Excess Lifetime Cancer Risk due to gamma radioactivity in and around Warri Refining and Petrochemical Company in Niger Delta, Nigeria.

Abstract

Radioactivity measurements were carried out in and around Warri Refining and Petrochemical Company in the Niger Delta region of Nigeria for the naturally occurring radionuclides of ^{40}K, ^{238}U and ^{232}Th. The values were used to determine the excess lifetime cancer risk (ELCR) and the radiation health hazard index. Results show that the ELCR value within the company premises is 0.12×10^{-3} while the highest value is 0.17×10^{-3} from Ugborikoko Community. The internal health hazard index is ranges from 0.02 – to 0.641 and the external health hazard index ranges from 0.02 – 0.326. All these values were less than the world permissible standard. It could be concluded that the potential carcinogenic risk from gamma radiation doses to the population in and around the refining and petrochemical company is low.

Keywords: Activity concentration, effective dose, cancer risk and hazard index.

1. Introduction

Human beings are always exposed to background radiation that arises both from natural and man- made sources. Natural radioactivity is widespread in the earth's environment and they exist in various geological formations such as rocks, earth crust, plants, water and air [1]. When a nuclear radiation type passes through a living cell, both excitation and ionization takes place thereby altering the structure of the cells. These cells may be damaged directly by the radiation or indirectly by the free radicals (OH and H) produced in the adjacent cells. Many forms of damage could occur from radiation but the most important is that done to the deoxyribonucleic acid (DNA). A damage to the DNA results in gene mutation, chromosomal aberration and breakages or cell death. More frequently repairs can take place. This however depends on the condition that the damage is not a lethal damage. If repair is not perfect, it may result in a genetically modified cell. When human cells in an organ or tissue are killed or prevented from reproducing and functioning normally, there will be loss of organ function. A modified germ cell for instance in the gonads of an individual may transmit incorrect hereditary information, which may cause severe hereditary effects. Exposure to ionizing radiation over extended period of time is known to result in non- leather mutation which could increase the risk of cancer [2]. There is a linear, no-threshold (LNT) relationship between radiation dose and the occurrence of cancer. This dose-response hypothesis suggests that any increase in radiation dose, no matter how small, could results in an increase in cancer risk [3]. Diseases caused by radioactivity exposure includes lung cancer, pancreas, hepatic, skin, kidney cancers cataracts, sterility, atrophy of the kidney and leukaemia [4].

A radiation – induced cancer can develop from a single damaged cell independently of other damaged cells in the tissue of interest. The period of time between radiation exposure and the detection of cancer is known as the latent period and could be many years. Therefore excess lifetime cancer risk is the probability that an individual will develop cancer over his/her lifetime of exposure. Initial study by Jibiri and Emelue [5] looked at the radionuclide concentration and the annual effective dose of the soil in and around the refining and petrochemical company. This particular study is focused mainly on the health hazard index and the cancer risk due to the radionuclide concentration in the area. Therefore the purpose of this work is to determine if the 35 years duration of the refinery has any cancer implications to the workers inside it and the communities surround it.

2. Material and methods

Surface – soil samples were collected from inside the refinery and 13 communities around it in a labelled waterproof nylon bag and transferred to the laboratory for analysis. . 6 samples were collected inside the refinery premises,while 36 samples were collected from the 13 surrounding communities to make a total of 42 samples. The communities where the samples were collected are given in Table 2 with the number of samples collected in parenthesis beside each location. While Figure 1 is the map of the study area. They were air dried and homogenized to pass 1mm mesh sieve. Then about 0.2Kg of each sample were weighed and transferred to a plastic container of about 8cm in height and 7cm in diameter. They were sealed for 28 days for the short lived members of Uranium and Thorium series to reach a secular equilibrium . Then the samples were placed symmetrically on top of the detector and measured for 10hours (36000s). The net area under the corresponding photopeaks in the energy spectrum was computed by subtracting count due to Compton scattering of the background source from the total area of the photopeaks. The radionuclides was computed using the algorithm of the multichannel analyzer (MCA).

The scintillation detector used in this work is a lead shield Canberra 76mm x 76mm NaI(Ti) crystal models number 802 – series. One face of the cylindrical detector is free while the other is optically coupled to a Photomultiplier tube which detects the small visible light photons produced in the crystal and converts them into amplified electrical pulses which is fed into analyzer systems (Canberra series 10 plus multichannel analyzer MCA) through a preamplifier base.

The gamma spectrometry detector was calibrated before it was used for analysis. This was done to ensure that the radiation parameters in the samples could be expressed in physical radiometric units. This calibration was done in two stages. This is energy calibration and efficiency calibration. The energy calibration convert channel numbers to γ - ray energy in Mev. This was done by placing different gamma sources of known energy on the detector at a distance of 7cm from it. After a preset counting time of 36,000s, the channels of the various photopeaks corresponding to the gamma energies were identified. The efficiency calibration was to determine the gamma ray counting efficiencies over energy range of 0.662 – 2.615 MeV. This was done by converting the count per seconds under the photopeaks to activity concentration Bq/kg of certified reference standard samples. The certified reference standard samples have activity concentrations of 7.24 Bq/kg for ^{137}Cs (0.662 MeV), 510.00 Bq/kg for ^{40}K (1.460 MeV), 631.00 Bq/kg for ^{226}Ra (1760 MeV of ^{214}Bi) and 11.00 Bq/kg for ^{232}Th (2.615 MeV of ^{208}TI). Efficiencies at different gamma energy peaks are given in Table 1. The reference standard sources were counted for 10 hours (36,000s) after which the counting efficiencies of the different gamma energies were determined. According to [6] and [7], the count rate A_{net} under the photopeak of each of the three primordial radionuclides is related to activity concentration by the equation 1.

$$A_s = \frac{A_{net}}{\varepsilon_y Y_\gamma M_s t} \qquad 1$$

Where A_s = activity concentration in $BqKg^{-1}$

ε_γ = the efficiency of the detector at a particular γ – energy

A_{net} = count rate under the photopeak of the 3 primordial radionuclides,

Y_γ = the yield of the gamma ray at a particular energy,

M_s = the mass of the samples (0.2Kg)

t_s = the counting time in seconds.

Table 1. Efficiencies at different gamma energy peaks.

Radionuclide	Energy (MeV)	Gamma Yield	Area Count/25200s)	Efficiency (%)
Cs-137	0.662	0.852	2476	5.57
K- 40	1.460	0.107	8342	1.87
Ra-226	1.760	0.159	400	1.67
Th-232	2.615	0.358	364	1.35

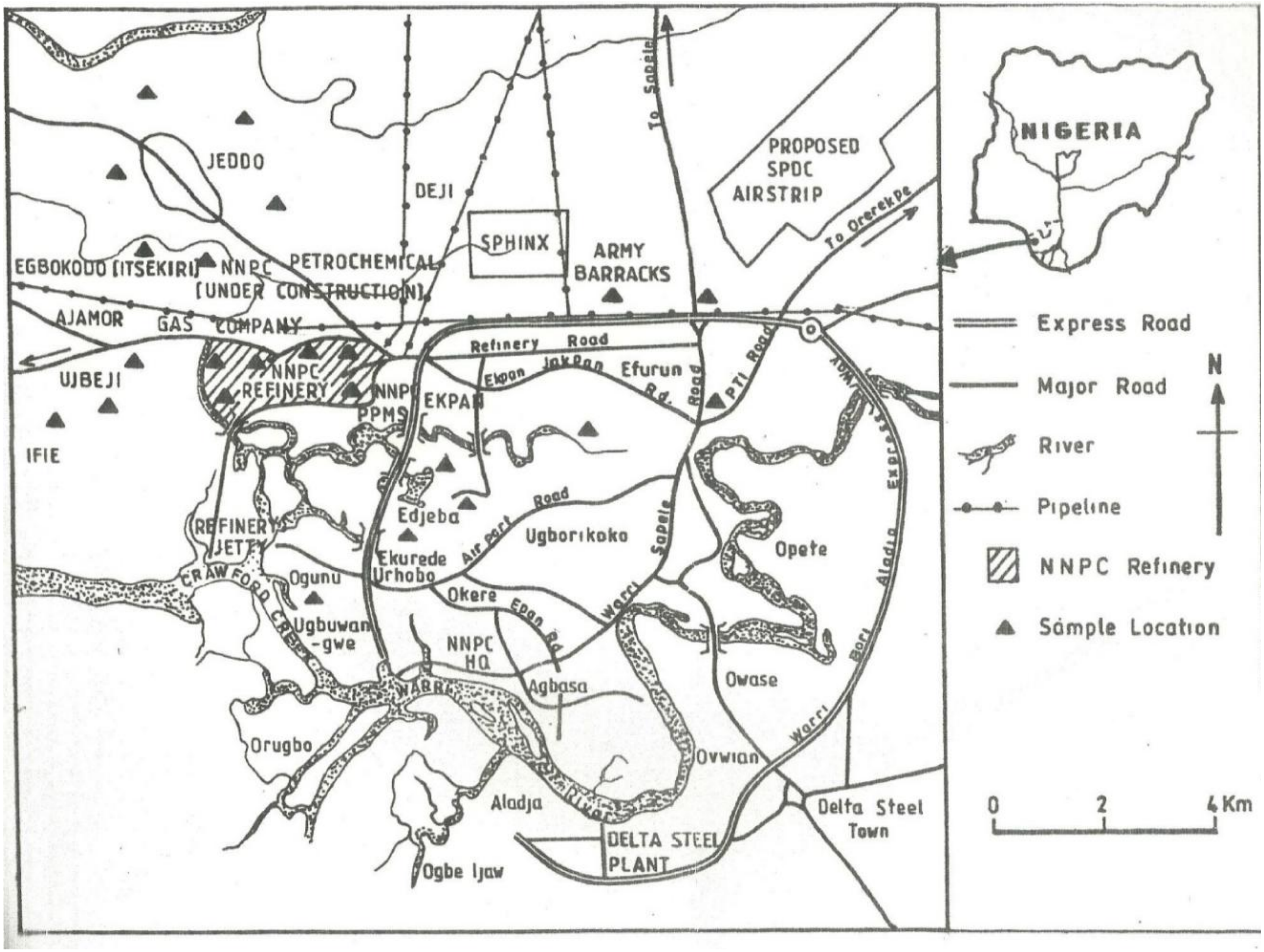
JEDDO
DEJI
SPHINX
ARMY BARRACKS
PROPOSED SPDC AIRSTRIP
To Sapele
To Orerekpe
NIGERIA
EGBOKODO (ITSEKIRI) NNPC PETROCHEMICAL (UNDER CONSTRUCTION)
AJAMOR GAS COMPANY
UJBEJI
IFIE
NNPC REFINERY
NNPC PPMS
EKPAN
Refinery Road
Ekpan Jakpan Efurun Rd.
Road
PTI Road
Edjeba
Ekurede Urhobo
Airport Road
Ugborikoko
Sapele
Opete
REFINERY JETTY
CRAWFORD CREEK
Ogunu
Ugbuwan-gwe
Okere Epan Rd.
Warri
NNPC HQ
Agbasa
WARRI
Owase
Orugbo
Aladja
Ovwian
Warri River
Delta Steel Town
DELTA STEEL PLANT
Ogbe Ijaw
Aladja Express Way
Bori Warri
Express Road
Major Road
River
Pipeline
NNPC Refinery
Sample Location
N
0 2 4 Km

Figure 1. A map of Warri showing the company premises and surrounding communities from where samples were collected.

3. Results and Analysis

In order to study the radiation health hazards associated with soil samples from the area, the following parameters were defined.

3.1 Samples Activity Concentrations

The values of the range and mean of the activity concentrations of the 3 radionuclides has earlier been published in [5].

Table 2. The range and mean soil activity concentrations of the 3 radionuclides at different locations in the company premises and the surrounding communities

	^{40}K (Bqkg^{-1})		**^{226}Ra (Bqkg^{-1})**		**^{228}Th (Bqkg^{-1})**	
Locations	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Refinery (6)	261.3-932.3	560.3±212.0	<4.2-23.0	1.7±0.9	<5.1-10.2	6.6±3.1
Ekpan (4)	<17.2-766.3	497.6±221.0	<4.2-15.4	4.9±5.4	<5.1-9.0	6.0±2.3
Deji (1)	A	73.6±13.6	a	3.2±0.5	a	3.5±0.3
Jeddo (4)	<17.2-628.9	234.6±209.4	<4.2-18.9	1.2±0.2	<5.1-8.1	4.1±2.6
Ubeji (3)	<17.2-406.9	242.7±166.6	<4.2	<4.2	<5.1-7.5	3.9±2.4
Ajah-Etta (2)	79.9-99.2	89.6±9.7	<4.2	<4.2	<5.1	<5.1
Jetty Ajala (2)	145.4-239.6	192.5±47.1	<4.2	<4.2	<5.1	<5.1
Ifie (2)	26.8-76.1	51.5±24.7	9.2-14.0	11.6±2.4	<5.1	<5.1
Ugborikoko (4)	112.9-292.0	205.5±65.0	<4.2-104.7	61.9±17.1	0.7-9.1	5.3±3.6
Egbokodo (3)	<17.2-416.2	218.4±163.6	<4.2-44.2	20.6±2.4	4.9-13.1	8.8±3.4
Edjeba (3)	199.1-423.1	336.3±98.2	<4.2-8.6	3.1±3.2	2.1-6.9	4.6±2.0

Ogunu (1)	A	91.1±10.7	a	2.4±0.9	a	1.6±0.1
Ekurede (3)	82.4-307.6	194.7±91.9	<4.2-5.3	1.5±1.9	<5.1-13.7	6.0±5.6
Effurun (4)	265.2-581.6	372.4±127.6	<4.2-43.2	9.4±6.9	5.2-9.4	7.8±1.7

[a] only one sample was collected.

With the measurement system used in this present work, detection limits obtained were 17.2BqKg^{-1} , 4.2 BqKg^{-1} and 5.1 BqKg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th respectively. Values below these numbers were taken in this work as being below the detection limit (BDL) of the detector.

Table 3 Radium equivalent activity, Annual gonad equivalent dose, health hazard index, Annual effective dose equivalent and the cancer risk.

Locations	**Raeq Bq/Kg**	**AGED µSv/Yr**	**H_{ex}**	**H_{in}**	**Effective dose (Svy^{-1})**	**ELCR**
Inside refinery (6)	54.28	208.78	0.147	0.151	35.2×10^{-6}	0.12×10^{-3}
Ekpan (4)	51.80	196.47	0.140	0.153	33.1×10^{-6}	0.12×10^{-3}
Deji (1)	13.87	47.63	0.040	0.050	8.30×10^{-6}	0.03×10^{-3}
Jeddo (4)	25.13	94.51	0.070	0.070	21.7×10^{-6}	0.08×10^{-3}
Ubeji (3)	24.27	92.51	0.070	0.070	15.1×10^{-6}	0.05×10^{-3}
Ajah – Ettah (2)	6.90	28.13	0.020	0.020	5.80×10^{-6}	0.02×10^{-3}
Jetty – Ajala (2)	14.82	60.45	0.040	0.040	10.1×10^{-6}	0.04×10^{-3}
Ifie (2)	15.57	52.02	0.326	0.641	8.60×10^{-6}	0.03×10^{-3}
Ugborikoko (4)	84.87	277.95	0.231	0.398	47.5×10^{-6}	0.17×10^{-3}
Egbokodo (3)	50.00	169.02	0.090	0.191	29.2×10^{-6}	0.10×10^{-3}
Edjeba (3)	35.57	134.41	0.100	0.104	22.7×10^{-6}	0.08×10^{-3}
Ogunu (1)	11.70	42.71	0.003	0.038	7.20×10^{-6}	0.03×10^{-3}
Ekurede (3)	25.07	90.85	0.007	0.072	15.8×10^{-6}	0.06×10^{-3}
Effurun (4)	49.23	178.58	0.133	0.158	30.6×10^{-6}	0.11×10^{-3}
World Standard values	370	300	1.0	1.0	70x 10^{-6}	0.29 x 10^{-3}

(Note the number of samples collected are given in parenthesis beside each community)

3. 2 Radium Equivalent Activity (Ra_{eq})

The distribution of ^{40}K, ^{232}Th and ^{226}Ra in the soil is not uniform. Uniformity with respect to exposure to radiation has been defined by radium equivalent activity Ra_{eq} in Bq/Kg. This compares the specific activity of materials containing different amounts of ^{40}K, ^{232}Th and ^{226}Ra. It is defined as an estimation of radiation 370Bq/Kg of ^{226}Ra, 259Bq/Kg of ^{232}Th and 4810 Bq/Kg of ^{40}K that produce the same gamma dose rate. Ra_{eq} is calculated using the formula in equation 2. [8].

$$Ra_{eq} = (C_{Ra}/370 + C_{Th}/259 + C_K/4810) \times 370 \qquad 2$$

The values of Ra_{eq} inside the refinery and the communities are in Table 3 and the chart compare the values to the world permissible level is in Figure 2. The world maximum tolerable value is 370Bq/Kg [9].

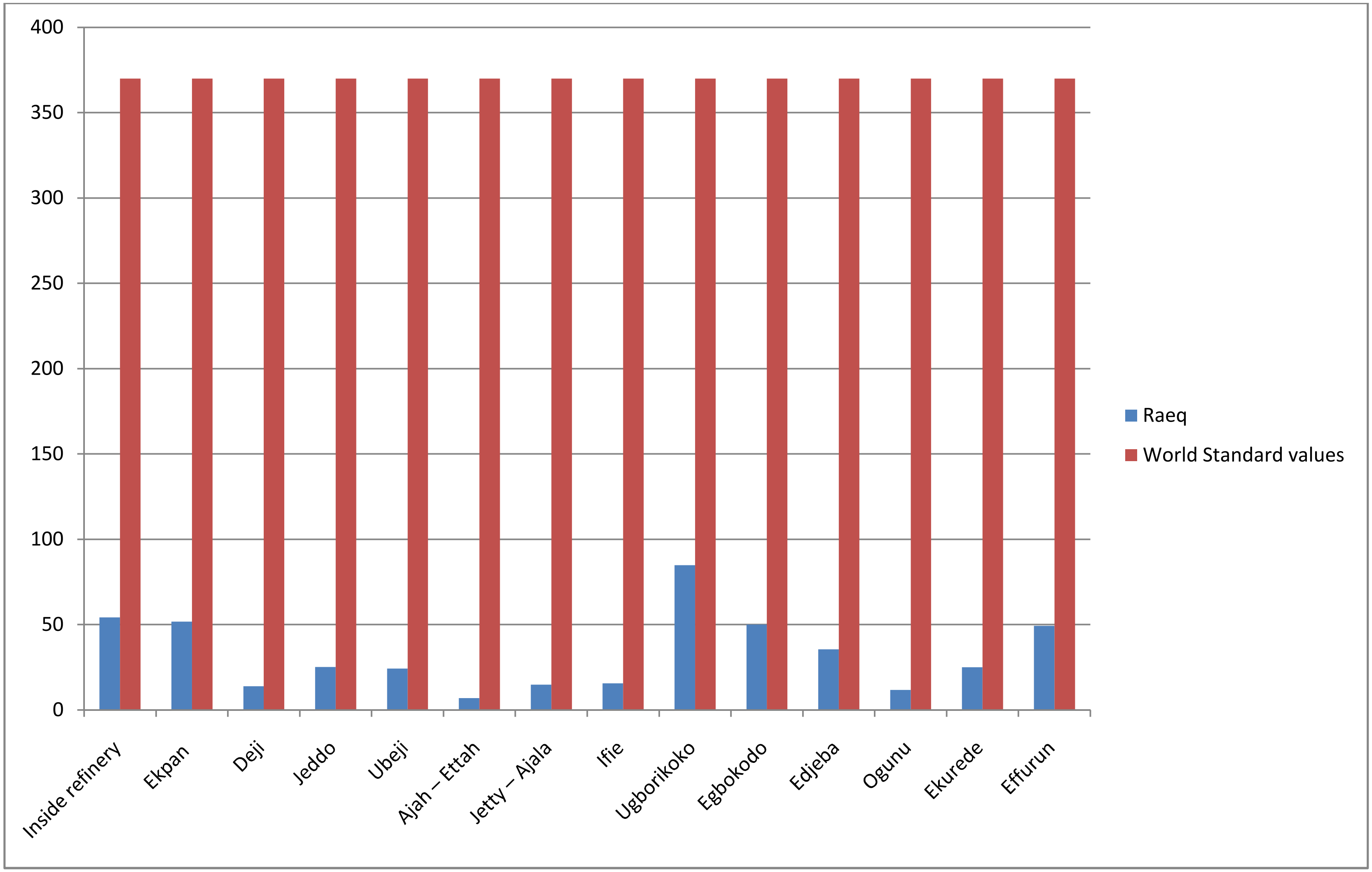

Figure 2 Radium equivalent activity compared to the world permissible value

3.3 Annual Gonad Equivalent Dose (AGED)

The gonads, the activity bone marrow and the bone surface cells are considered as organs of interest [10]. The AGED for the refinery and the communities were calculated using equation 3. The values got are in Table 3 and the chart that compared the values to the world permissible standard is in Figure 3. C_k, C_{Ra}, and C_{Th} are the activity concentrations of Potassium, Radium and Thorium respectively.

$$\text{AGED} = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K \qquad 3$$

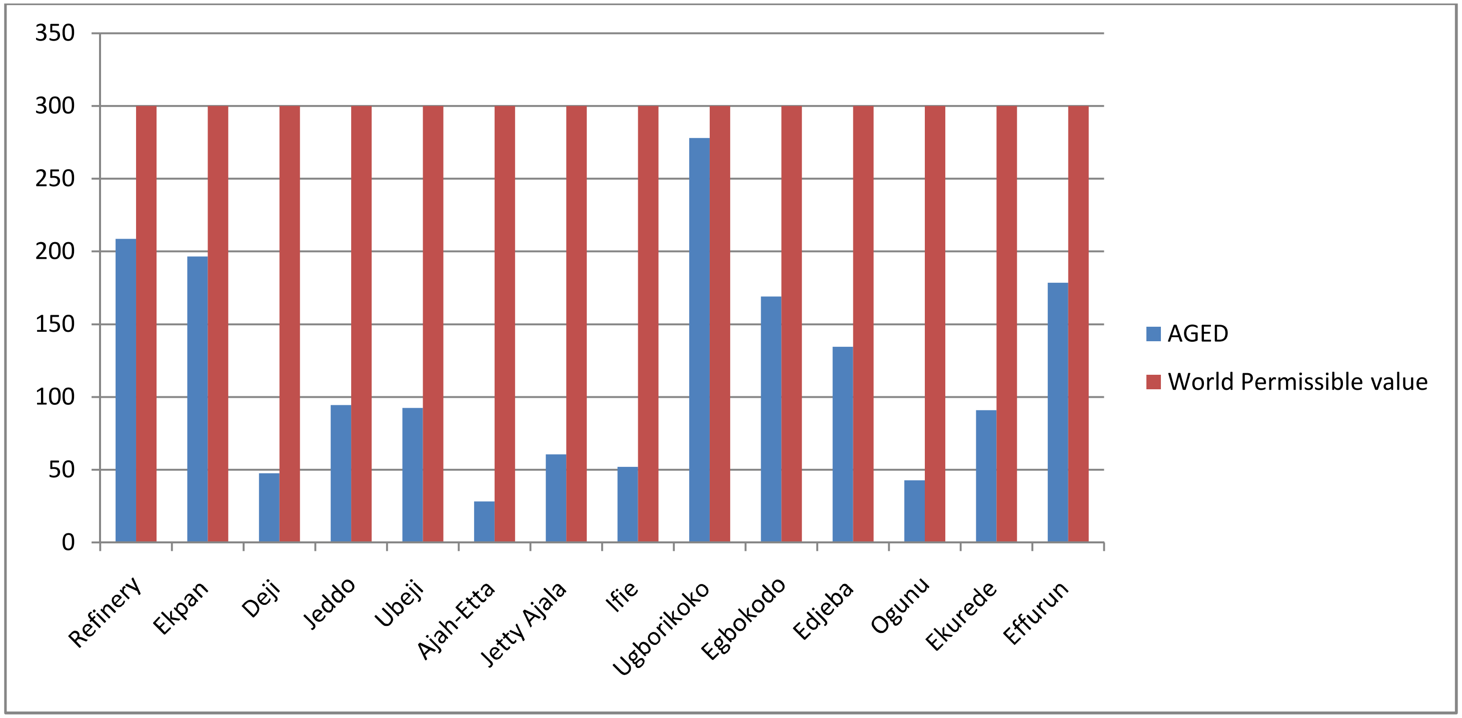

Figure 3 Annual gonad equivalent dose compared to the world permissible value.

3.4 External Hazard Index (Hex)

The external hazard index is an evaluation of the outdoor hazard of the natural gamma radiation. This is defined in equation 4. [11]

$$\text{Hex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \leq 1 \qquad 4$$

The values of Hex in this work is recorded in Table 3. This must be less than unity for the radiation hazard to be negligible.

3.5 Internal Hazard Index (Hin)

Internal radiation hazard index was also considered in this work because this could cause respiratory diseases like asthma and cancer. This is defined by equation 5. [11].

$$\text{Hin} = C_{Ra}/185 + C_{Th}/259 + C_K/4810 \leq 1 \qquad 5$$

The values of Hin in this work is recorded in Table 3. This must also be less than unity for the radiation hazard to be negligible. The chart that compares the internal and external hazard index to the world permissible standard are in Figure 3.

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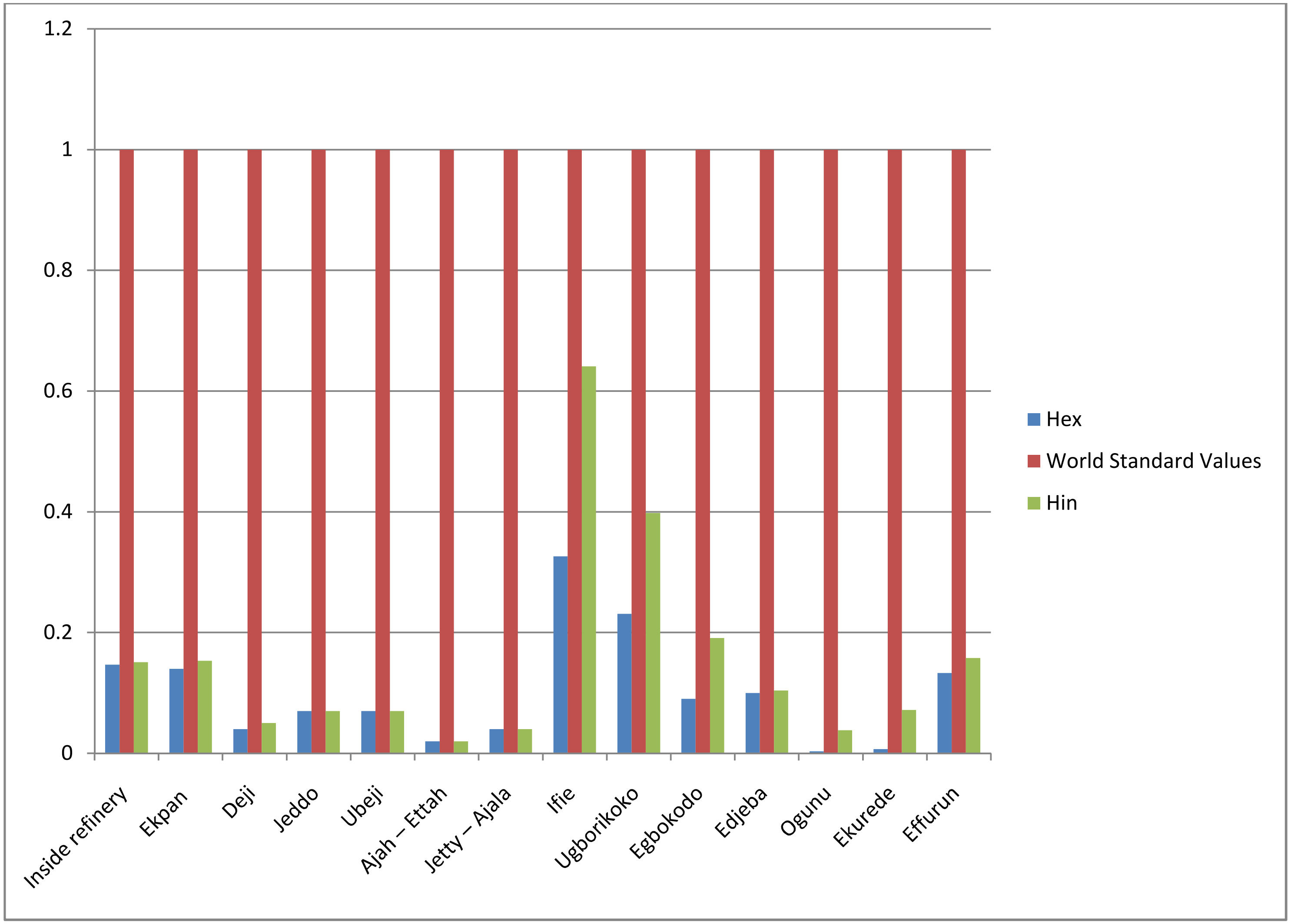

150 Figure 4 Health hazard index compared to the world permissible value

3.6 Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent radiation is computed from absorbed dose rate by applying a dose conversion factor of 0.7Sv/Gy and occupancy factor of 0.8 (19/24 hours) for outdoor radiation and 0.2 (5/24 hours) for indoors. This is on the estimation that an average man spends about 19 hours outdoors and 5 ours indoors. [12]. The equation use for outdoor AEDE are given in equation 6.

$$\text{AEDE (outdoor)} = \text{absorbed dose} \times 8760\text{hrs} \times 0.7\text{Sv/y} \times 0.2 \times 10^{-3} \qquad 6$$

The values obtained inside the refinery and the communities are in Table 3. The world permissible annual effective dose equivalent is 70 μSv/y for the outdoor AEDE.[10].

3.7 Excess Lifetime Cancer Risk ELCR

This deals with the probability of developing cancer over a lifetime at a give exposure level. ELCR is given as equation 7 [4].

$$\text{ELCR} = \text{AEDE} \times \text{DL} \times \text{RF} \qquad 7$$

Where AEDE is the annual effective dose equivalent,

DL is the average duration of life (estimated to be 70 years) and

RF is the risk factor i.e. fatal cancer risk per sievert. For stochastic effects, ICRP uses Rf as 0.05 for the public [4]. The result is recorded in Table 3 and the chart comparing the values to the world permissible standard of 0.29×10^{-3}[4] is in Figure 5.

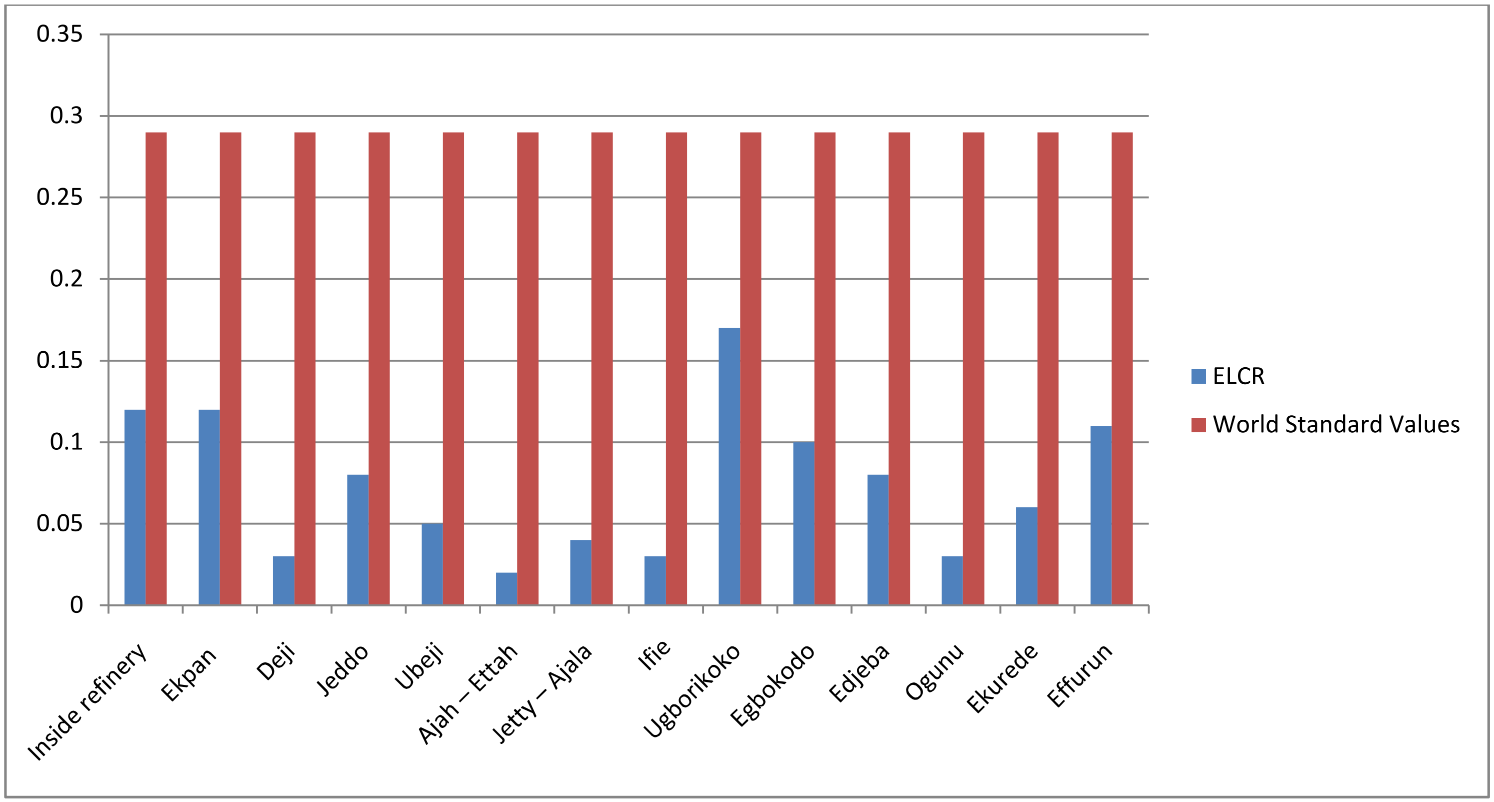

Figure 5 Excess lifetime cancer risk compared to world permissible values

4. Conclusions

The risk of developing cancer due to exposure to NORMs in the premises of the refining and petrochemical company Warri, and the communities around it has been determined. The values obtained when compared to the world permissible values were found to be below standard for such environment. Hence the risk of developing cancer by the workers in the refinery and the communities around it are relatively low.

Acknowledgement

We want to acknowledge the cooperation of the community leaders who gave us the permission to collect soil samples from their communities, despite stiff oppositions from the youth.

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