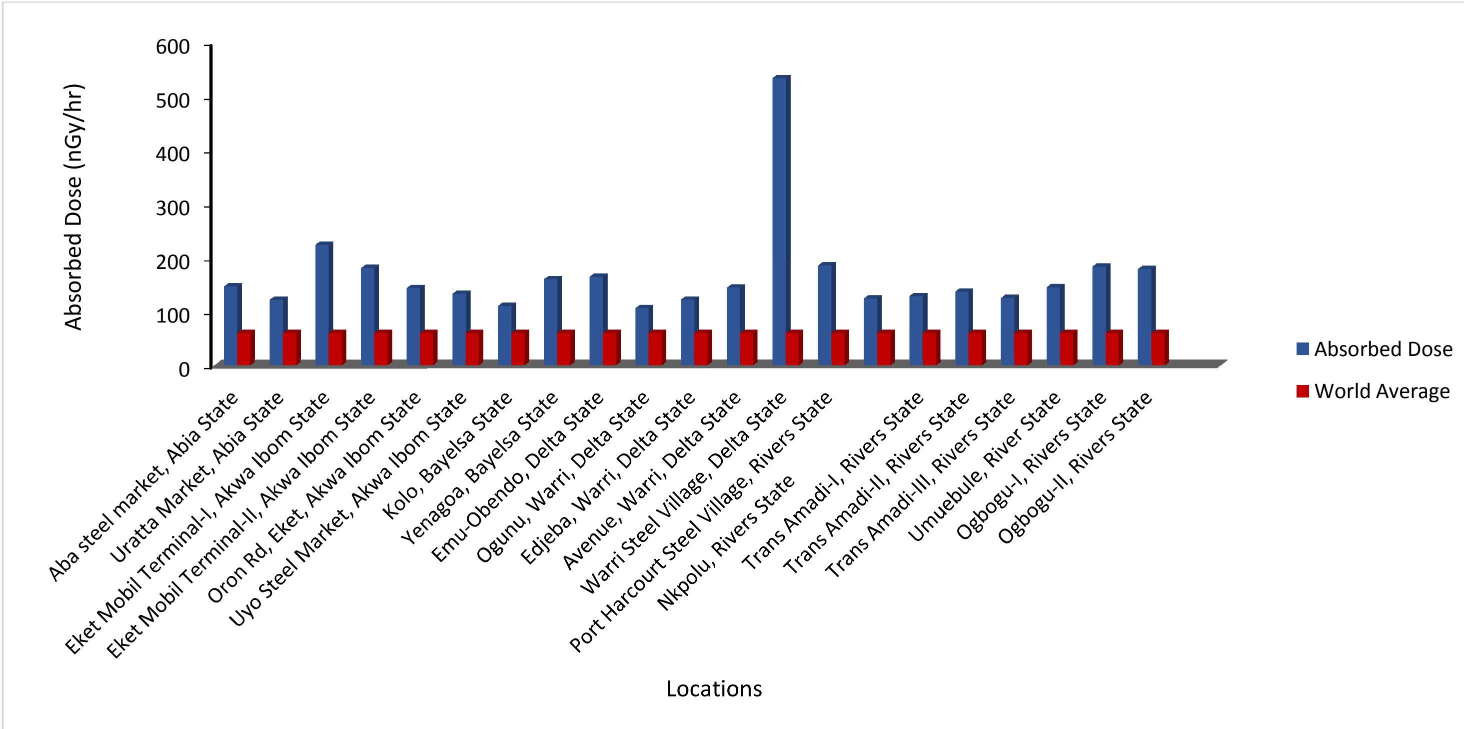

Fig. 4. Comparison of absorbed dose rate with Normal Background of Standard

Table 1. Mean exposure rate measured and their radiation parameters

S/No	Locations	Exposure Rate (μR/hr)	Absorbed Dose (nGy/hr)	AEDE (μSv/y)	ELCR x 10^{-3}
1.	Aba steel market, Abia State	16.9	146.6	224.73	0.62
2.	Uratta Market, Abia State	14.0	121.8	186.72	0.51
3.	Eket Mobil Terminal-I, Akwa Ibom State	25.8	224.0	343.43	0.94
4.	Eket Mobil Terminal-II, Akwa Ibom State	20.8	181.0	277.41	0.76
5.	Oron Rd, Eket, Akwa Ibom State	16.5	143.6	220.06	0.61
6.	Uyo Steel Market, Akwa Ibom State	15.3	133.1	204.06	0.56
7.	Kolo, Bayelsa State	12.7	110.5	169.38	0.47
8.	Yenagoa, Bayelsa State	18.4	160.1	245.40	0.67
9.	Emu-Obendo, Delta State	19.0	164.9	252.74	0.70
10.	Ogunu, Warri, Delta State	12.2	106.1	162.71	0.45
11.	Edjeba, Warri, Delta State	14.1	122.2	187.39	0.52
12.	Avenue Rd, Warri, Delta State	16.6	144.4	221.40	0.61
13.	Warri Steel Village, Delta State	61.4	533.7	818.23	2.25
14.	Port Harcourt Steel Village, Rivers State	21.4	185.7	284.75	0.78
15.	Nkpolu, Rivers State	14.3	124.4	190.72	0.52
16.	Trans Amadi-I, Rivers State	14.8	128.8	197.39	0.54
17.	Trans Amadi-II, Rivers State	15.75	137.0	210.06	0.58
18.	Trans Amadi-III, Rivers State	14.4	125.3	192.05	0.53
19.	Umuebule, River State	16.7	145.3	222.73	0.61
20.	Ogbogu-I, Rivers State	21.1	183.6	281.40	0.77
21.	Ogbogu-II, Rivers State	20.6	179.2	274.74	0.76
	Mean	**19.18±10.25**	**166.73±89.08**	**255.60±136.57**	**0.70±0.38**
	World Average (UNSCEAR, 2000)	**13.0**	**60.0**	**70.0**	**0.29**

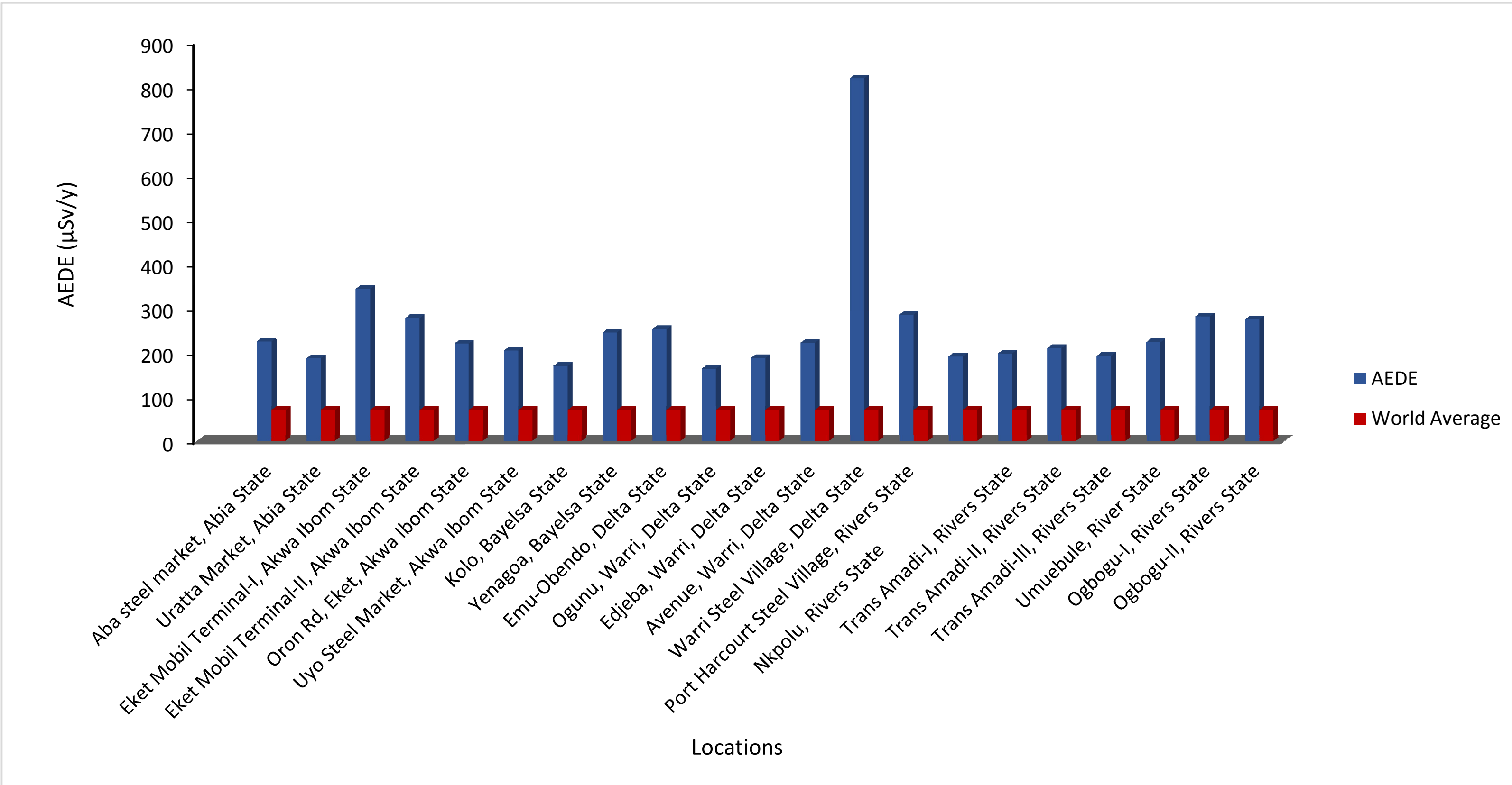

Fig. 5. Comparison of annual effective dose equivalent with normal background of standard

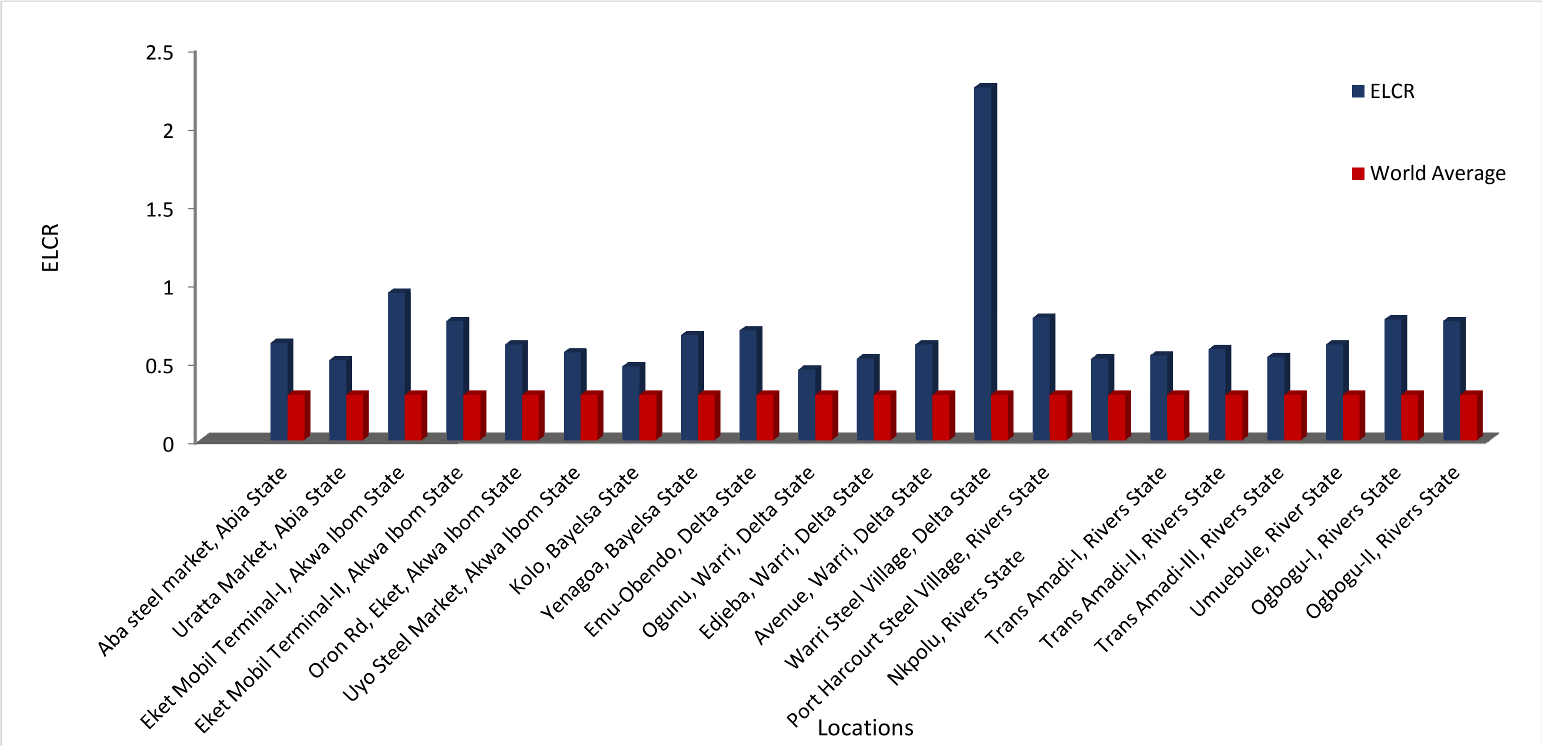

Fig. 6. Comparison of ELCR with normal background of standard

The radiation exposure rate were highest for Warri Steel Village in Delta State, followed by Eket Mobil Terminal-I in Akwa Ibom State, then Port Harcourt Steel Village in Rivers State, Ogbogu-I in Rivers State, then Eket Mobil Terminal-II in Akwa Ibom State, then Eket Mobil Terminal-II in Akwa Ibom State, then Ogbogu-II in Rivers State location in that order. The location that recorded the highest exposure rate is discarded steel / pipes main market in Warri. This location is the collection centre for discarded crude oil production pipes from different oil and gas companies operating in various Niger Delta communities as the sources are not local to Warri. Radioactive contamination might explain the high radiation level recorded in this location since there are no primordial radionuclides in the area. The mean exposure rate in this study was higher than the ones reported by [24,26,28,29].

The absorbed dose values ranged from 106.1 to 533.7nGyhr^{-1} with mean value of 166.73 ± 89.08 nGyh^{-1} is higher than the world weighted average of 60nGyh^{-1} [25]. The mean value for this study is also higher than the mean absorbed dose rate reported by Agbalagba [29], Ovuomarie-kevin et al. [30,31] and some countries reported by [25]. The calculated annual effective dose ranges from 162.71 to 818.23 µSvy^{-1} with an average value of 255.60 ± 136.57 µSvy^{-1}. The calculated result is also higher than the world average (70.0 µSvy^{-1}) [25].

The excess lifetime cancer risk ranges from 0.45 to 2.25 × 10^{-3} with mean value of 0.70 ± 0.38 × 10^{-3} which when compared with the world standard value of 0.29 × 10^{-3} [25] is higher. The excess lifetime cancer risk estimated from the annual effective dose in all the locations exceeded the world weighted average of 0.29 x 10^{-3}. Therefore the probability of developing extra cancer due to long term exposure ionizing radiation in these locations is significant. The excess lifetime cancer risk high values suggest that those carrying out their day to day activities around the storage locations will receive appreciably long term ionizing radiation doses.

4. CONCLUSION

The study of occupational hazards from BIR in selected crude oil production pipes storage locations in Niger Delta Region of Nigeria to estimate hazard indices has been carried out. The study revealed that all the radiation hazard parameters determined exceeded their respective world safe values. This suggests that TENORM and artificial (sealed and unsealed) radioactive materials contaminated pipes may have contributed to the raised ionizing radiation values in these areas. The values of the radiation health hazard parameters were highest for Warri Steel Village in Delta State, followed by Eket Mobil Terminal-I in Akwa Ibom State, Port Harcourt Steel Village in Rivers State, Ogbogu-I in Rivers State, Eket Mobil Terminal-II in Akwa Ibom State, Eket Mobil Terminal-II in Akwa Ibom State, Ogbogu-II in Rivers State location in that order.

These elevated values may constitute health risk to those working and leaving in the studied locations. The authors cautions against prolonged exposure to ionization radiation and recommends ALARA (as low as reasonably achievable) principle for the workers and the public. This result suggests further studies of other environmental media such soil, water and crops from the studied locations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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