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# Assessment of Background Gamma Radiation and Development of Radiation Contour Map for Kogi Central District, Kogi State, Nigeria

**Salawu Moshood[a], Osita Meludu[a] and Anikoh. S. Oricha[c]**

[a]*Department of Physics, Modibbo Adama University, Yola, Adamawa State, Nigeria*

[b]*Department of Science Laboratory Technology, Federal Polytechnic Nasarawa, Nasarawa State, Nigeria*

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A B S T R A C T

Environmental radiation measurement was carried out in Kogi Central Senatorial District of Kogi State, Nigeria. An in-situ measurement approach was adopted using GCA-O6W, Digital Geiger counter and a handheld Global Positioning System equipment. A total of 101 locations were surveyed across the district. In Adavi Local Government Area, the dose rate ranges from 0.04 µSv/h at Iruvucheba to 0.27 µSv/h at Kuroko with mean and standard deviation (SD) value of 0.12±0.048 µSv/h. For Okehi LGA, the dose rate ranges from 0.06 µSv/h at Ebako to 0.39 µSv/h at Itakpe1 with a mean and SD value of 0.16±0.070 µSv/h. In Ogori-Magongo LGA, the dose rate ranges from 0.11 µSv/h at Oturu to 0.29 µSv/h at Ogori with a mean and SD of 0.17±0.048 µSv/h, those at Okene LGA, ranges from 0.10 µSv/h to 0.28 µSv/h with a mean and standard deviation of 0.16±0.044 µSv/h and finally the dose rate at Ajaokuta LGA, ranges from 0.10 µSv/h to 0.36 µSv/h with a mean and standard deviation of 0.20±0.076 µSv/h. The average annual effective dose rate is approximately 0.175±0.06 mSv/yr. However, these values are seen to be lower than the yearly recommended value of 1.0 mSv/yr for public exposure and 20.00 mSv/yr for occupational workers.

## 1. Introduction

Radiation is the energy in motion in the form of waves or particles. Radiation is present everywhere around us in many forms. Radiation includes: radio waves, microwaves, infrared, visible light, ultraviolet rays, X-rays and γ-rays (Rajan, 2017). Radiation has been part of the environment since the creation of the earth and as such, humans are continually and unavoidably exposed daily to varying doses of ionizing radiation (Ugbede and Echeweozo, 2017). This radiation called background ionizing radiation (BIR) has become a huge public concern all over the world and it is an inevitable part of the natural environment. The radioactive elements and their radiations are indispensable part of nature. Their influence on living organisms is imminent and very important to study (UNSCEAR, 1993). Environmental radioactivity measurements are necessary for determining the background radiation level due to natural radioactive sources of terrestrial and cosmic origins (Shashikumar *et al*., 2008). Investigations and measurement of natural environmental radiation and radioactivity are of immense importance and of interest in health physics because it can be used for assessment of public dose exposure rates and keeping reference data records to ascertain possible changes in the environmental radioactivity over time (Ningappa *et al*., 2008).

The distribution and availability of radionuclides depend mainly on the geology and geographical characteristics of the place and human activities (Bouzarjomehri *et al*., 2005). Natural background radiation contributes significantly to the annual effective dose received by the general population. Therefore, the knowledge of natural sources of background radiation is the most important and immediate concern to the general population (Chandrashekara *et al*., 2012; Szegvary *et al*., 2007). Monitoring overexposure begins with understanding the natural radiation level in our

* Corresponding author. Tel.: +2349035111185
E-mail address: @mau.edu.ng (Salawu Moshood)
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environment. In many instances the human body system adapts to this background radiation level without suffering adverse health effects but any exposure beyond this level may come with certain health problems. This over exposure arises mostly from human activities which include mining, milling, quarrying operations, farming and burning of fossil fuel (Saleh *et al*., 2007). These operations bring large amounts of buried material containing natural occurring radionuclides to the surface of the environment thereby enhancing the exposure rate. In Kogi Central district, these human activities are on the increase everyday hence an increase in the background radiation is imminent. The perceived implication of the increase in background radiation levels due to these human activities mentioned above suggest the need to investigate the background radiation levels and doses in Kogi Central district. This pioneering study in the area is aimed at providing part of baseline data of background radiation in Kogi State, Nigeria.

The aim of this research is to assess the environmental background radiation level, its radiological implications and to develop a background radiation contour map for Kogi Central Senatorial District of Kogi State.

## 2. Materials and Methods

### 2.1 Materials

The study was carried out in Kogi Central district in Kogi Sate, North central Nigeria. The State lies between longitudes 6° 42′ E and 6° 70′ E and latitudes 7° 30′ N and 7° 50′ N. It has a landmass of 29,833 *sq km*. Kogi central district comprises of five local governments areas; Okene, Okehi, Adavi, Ogori magongo and Ajaokuta. Okene has a population of 325,623 and 328 $km^2$ area, Okehi with a population of 223,574 and 66 $km^2$ area, Ogori magongo with a population of 39,807 and 79 $km^2$ area. Adavi with population of 217,219 and 718 $km^2$ area and Ajaokuta with a population of 122,432 at the 2006 census and 1362 $km^2$ area. They occupy the hilly stretch of land with metaphoric rocks and undulating plains which rise to a peak of about 2000 feet, located southwest of the Niger- Benue confluence area and share boundaries with the Yoruba-speaking people of Akoko, Owe, and Ijumu to the west, Lokoja, the State capital to the north and the River Niger to the East (Okene, 2008).

The materials used in the research that relate to the various stages of the research are listed below:

i. Kogi State map showing Kogi Central district.

ii. Environmental radiation dosimeter, which is specially designed to serve as a low-level radiation survey meter. It is an ideal choice for environmental radiation monitoring and also for geological prospecting of radioactive minerals.

iii. Geographical positioning system (GPS). To determine the precise locations of the sites measured in terms of latitudes and longitudes.

iv. The surge gridding, mapping software and a computer system for producing the background radiation contour map for Kogi central district.

Environmental radiation dosimeter (Digital Geiger Counter, GCA-06W), manufactured by Image Scientific Instruments, Inc. USA, shown in plate 1. It is used to measure the natural background radiation as well technologically enhanced naturally occurring radioactive materials in our environment, it is specially designed to serve as a low-level survey meter. It is an ideal choice for environmental radiation monitoring and also for geological prospecting of radioactive minerals. The instrument is calibrated to read exposure rate in two ranges with radiation resolution or measuring sensitivity of 1.0 μR/h to 1000 mR/h or 0.01 μSv/h to 10 mSv/h.

**2.2 Methods**

**In-situ data collection**

The activity for each location was measured in count per minute, (cpm) using the environmental radiation dosimeter. The timing methods that was adopted as recommend by images Inc. (2007). In the method the count per minute was measured four times at each grid point in a site and the mean count recorded. In addition, measurement was taken from three sites within any chosen location, separated by about 500 meters or 1 kilometre from each other and applying the method described earlier to all the sites. The average for the three sites was recorded as the mean activity for the given location. Thus, the recorded mean for any location was actually the average of twelve different readings. The number of locations that was visited across the five local government areas depend on the size of the local government. An in-situ approach of measurement with the standard practice of elevating the detector tube 1.0 m above ground level with its window facing the point under investigation was adopted to enable sample points maintain their original environmental characteristics (Azu, 2014; Ugbede and Echeweozo, 2017). This study followed the National Council on Radiation Protection and Measurements recommendation to acquire data between 1300 and 1600 hours, as this is when radiation meter responds to radiation the maximum (Isa, *et al.,* 2024). Finally, the data were recorded manually in the field using data capture sheets.

**Radiological parameters**

**Absorbed Dose rate**

The average exposure rates were then converted to absorbed dose (AD) rate in nGy/h using (1) according to (Agbalagba. 2017; Rafique, *et al.,* 2014).

$$1\mu\text{Sv/h} = 8.7 \times 10^2\ (\text{nGy/h}) \qquad (1)$$

***The Annual Effective Dose Equivalent***

The annual effective dose equivalent (AEDE) to the population can be calculated From the absorbed dose rate by applying the dose conversion factor of 0.7 $SvGy^{-1}$ and an outdoor occupancy factor of 0.2 (UNSCEAR 2000). Therefore, the annual effective doses equivalent (outdoor) is obtained by using this relation in equation 2 (Huy and Luyen, 2006).

$$AEDE(mSv/yr) = [D_r(nGy/h) \times 0.2 \times 8760 \times 0.7Sv/Gy] \qquad (2)$$

***Excess Lifetime Cancer Risk***

Excess Lifetime Cancer Risk (ELCR) is calculated using the equation below (Ramasamy *et al.,* 2009).

$$ELCR = AEDE \times DL \times RF \qquad (3)$$

where AEDE, DL and RF are the total annual effective dose equivalent (in $\mu Svy^{-1}$), duration of life (70 years) and risk factor ($Sv^{-1}$), fatal cancer risk per Sievert. For stochastic effect, ICRP 60 uses values of 0.05 for the public (Ugbede and Echeweozo, 2017).

**Contour Mapping**

The Surge mapping and gridding software was used to produce the contour map. It has the inbuilt capacity for filtering the locations to produce the best fitting contour lines

## 3. Results and Discussions

### 3.1 Field Survey Results

The results for the background radiation exposure level obtained from the in-situ measurements and the associated radiological health parameters for the five local Governments areas in Kogi central senatorial district are given in Table 1-5 respectively. The mean values for the five local Governments in count per minute (*cpm*), Absorbed dose rate (*nGy/h*), Annual Effective Dose rate (*mSv/yr*) and Excess Lifetime Cancer risk is given in Table 6.

**Table 1:** Activity and Coordinates of Locations in Adavi Local Government Area

| S/N | Locations | Longitude(N) | Latitude(N) | Activity (CPM) | Average Equivalent Dose rate (*µSv/h*) | Annual Effective Dose rate (*mSv/yr*) |
|---|---|---|---|---|---|---|
| 1 | Karaworo | $6^{0}$14ˋ26.310” | $7^{0}$33ˋ11.586” | 08.40 | 0.07 | 0.075 |
| 2 | Iresuha | $6^{0}$14ˋ97.550” | $7^{0}$33ˋ26.040” | 12.00 | 0.10 | 0.107 |
| 3 | Inoziomi-Layout | $6^{0}$14ˋ65.067” | $7^{0}$32ˋ32.620” | 14.40 | 0.12 | 0.128 |
| 4 | Inoziomi | $6^{0}$14ˋ42.820” | $7^{0}$33ˋ48.558” | 20.40 | 0.17 | 0.181 |
| 5 | Ebogogo | $6^{0}$14ˋ06.309” | $7^{0}$34ˋ03.666” | 18.00 | 0.15 | 0.160 |
| 6 | Kuroko | $6^{0}$14ˋ34.128” | $7^{0}$34ˋ16.770” | 32.80 | 0.27 | 0.288 |
| 7 | Osisi | $6^{0}$13ˋ30.030” | $7^{0}$34ˋ41.022” | 12.00 | 0.10 | 0.107 |
| 8 | Ipaku | $6^{0}$14ˋ06.312” | $7^{0}$34ˋ03.768” | 13.20 | 0.11 | 0.117 |
| 9 | Iruvucheba | $6^{0}$13ˋ28.914” | $7^{0}$34ˋ53.898” | 04.80 | 0.04 | 0.043 |
| 10 | Inorere | $6^{0}$13ˋ15.552” | $7^{0}$35ˋ15.660” | 09.60 | 0.08 | 0.085 |
| 11 | Ohugogo | $6^{0}$14ˋ38.604” | $7^{0}$34ˋ30.018” | 13.20 | 0.11 | 0.117 |
| 12 | Kaba-junction | $6^{0}$13ˋ35.118” | $7^{0}$35ˋ44.418” | 14.40 | 0.12 | 0.128 |
| 13 | Nagazi Eba | $6^{0}$13ˋ28.890” | $7^{0}$34ˋ53.556” | 10.80 | 0.09 | 0.096 |
| 14 | Nagazi Uvete | $6^{0}$14ˋ39.354” | $7^{0}$36ˋ06.300” | 09.60 | 0.08 | 0.085 |
| 15 | Ino’odovo | $6^{0}$14ˋ50.952” | $7^{0}$34ˋ22.644” | 21.60 | 0.18 | 0.192 |
| 16 | Ateba | $6^{0}$14ˋ69.402” | $7^{0}$34ˋ47.028” | 21.60 | 0.18 | 0.192 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 17 | Oziokutu | $6^{0}$13'10.116” | $7^{0}$35'47.292” | 12.00 | 0.10 | 0.107 |
| 18 | Zango | $6^{0}$13'25.812” | $7^{0}$36'14.148” | 14.40 | 0.12 | 0.128 |
| 19 | Idanuwha | $6^{0}$13'14.310” | $7^{0}$34'57.360” | 15.60 | 0.13 | 0.139 |
| 20 | Osara | $6^{0}$25'19.866” | $7^{0}$40'24.588” | 19.20. | 0.16 | 0.171 |
| 21 | Okunchi | $6^{0}$13'37.602” | $7^{0}$33'36.510” | 15.60 | 0.13 | 0.139 |

**Table 2:** Activity and Coordinates of Locations in Okehi Local Government Area

| S/N | Locations | Longitude(E) | Latitude(N) | Activity (CPM) | Average Equivalent Dose rate (*μSv/h*) | Annual Effective Dose rate (*mSv/yr*) |
|---|---|---|---|---|---|---|
| 1 | Ikaturu | $6^{0}$15'12.822” | $7^{0}$34'56.460” | 14.40 | 0.12 | 0.128 |
| 2 | Eba-oze | $6^{0}$16'30.516” | $7^{0}$34'78.154” | 18.00 | 0.15 | 0.160 |
| 3 | Eika | $6^{0}$15'47.814” | $7^{0}$35'04.187” | 20.40 | 0.17 | 0.181 |
| 4 | Ohizenyi | $6^{0}$16'06.252” | $7^{0}$35'15.204” | 14.40 | 0.12 | 0.128 |
| 5 | Iresu-Uhe-Ege | $6^{0}$16'98.974” | $7^{0}$36'25.758” | 09.60 | 0.08 | 0.085 |
| 6 | Itakpe1 | $6^{0}$19'47.874” | $7^{0}$36'48.816” | 46.50 | 0.39 | 0.416 |
| 7 | Itakpe2 | $6^{0}$19'58.722” | $7^{0}$37'21.732” | 34.80 | 0.29 | 0.309 |
| 8 | Abobo | $6^{0}$18'18.708” | $7^{0}$37'06.510” | 25.20 | 0.21 | 0.224 |
| 9 | Camp2 | $6^{0}$16'52.266” | $7^{0}$37'18.840” | 25.60 | 0.21 | 0.224 |
| 10 | Eika Adagu | $6^{0}$16'78.806” | $7^{0}$36'46.326” | 21.60 | 0.18 | 0.192 |
| 11 | FCE | $6^{0}$15'35.052” | $7^{0}$36'30.252” | 16.80 | 0.14 | 0.149 |
| 12 | Usu-wge | $6^{0}$12'.53.778” | $7^{0}$37'19.542” | 14.20 | 0.12 | 0.128 |
| 13 | Okaito | $6^{0}$12'06.138” | $7^{0}$37'39.672” | 12.00 | 0.10 | 0.107 |
| 14 | Uboro | $6^{0}$11'23.184” | $7^{0}$37'33.318” | 18.00 | 0.15 | 0.160 |
| 15 | Obangede | $6^{0}$11'90.854” | $7^{0}$38'46.104” | 10.80 | 0.09 | 0.096 |
| 16 | Uhuodo | $6^{0}$12'14.094” | $7^{0}$35'22.728” | 14.40 | 0.12 | 0.128 |
| 17 | Ikuehi | $6^{0}$10'30.306” | $7^{0}$34'22.830” | 20.40 | 0.17 | 0.181 |
| 18 | Obeiba | $6^{0}$10'96.990” | $7^{0}$34'48.552” | 19.20 | 0.16 | 0.171 |
| 19 | Utabobo | $6^{0}$09'33.802” | $7^{0}$35'19.818” | 15.60 | 0.13 | 0.139 |
| 20 | Oboreke | $6^{0}$09'92.998” | $7^{0}$35'39.936” | 09.60 | 0.08 | 0.085 |
| 21 | Oboreke-Eba | $6^{0}$08'40.824” | $7^{0}$36'12.906” | 13.20 | 0.11 | 0.117 |
| 22 | Ihima | $6^{0}$10'09.702” | $7^{0}$34'56.568” | 21.60 | 0.18 | 0.192 |
| 23 | Ohueta | $6^{0}$10'82.118” | $7^{0}$34'16.870” | 24.00 | 0.20 | 0.213 |
| 24 | Ebako | $6^{0}$11'55.392” | $7^{0}$33'27.984” | 07.20 | 0.06 | 0.064 |

**Table 3:** Activity and Coordinates of Locations in Ogori-Magongo Local Government Area

| S/N | Locations | Longitude(E) | Latitude(N) | Activity (CPM) | Average Equivalent Dose rate (*μSv/h*) | Annual Effective Dose rate (*mSv/yr*) |
|---|---|---|---|---|---|---|
| 1 | Magongo | $6^0$08˙17.154” | $7^0$29˙01.722” | 18.00 | 0.15 | 0.160 |
| 2 | Akpafa-Road | $6^0$09˙28.004” | $7^0$28˙47.028” | 21.60 | 0.18 | 0.192 |
| 3 | Obinoyin | $6^0$09˙76.028” | $7^0$29˙58.070” | 16.80 | 0.14 | 0.149 |
| 4 | Oturu | $6^0$09˙09.816” | $7^0$28˙25.812” | 13.20 | 0.11 | 0.117 |
| 5 | Oturu-Opou | $6^0$08˙55.860” | $7^0$28˙67.598” | 21.60 | 0.18 | 0.192 |
| 6 | Afotebi | $6^0$09˙99.084” | $7^0$28˙92.196” | 16.80 | 0.14 | 0.149 |
| 7 | Akpafa | $6^0$10˙00.840” | $7^0$27˙31.806” | 14.40 | 0.12 | 0.128 |
| 8 | Ayo-Nio | $6^0$10˙91.650” | $7^0$27˙58.746” | 25.20 | 0.21 | 0.224 |
| 9 | Udoba | $6^0$10˙54.240” | $7^0$27˙31.212” | 22.80 | 0.19 | 0.203 |
| 10 | Ogori | $6^0$11˙06.540” | $7^0$27˙88.614” | 34.30 | 0.29 | 0.309 |
| 11 | Okuhapa | $6^0$11˙59.340” | $7^0$29˙47.580” | 24.00 | 0.20 | 0.213 |

**Table 4:** Activity and Coordinates of Locations in Okene Local Government Area

| S/N | Locations | Longitude(E) | Latitude(N) | Activity (CPM) | Average Equivalent Dose rate (*μSv/h*) | Annual Effective Dose rate (*mSv/yr*) |
|---|---|---|---|---|---|---|
| 1 | Idogido | $6^0$14˙28.176” | $7^0$33˙00.000” | 20.40 | 0.17 | 0.181 |
| 2 | Inike | $6^0$14˙49.560” | $7^0$32˙46.320” | 18.00 | 0.15 | 0.160 |
| 3 | Idare | $6^0$14˙94.832” | $7^0$33˙03.726” | 15.60 | 0.13 | 0.139 |
| 4 | Idoji | $6^0$15˙39.320” | $7^0$32˙35.520” | 13.20 | 0.11 | 0.117 |
| 5 | Enyi-nare | $6^0$15˙51.660” | $7^0$31˙51.960” | 12.00 | 0.10 | 0.107 |
| 6 | OsochiOk | $6^0$15˙18.360” | $7^0$31˙30.720” | 21.60 | 0.18 | 0.192 |
| 7 | Upogoro | $6^0$13˙56.280” | $7^0$31˙44.766” | 19.20 | 0.16 | 0.171 |
| 8 | Ahache | $6^0$13˙25.326” | $7^0$32˙81.640” | 14.40 | 0.12 | 0.128 |
| 9 | Agassa | $6^0$13˙68.320” | $7^0$32˙53.166” | 24.00 | 0.20 | 0.213 |
| 10 | Ooro | $6^0$12˙43.561” | $7^0$32˙57.488” | 21.60 | 0.18 | 0.192 |
| 11 | Idoma | $6^0$12˙05.040” | $7^0$32˙63.522” | 20.40 | 0.17 | 0.181 |
| 12 | Ageva | $6^0$11˙39.122” | $7^0$32˙15.726” | 16.80 | 0.14 | 0.149 |
| 13 | Obehira | $6^0$12˙08.388” | $7^0$32˙22.122” | 22.80 | 0.19 | 0.203 |
| 14 | Odenku | $6^0$11˙56.766” | $7^0$32˙34.444” | 18.00 | 0.15 | 0.160 |
| 15 | Okegwe | $6^0$11˙46.682” | $7^0$32˙59.287” | 21.60 | 0.18 | 0.192 |
| 16 | Uruvu-uc | $6^0$13˙42.244” | $7^0$33˙01.446” | 19.20 | 0.16 | 0.171 |
| 17 | Ozuwaya | $6^0$13˙59.200” | $7^0$33˙09.040” | 13.20 | 0.11 | 0.117 |
| 18 | Idozumi | $6^0$14˙02.450” | $7^0$32˙91.056” | 12.00 | 0.10 | 0.107 |
| 19 | Ahogede | $6^0$14˙09.280” | $7^0$32˙49.200” | 22.80 | 0.19 | 0.203 |
| 20 | Okene-ba | $6^0$14˙96.322” | $7^0$32˙46.320” | 33.60 | 0.28 | 0.299 |
| 21 | Badoko | $6^0$14˙72.680” | $7^0$32˙41.860” | 30.00 | 0.25 | 0.267 |
| 22 | GRA | $6^0$14˙17.880” | $7^0$33˙22.688” | 24.00 | 0.20 | 0.213 |
| 23 | GP | $6^0$14˙92.240” | $7^0$33˙15.840” | 20.40 | 0.17 | 0.181 |

**Table 5:** Activity and Coordinates of Locations in Ajaokuta Local Government Area

| S/N | Locations | Longitude(E) | Latitude(N) | Activity (CPM) | Average Equivalent Dose rate ($\mu Sv/h$) | Annual Effective Dose rate ($mSv/yr$) |
|---|---|---|---|---|---|---|
| 1 | Uruvusechi | $6^0$27ˋ81.414” | $7^0$31ˋ42.866” | 13.20 | 0.11 | 0.117 |
| 2 | Badoko | $6^0$27ˋ39.086” | $7^0$31ˋ29.420” | 16.80 | 0.14 | 0.149 |
| 3 | Ogigiri | $6^0$27ˋ57.448” | $7^0$31ˋ96.620” | 12.00 | 0.10 | 0.107 |
| 4 | Apam-unosi | $6^0$27ˋ01.129” | $7^0$30ˋ91.810” | 15.60 | 0.13 | 0.139 |
| 5 | Adogo1 | $6^0$28ˋ44.400” | $7^0$30ˋ36.720” | 21.60 | 0.18 | 0.192 |
| 6 | Adogo2 | $6^0$28ˋ69.590” | $7^0$30ˋ72.441” | 19.20 | 0.16 | 0.171 |
| 7 | Unosi | $6^0$28ˋ45.732” | $7^0$30ˋ27.396” | 16.80 | 0.14 | 0.149 |
| 8 | Eganyi | $6^0$27ˋ34.920” | $7^0$31ˋ38.280” | 18.00 | 0.15 | 0.160 |
| 9 | Ebiya North | $6^0$25ˋ39.240” | $7^0$32ˋ25.320” | 21.60 | 0.18 | 0.192 |
| 10 | Adu | $6^0$24ˋ41.431” | $7^0$33ˋ06.010” | 09.60 | 0.08 | 0.085 |
| 11 | Ebiya South | $6^0$25ˋ99.210” | $7^0$33ˋ41.810” | 15.60 | 0.13 | 0.139 |
| 12 | Upake | $6^0$38ˋ43.669” | $7^0$33ˋ86.910” | 27.60 | 0.23 | 0.245 |
| 13 | Ajaokuta | $6^0$39ˋ17.890” | $7^0$33ˋ44.240” | 36.00 | 0.30 | 0.320 |
| 14 | Geregu | $6^0$40ˋ34.112” | $7^0$33ˋ67.480” | 38.40 | 0.32 | 0.341 |
| 15 | Steel Complex | $6^0$39ˋ86.420” | $7^0$33ˋ11.301” | 43.20 | 0.36 | 0.384 |
| 16 | Prime Complex | $6^0$38ˋ01.190” | $7^0$34ˋ17.550” | 33.60 | 0.28 | 0.299 |
| 17 | Forest | $6^0$38ˋ44.662” | $7^0$33ˋ82.332” | 32.40 | 0.27 | 0.288 |
| 18 | Ageregu | $6^0$39ˋ42.510” | $7^0$33ˋ29.460” | 26.40 | 0.22 | 0.235 |
| 19 | Apanko | $6^0$38ˋ91.663” | $7^0$32ˋ66.431” | 31.20 | 0.26 | 0.277 |
| 20 | Iyasa | $6^0$37ˋ82.112” | $7^0$33ˋ43.121” | 33.60 | 0.28 | 0.299 |
| 21 | Ganaja | $6^0$39ˋ88.411” | $7^0$33ˋ14.866” | 24.00 | 0.20 | 0.213 |
| 22 | Ademe | $6^0$28ˋ03.443” | $7^0$33ˋ72.177” | 21.60 | 0.18 | 0.192 |

**Table 6**: Comparison of average background radiation exposure rate and associated radiological parameter of the five LGA with World Average Value

| SN | Local Government Area | Average Activity (CPM) | Average Equivalent Dose rate ($\mu Sv/h$) | Absorbed dose rate ($nGy/h$) | Annual Effective Dose rate ($mSv/yr$) | Excess Lifetime Cancer risk $\times 10^{-3}$ |
|---|---|---|---|---|---|---|
| 1 | Adavi | $14.93 \pm 5.85$ | $0.12 \pm 0.048$ | 107.88 | $0.133 \pm 0.051$ | 0.466 |
| 2 | Okehi | $18.65 \pm 8.41$ | $0.16 \pm 0.070$ | 134.85 | $0.166 \pm 0.075$ | 0.581 |
| 3 | Ogori-Magongo | $20.79 \pm 5.69$ | $0.17 \pm 0.048$ | 151.38 | $0.185 \pm 0.052$ | 0.648 |
| 4 | Okene | $19.77 \pm 5.24$ | $0.16 \pm 0.044$ | 150.51 | $0.176 \pm 0.021$ | 0.616 |
| 5 | Ajaokuta | $25.75 \pm 9.30$ | $0.20 \pm 0.076$ | 174.00 | $0.213 \pm 0.081$ | 0.746 |
| | World Average Value | | 0.13 | 59.00 | 0.07 | 0.29 |

### 3.2 Discussions

***Activity Pattern***

A total of 101 locations was surveyed across the five local Governments Area in Kogi central senatorial districts for background environmental radiation. Table 1 shows that in Adavi local Government Area the dose rate varies from 0.04 *μSv/h* at Iruvucheba to 0.27 *μSv/h* at Kuroko with mean and standard deviation (SD) value of $0.12 \pm 0.048$ μSv/h, table 2 shows that, for Okehi LGA, the minimum dose rate of 0.06 *μSv/h* was obtained at Ebako while the maximum dose rate of 0.39 *μSv/h* was obtained at Itakpe1 with a mean and SD value of $0.16 \pm 0.070$ *μSv/h*, In Ogori-Magongo LGA, the minimum dose rate of 0.11 *μSv/h* was obtained at Oturu while maximum dose rate of 0.29 *μSv/h* was obtained at Ogori with a mean and SD of $0.17 \pm 0.048$ *μSv/h* as shown in table 3. Table 4 shows that those at Okene LGA, ranges from 0.10 *μSv/h* to 0.28 *μSv/h* with a mean and standard deviation of $0.16 \pm 0.044$ *μSv/h* and finally the dose rate at Ajaokuta LGA, ranges from 0.10 *μSv/h* to 0.36 *μSv/h* with a mean and standard deviation of $0.20 \pm 0.076$ *μSv/h* as shown in table 5. This variation in background radiation values can be attributed to the different agrochemicals and fertilizers contents and their concentration in the farm soil and also to the different geological and geophysical characterization of the environments. The mean background radiation level in Okehi, Ogori-magongo, Okene and Ajaokuta LGA, exceeded the recommended ambient background radiation exposure level of 0.13 *μSv/h* (ICRP, 2007; Osimobi *et al.,* 2015;) while those at Adavi LGA,are in agreement. The values also show that the background radiation exposure level in some of the locations studied within the five local Government Area are above the recommended safe limit.

Table 6 shows the comparison between the mean exposure rates, mean absorbed dose, mean AEDE and mean ELCR of the five local Government area with the world average value (WAV). The mean absorbed doses and annual effective dose equivalent in the five local government areas (Table 6) were significantly higher the world average value of 59.00 *nGy/h* (Monica *et al.*, 2016; Agbalagba, 2016) and recommended safe limit of 84.0 *nGy/h* (UNSCEAR, 2008; Ononugbo and Mgbemere, 2016).

The annual effective dose is a radiation protection index which quantifies the whole body absorbed dose per year. However, these values are seen to be lower than the recommended value of 1.0 *mSv/yr* for public exposure and 20.00 *mSv/yr* for occupational workers within a year placed by the Basic Safety Standards (BSS) SCHEDULE II and the International Commission on Radiological Protection (ICRP) REPORT 60 (ICRP, 1991). This indicates that the studied areas are in good agreement with permissible limit. The absorbed dose rates arising from the background radiation exposure levels across the five local Government area and the annual effective radiation doses at these rates do not constitute any immediate radiological health effect to the general public.

The excess lifetime cancer risks values for five local government areas were higher than the world average value of $0.29 \times 10^{-3}$ (UNSCEAR, 2008; Avwiri *et al*, 2017) indicating potential health concern.

The statistical analysis of these values however has clouded some localized areas of relatively higher activity. Such locations include Kuroko in Adavi LGA, Ogori in Ogori-Magongo LGA, Okene-eba in Okene LGA, Itakpe1 and Itakpe2 in Okehi LGA and Ajaokuta, steel complex and Geregu in Ajaokuta LGA as shown in table 7.

The high background radiation levels in Kuroko and Okene-eba is attributed to the fact that the locations are at high altitude. The high values of background radiation exposure level in Itakpe1 and Itakpe2 of Okehi LGA can be attributed to the mining of iron ore mineral deposit located in Itakpe hill. The elevated background radiation exposure level at Ajaokuta, Geregu, Ogori and Steel complex may be attributed to the geology of these locations, from geology point of view these locations belong to basement complex which is associated with igneous rock. These corroborates the report that igneous rock such as granite are associated with a higher level of radiation when compared with sedimentary rock (Sahu *et al*., 2014). The corresponding values of the radiological parameters such as Absorbed dose rate (*nGy/h*), Equivalent dose rate (***μ****Sv/h*) and Excess lifetime cancer risk are much higher than their world average values and recommended save limit value. Therefore, people living or working in these areas may be exposed to high radiation from natural radionuclides which may put people around these areas on a radiological hazard. It is very important that the radiation levels in these locations be monitored against any further increase.

**Table 7**: Comparison of background radiation exposure rate and associated radiological parameters of the locations with high values of activity within the locations in the five LGA with World Average Value

| SN | **Locations** | **Activity (CPM)** | **Equivalent Dose rate ($\mu Svhr^{-1}$)** | **Absorbed dose rate (*nGy/h*)** | **Annual Effective Dose rate (*mSv/yr)*** | **Excess Lifetime Cancer risk $\times 10^{-3}$** |
|---|---|---|---|---|---|---|
| 1 | Itakpe1 | 46.50 | 0.39 | 339.3 | 0.416 | 1.456 |
| 2 | Itakpe2 | 34.80 | 0.29 | 252.3 | 0.309 | 1.082 |
| 3 | Steelcomplex | 43.20 | 0.36 | 313.2 | 0.384 | 1.344 |
| 4 | Geregu | 38.40 | 0.32 | 278.4 | 0.341 | 1.194 |
| 5 | Ajaokuta | 36.00 | 0.30 | 261.0 | 0.320 | 1.120 |
| 6 | Ogori | 34.30 | 0.29 | 252.3 | 0.309 | 1.082 |
| 7 | Okene-eba | 33.60 | 0.28 | 243.6 | 0.299 | 1.047 |
| 8 | Kuroko | 32.80 | 0.27 | 234.9 | 0.288 | 1.008 |
| | World average value | | 0.13 | 59.00 | 0.070 | 0.290 |

**Contour Map**

The activity data were employed to develop the contour using SurGe gridding and surfer 11 mapping software. The resulting contour map for all the five local government area in Kogi central senatorial district is shown in figure 1-5 and figure 6 is the contour map for Kogi central district in general.

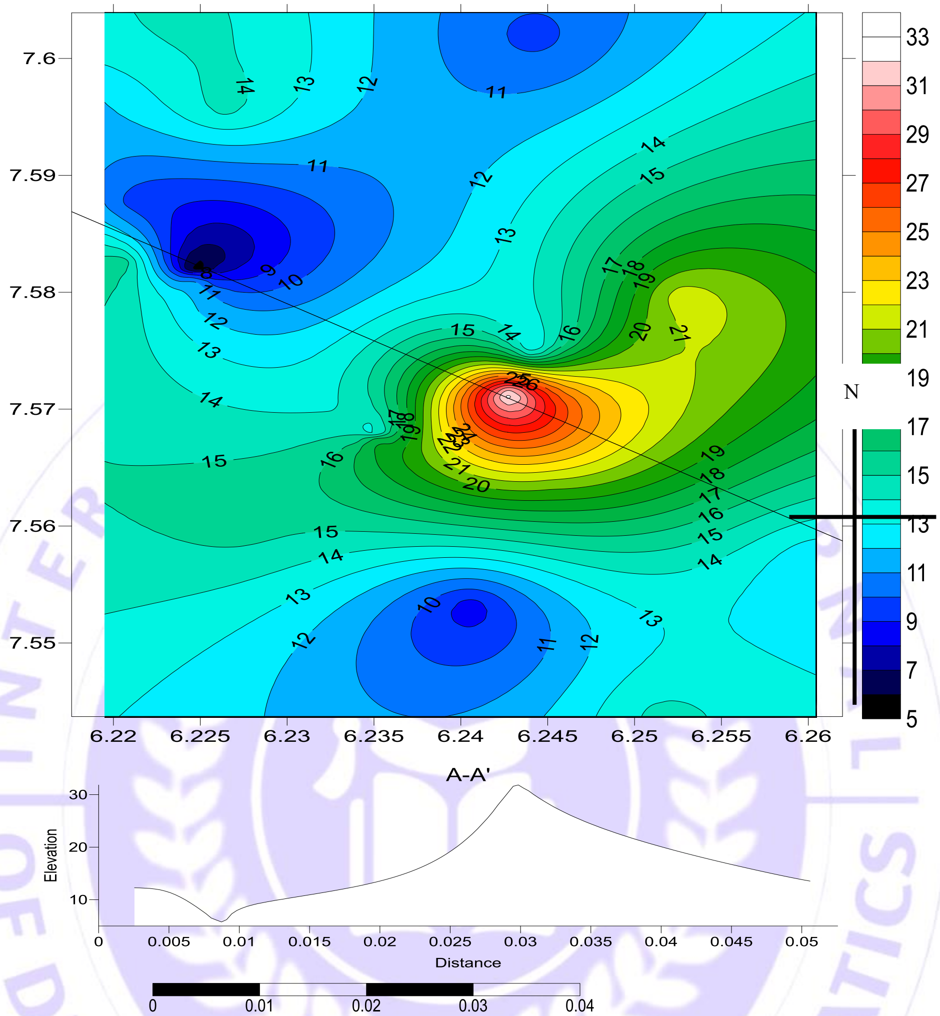


Figure 1: Contour map of Ambient for Adavi LGA

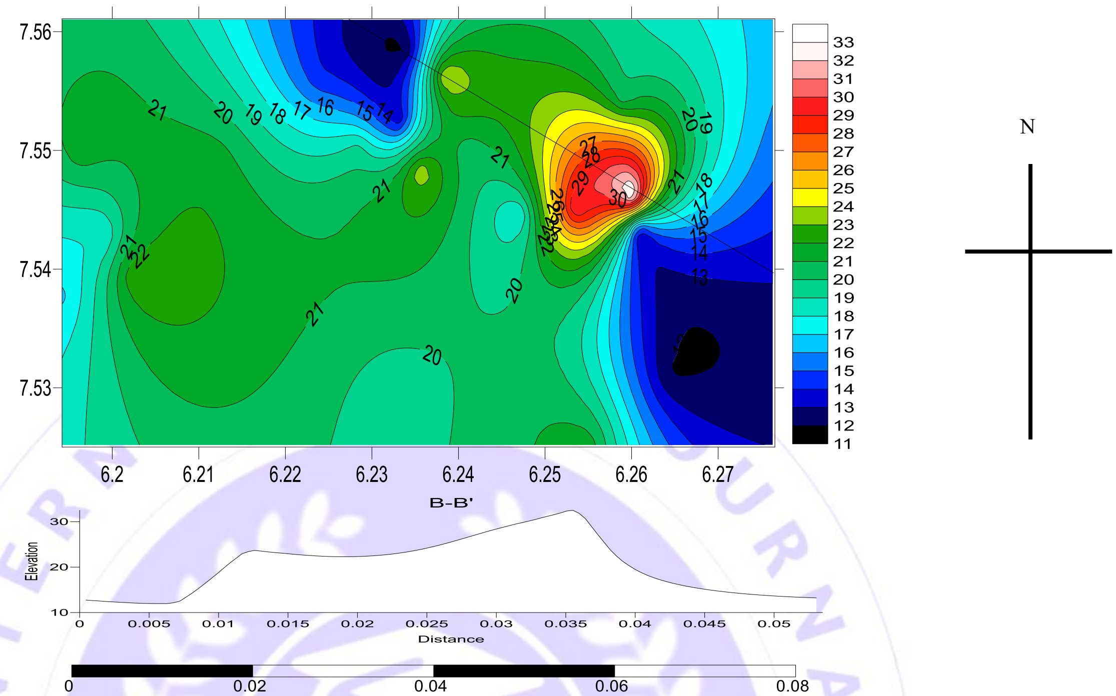


Figure 2: Contour map of Ambient for Okene LGA

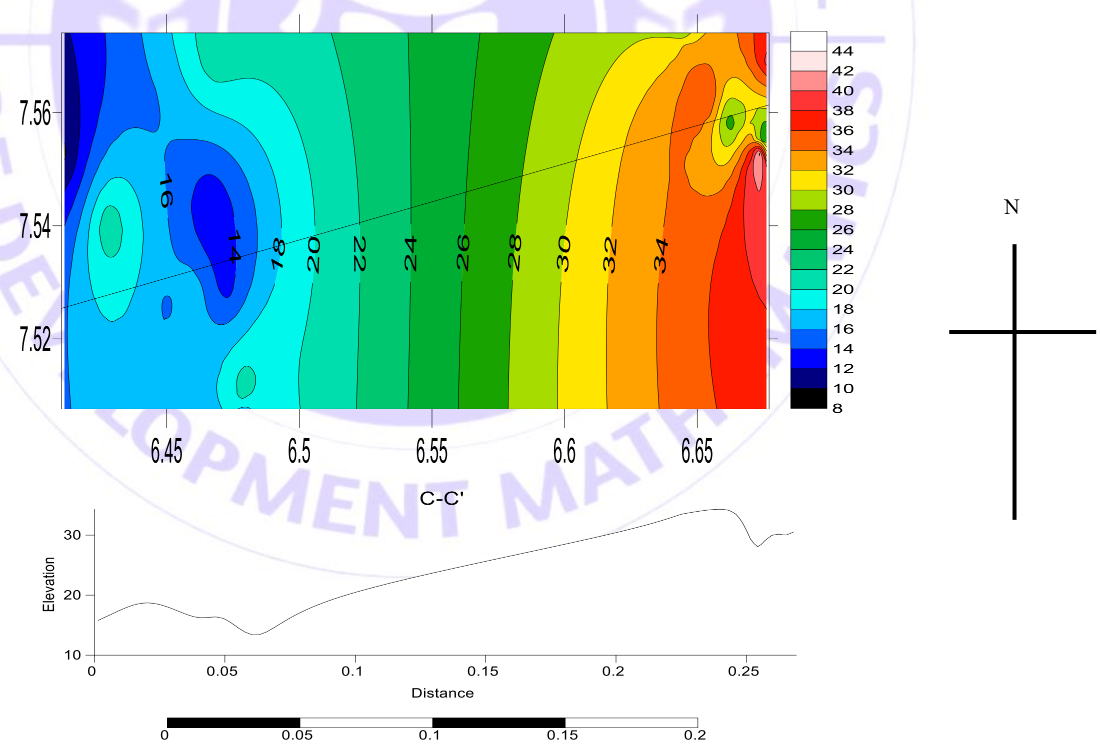


Figure 3: Contour map of Ambient for Ajaokuta LGA

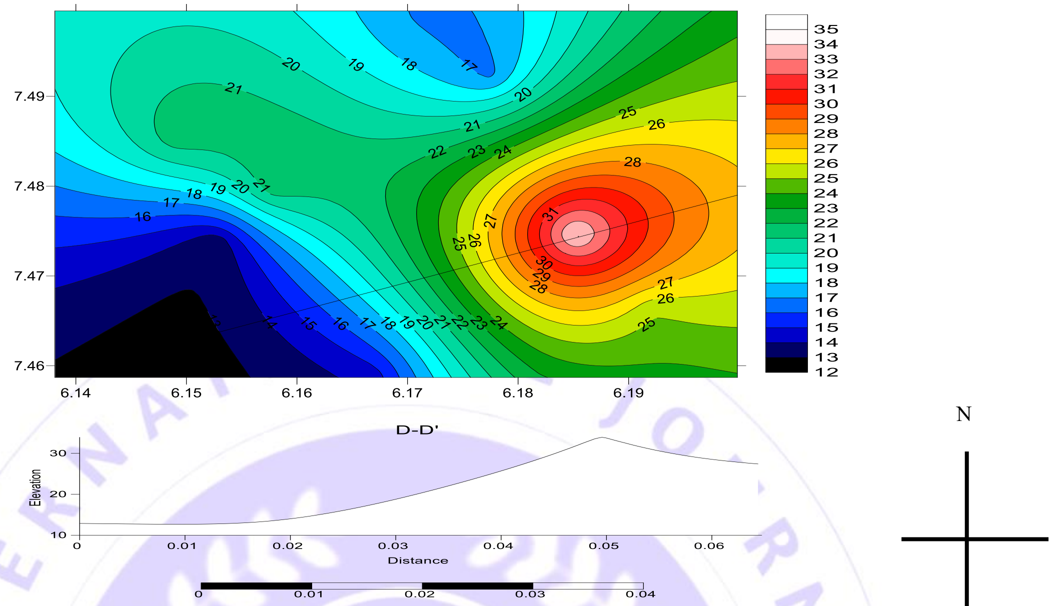


Figure 4: Contour map of Ambient for Ogori-Magongo LGA

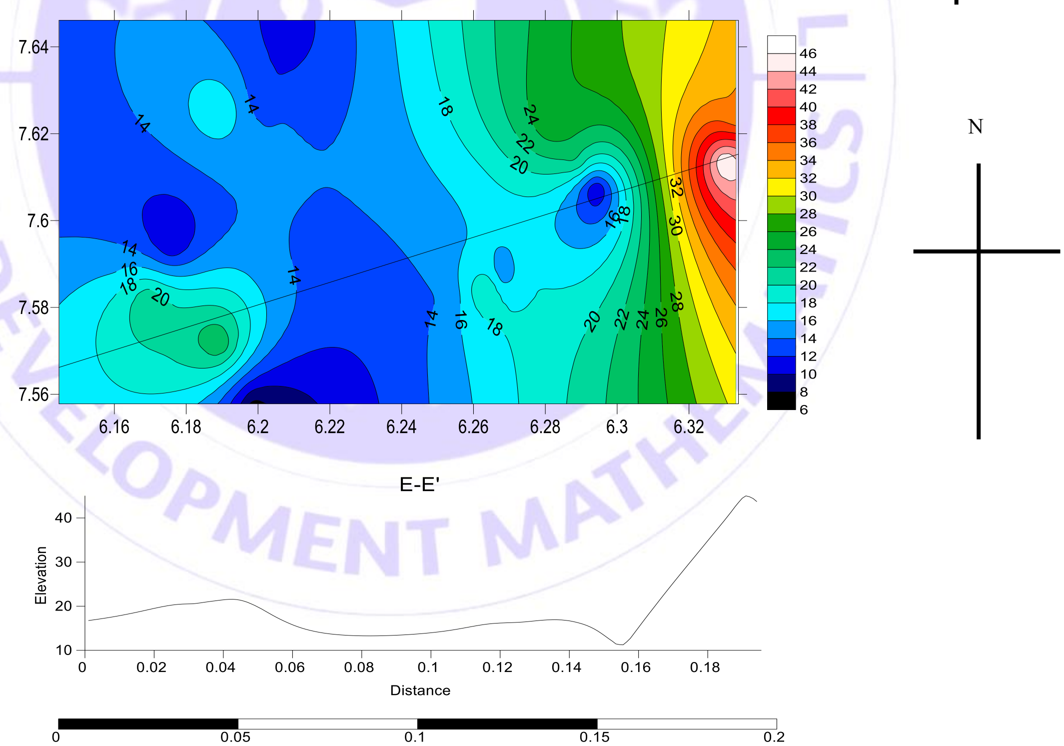


Figure 5: Contour map of Ambient for Okehi LGA

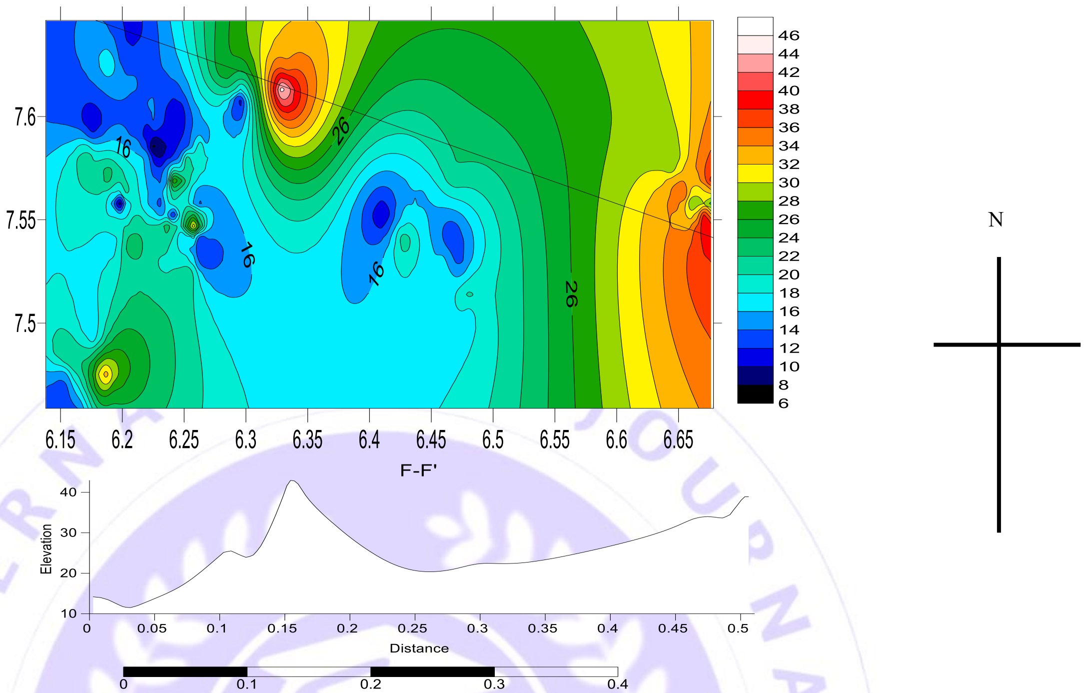


Figure 6: Contour map of Ambient for Kogi central district of Kogi State

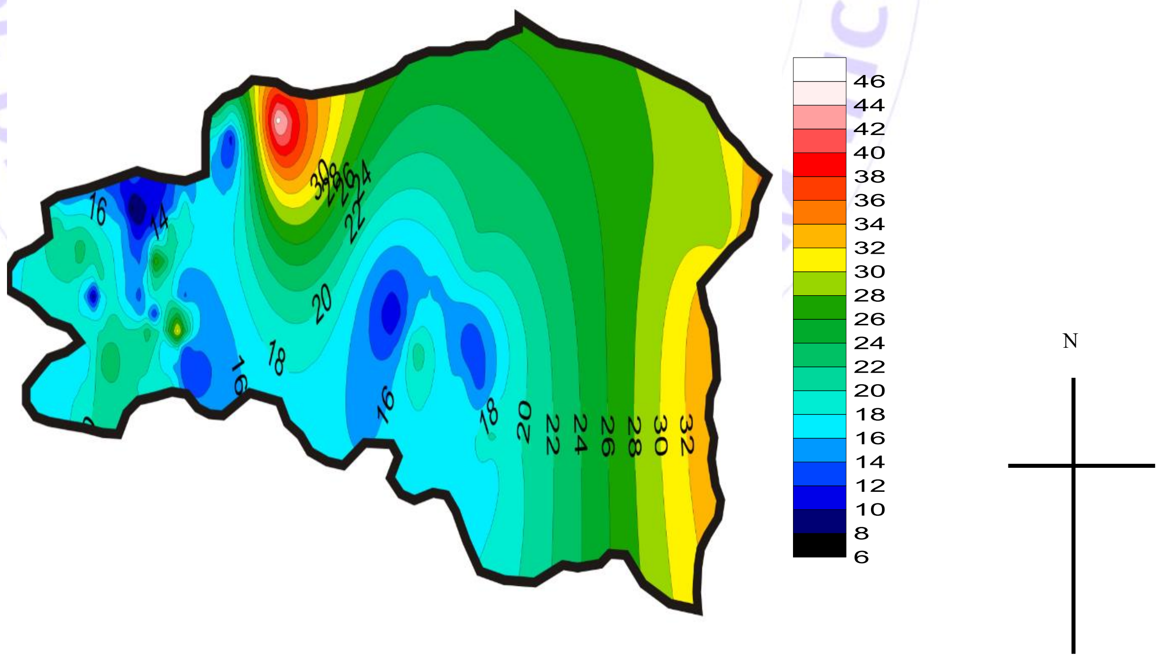


Figure 7: Contour map of Ambient for Kogi central district

## 4. Conclusion and Recommendation

### 4.1 Conclusion

The study successfully assessed the environmental background radiation and its radiological implication and developed a contour map for Kogi Central Senatorial District. While some areas showed high radiation parameter values from the facts summarised, the research established a scientific benchmark for future radiation changes in the district. It is crucial to monitor radiation levels in areas with elevated values for further increase and prevent potential health risk.

### 4.2 Recommendations

The following recommendations are based on the success and finding of this work are as follow:

i. Mechanism should be put in place for regular monitoring of radiation levels in area with elevated values for further increase to prevent potential health risks.

ii. Assessment of concentration of radionuclides in soil and water samples should be carried out in locations with high radiation level.

A radon risk assessment should be carried at steel complex and ltakpe2 to ascertain radon risk as indigenes use the soil from these locations for building construction.

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