International Journal of Basic Science and Technology
June 2019, Volume 5, Number 1, Pages 65 - 74

Evaluation of Annual Effective Dose Equivalent from Environmental Gamma Radiation at Sand Mine Valley in Yenagoa, Nigeria

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Article Information

Article # 0909
Received date: 10th May., 2019
1st Revision 16th June, 2019
2nd Revision: 20th June, 2019
Acceptance: 7th July, 2019
Published: 20th July, 2019

Key Words
Evaluation; Effective Dose
Gamma Radiation;
Sand Dump

Abstract

Annual Effective Dose Equivalent (AEDE) was evaluated from ionizing radiation exposure rates at sand dredging and dump site using Digiler-200 radiation survey meter. Radiation Exposure rates ranged from 0.010mR^{-h} to 0.028mR^{-h}. The result of Annual Effective Dose Equivalent ranged from 0.10 to 0.29 $mSvy^{-1}$. The average value of absorbed dose was found to be 141.70 $nGyh^{-1}$. A plot of height of dumped sand with Background ionizing radiation suggests that more radionuclides exist in less washed sand. Computed average values of annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) were 0.171 $mSvy^{-1}$ and 0.43 x 10^{-3} respectively. It was observed that all the radiological indices exceeded the standard value except the annual effective dose equivalent which was based on dose conversion factor of 0.7 and occupancy factor of 0.25, and it is less than the permissible dose limit of 1 mSv/yr set by the International Commission on Radiological Protection. In this regard, the sand is highly recommended as building material since the radiological burden it poses is minimal. However a different batch of dredged sand in the same location may radiate different levels of nuclide therefore regular monitoring is necessary.

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INTRODUCTION

No level of exposure to ionizing radiation is good but unfortunately radionuclides can be detected in all human environments. The environmental impact due to dredging occurs from the suspension of sediments and the release of pollutants from the disturbed sediment and consequently may increase radiation level. These pollutants may contain radioactive materials in their natural geometry DuBois and Towle (1985).

The sand from Sand Mine Valley is used for building houses and knowledge of its radionuclides content may be useful, hence the understanding of health implication of premodial radioisotopes is useful to human beings in making sure that exposure will not be allowed to reach certain level. It is therefore very important to assess the radiation hazards arising due to the use of sand in the construction of dwellings (Kumar *et al.*,2003; Khatibeh *et al.*,1997). The Sand Mine Valley (SMV) is a major source of sand as building material and for land reclamation to many communities in Bayelsa State of Nigeria. Many researchers have done work on the natural nuclides content of building materials (Chen *et al*., 1993, Ali *et al*., 1996). Sand is granular material composed of finely divided rock mineral particles, it is define by size being finer than gravel and coarser than silt. Sand can also refer to as a textural class of soil meaning that sand is a type of soil.

Medical use of radiation accounts for 98 % of the population dose contribution from all artificial sources, and represents 20% of the total population exposure. Annually worldwide, more than 360 million diagnostic radiology examinations are performed, 37 million nuclear medicine procedures are carried out, and 7.5 million radiotherapy treatments are given (WHO, 2016). Cosmic radiation spread across all of space, the source is primarily outside the solar system. This radiation is in many forms and is from high speed heavy particle to high energy photons and muons (Kathren, 1991). Geographically, the amount of terrestrial radiation varies, from rocks to soil. The origination of terrestrial radiation is mostly from radiations of thorium (^{232}Th), Uranium (^{238}U) series radionuclides and potassium (^{40}K). Natural Potassium, which is a pervasive element in the soil, contains 0.0119% radioactive ^{40}K. Radon (^{222}Rn) gas is primarily daughter product of the ^{238}U and ^{232}Th series.

Radon is a gas to be looked out for in determining building materials. The radium content of surface soils in the United States is usually in the range 10–100 Bq kg−1 Nazaroff (1992). Radon in soil pores may be partitioned among three states: in the pore air, dissolved in the pore water, and absorbed to the soil grains Nazaroff (1992). Therefore, natural radioactivity is defined as the spontaneous transformation of unstable nuclei that results in the formation of new elements with the emission of particles and radiations (Cember, 1996). The time that it takes for half the original radionuclides to disintegrate or decay is called half–life. This differs for each radioelement, ranging from fractions of a second to billions of years. For example, the half-life of Iodine 131 is eight days, but for uranium 238, which is present in varying amounts all over the world, is 4.5 billion years. Potassium-40, the main source of radioactivity in our bodies, has a half-life of 1.42 billion years (Garba, *et al.*, 2008).

Naturally radon occurs but the exposure can either be increased or reduced by the activities of human i.e. building construction so it is significant to conduct radiation exposure level at the point of sand dredging. Usually basement sealing and suction ventilation reduce exposure from ionizing radiation inside a building. Some building materials, for example lightweight concrete with alum shale, phosphogypsum and Italian tuff may emanate radon if they contain radium and are porous to gas (UNSCEAR, 2006). The global average internal dose from radionuclides other than radon and its decay products is 0.29 mSv/a, of which 0.17 mSv/a comes from 40K, 0.12 mSv/a comes from the uranium and thorium series, and 12 µSv/a comes from 14C (UNSCEAR, 2008).

A typical chest x-ray delivers 0.02 mSv (2 mrem) of effective dose (Wall and Hart, 1997). A dental x-ray delivers a dose of 5 to 10 µSv (Hart and Wall, 2002). A CT scan delivers an effective dose to the whole body ranging from 1 to 20 mSv (100 to 2000 mrem). The International Commission on Radiological Protection (ICRP) recommends limiting occupational radiation exposure to 50 mSv (5 rem) per year, and 100 mSv (10 rem) in 5 years (ICRP, 2007). Kuroda (1991) reported that the background radiation levels are from a combination of terrestrial (^{40}K, ^{232}Th, ^{226}Ra etc.) and cosmic radiation (Photons, Muons etc.). He reported that the level is fairly constant over the world, being 0.008-0.015 mR h^{-1}. But Brazil, India and China have higher background ionizing radiation, primarily due to the high concentrations of radioactive minerals (Monozite) in the soil (Ron Kathren, 1991).

Materials used for building (soil and rock) are major sources of radiation exposure to the population and also means of migration for the transfer of radionuclide into the environment. Natural radioactivity in soil is mainly due to 238U, 40K, 226Ra which cause external and internal radiological hazards due to emission of gamma rays and inhalation of radon and its daughters (UNSCEAR, 2008]). It is in this regard that Anekwe and Uzoekwe (2018) conducted environmental radioactivity in Federal University Otuoke and observed that the average exposure rate ranged from 9.0 to 29.0µRh-1. Mehra *et al.*(2009) reported the radionuclide contents in soil sample in terms of the activity concentration and concluded that average dose rates are lower than the national and standard values, hence soils from those regions were considered to be safe as material for construction.

Study Area

The study area is in Bayelsa State of Nigera, precisely within the state capital municipal Yenagoa. Sand Mine Valley (SMV) is the biggest Dredging and Sand Supplying company in Yenagoa. Bayelsa state is in the Oil-rich Niger Delta region. Niger Delta area is located in the Atlantic coast of Southern Nigeria and it is the world’s second largest delta of about 450km coastline that ends at Imo river entrance (Awosika, 1995). It is located close to the confluence of Ekole River and Epie Creek hence the study area lie within latitude 4^0 55” 29’N 04^0 91´N and longitude 06^0 26´E$6^0$15’51”E. The company undertakes the business of dredging, reclamation, Sand filling, haulage and heavy duty equipment leasing. At SMV several tons of Sands are carried on daily basis across the Ekole River to various construction sites around the city and neighbouring towns. The company sells quite large quantity of sand for block-molding, sandcreting, rendering etc within the State capital and beyond. The major soil types in Bayelsa state are young, shallow, poorly drained soils and acid sulphate soils (Anekwe and Ibe, 2017).

There are variations in the soils of Bayelsa State; some soil types occupy extensive areas whereas others are of limited extent. Several soil units could be identified in the state and they include sandy loam, silt loamy and loamy sandy soils. There exist soils of the low-lying levees with fine texture. Sandy silts are usually under the influence of tidal floods and fresh waters. The texture of majority of the soils ranges from medium to fine grains (Anekwe and Ibe, 2017).

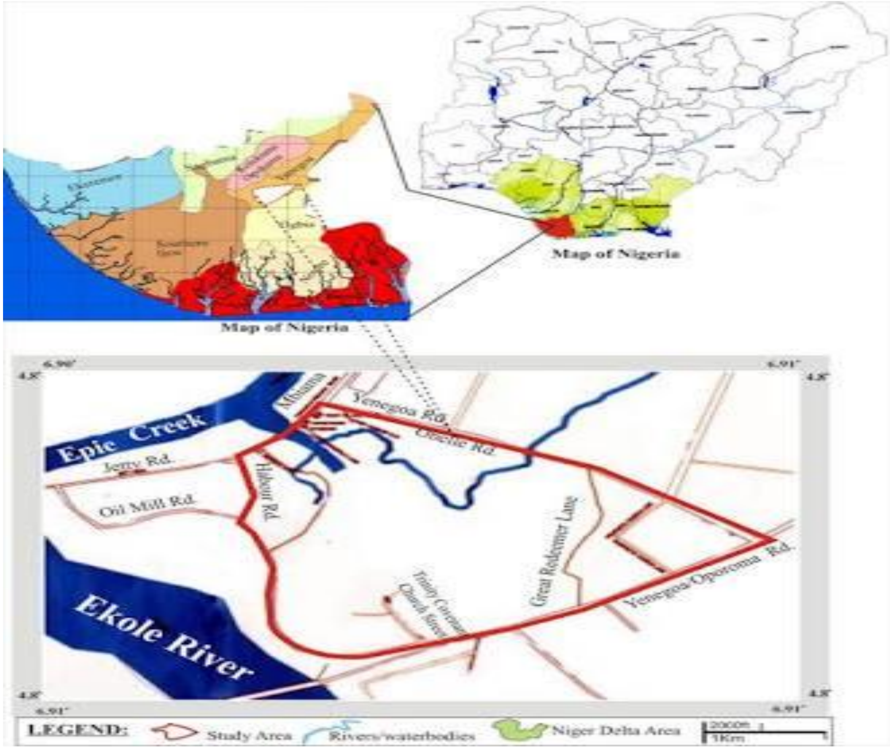

Fig. 1: Map of Nigeria showing Bayelsa State and the study area, SMV in Yenagoa LGA.

MATERIALS AND METHODS

The materials used were Radalert-100 radiation meter and a geographical positioning system (GPS). Measurements were done *in situ*. The *in situ* approach was adopted to make sure that the radionuclides were under their natural environmental characteristics. The meter was calibrated using Cs-137 radionuclide. Radilert-100 uses Geiger Muller tube to detect radiation. Each time radiation passes through the tube and causes ionization, the tube generate a pulse which is electronically detected and registered and displayed in the chosen mode mR/hr. The geographical positioning system (GPS) was used to map and locate the Longitude, latitude and elevation of each sampling point.

The readings were taken between 1300 and 1600 hours, when radiation meters have the maximum response to environmental ionizing radiation. The practical procedure was that the meter was held 1 m above the ground level in accordance with that reported by Laogun *et al.* (2006). The radiation meter allows alpha, low energy beta, and gamma radiation to penetrate the mica end of the tube. Readings were taken six (6) times at each sample point.

RESULTS AND DISCUSSION

The results are presented in Table 1 which shows values of exposure rate, average exposure rate, absorbed dose rate, annual effective dose equivalent and excess lifetime cancer risk. The Annual Effective Dose Equivalent (AEDE) has been computed and the results for all the sample points showed lower value than the 1.0 mSvy^{-1} permissible limit recommended by ICRP. Having conducted the evaluation of annually effective dose equivalent and other radiological parameters using international standards, radiation exposure rates ranged from 0.010mR^{-h} to 0.028mR^{-h} with average value of 0.016mRh^{-1} which is higher than the permissible value of 0.013mRh^{-1} as shown in figure 4. The result of Annual Effective Dose Equivalent ranged from 0.10 to 0.29 mSvy^{-1} and the values were computed using the following relation,

$$AEDE\ (Outdoor)(mSvy^{-1}) = Absorbed\ dose\ rate\ (nGyh^{-1}) \times 8760h \times \frac{0.7Sv}{Gy} \times 0.25, \text{ (UNSCEAR, (2000)}$$

Computed average values of annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) were 0.171 mSvy^{-1} and 0.43 x 10^{-3} respectively. The mean value of AEDE was 0.171mSvy^{-1} far less than the ICRP recommended value as shown in figure 5. The mean value of absorbed dose was found to be 141.70 nGyh^{-1} which is higher than 69.6 nGyh^{-1} reported by Xinwei and Xiaolan (2006). The radiological indices slightly exceeded the standard values except the annual effective dose equivalent which was based on dose conversion factor of 0.7 and occupancy factor of 0.25, and it is less than the permissible dose limit of 1 mSv/yr set by the International Commission on Radiological Protection. Human organ dose rate was calculated using the relation

, $D_{organ}(mSvy^{-1}) = Occupancy\ factor, O \times AEDE \times Conversion\ factor, F,$ Zaid *et al.* (2010), ICRP (1996). AEDE is the annual effective dose, the occupancy factor, O is 0.8. Effective dose rates delivered to the different human organs were computed using conversion factors, 0.82, 0.46, 0.69, 0.64, 0.62, 0.58, and 0.68 for testes, liver, bone marrow, lungs, kidney, ovaries and whole body respectively as shown in figure 6.

All the organ/tissue doses are far below the standard limit of 1.0 $mSvy^{-1}$. In the area under consideration the human testes would receive the highest effective dose but the dosage is insignificant and therefore poses no radiological concern. Fig 7. is a plot of Elevation and BIR which produced correlation coefficient of 0.4604 and this is not very poor relation meaning that at height where well washed sand were pile, radionuclides content may be less. The process of moving the sand up the heap makes it to be washed more than the freshly dredged. Therefore the value of the coefficient may suggest that at higher level of dumped sand the radionuclide content is less. The correlation coefficient of 0.46 does not suggest that as the height of the dumped sand increases the BIR increases.

CONCLUSION

Evaluation of annual effective dose equivalent (AEDE) has been conducted in sand dredging and dump site, the Sand Mine Valley in Yenagoa, Bayelsa State. The results showed that the exposure rate was elevated above the permissible level of $0.013mRh^{-1}$ but the computed AEDE was lower than the world standard value of $1.0mSvy^{-1}$. This suggests that the sand was not emitting ionizing radiation that could raise alarm. However further study should be conducted where the sand could be subjected to gamma spectroscopy and elemental characterization.

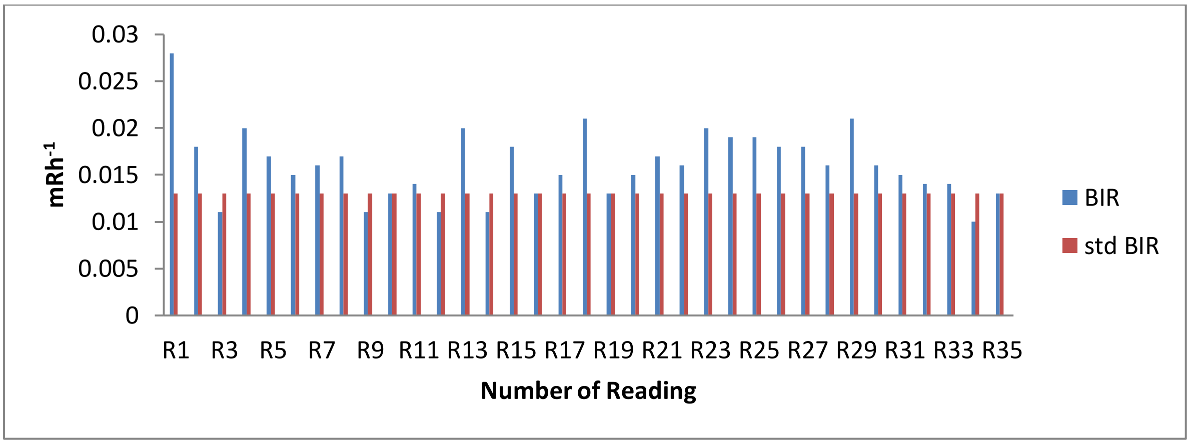

Fig. 2: Comparison of standard BIR and measured BIR

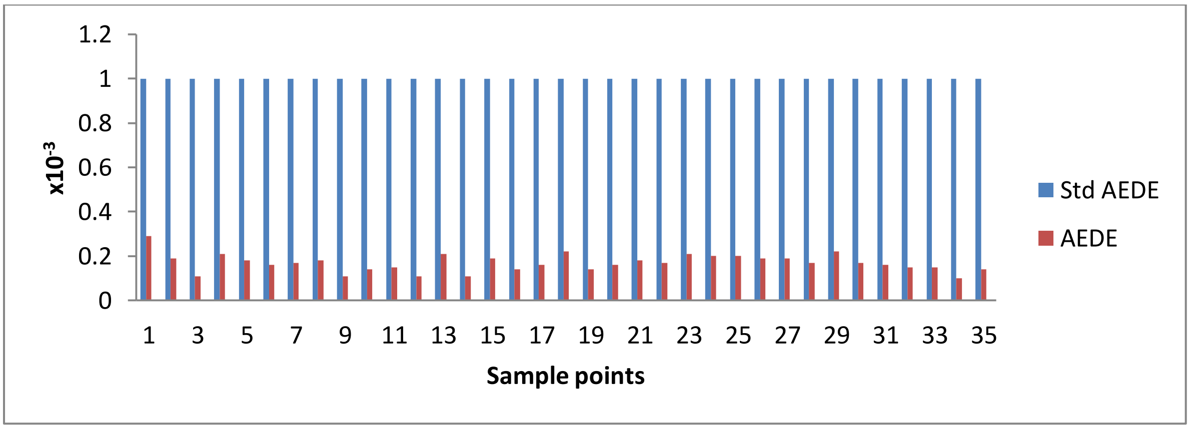

Fig. 3: Comparison of standard AEDE and measured AEDE

Table 1: Result of Average Exposure rate, Absorbed dose, Equivalent dose, AEDE and ELCR

S/No	R1 (mR/hr)	R2 (mE/hr)	R3 (mR/hr)	Longitude (°)	Latitude (°)	Height (m)	Average Exposure(m Rh^{-1})	Absorbed Dose (nGyh^{-1})	Equivalent Dose (mSvy^{-1})	AEDE (mSvy^{-1})	ELCR (x10^{-3})
1	0.029	0.027	0.028	6.262617	4.762411	10.5	0.028	243.6	2.35	0.29	0.73
2	0.020	0.019	0.016	6.288924	4.762074	11.0	0.018	156.6	1.51	0.19	0.48
3	0.012	0.011	0.010	6.289329	4.761427	11.5	0.011	95.7	0.92	0.11	0.26
4	0.018	0.017	0.021	6.288824	4.761145	16.5	0.020	174.0	1.68	0.21	0.53
5	0.018	0.016	0.016	6.288611	4.760858	17.0	0.017	147.9	1.43	0.18	0.45
6	0.015	0.013	0.016	6.288391	4.760575	18.0	0.015	130.5	1.26	0.16	0.40
7	0.017	0.015	0.016	6.288306	4.761660	16.5	0.016	139.2	1.34	0.17	0.43
8	0.017	0.018	0.015	6.289715	4.761110	22.0	0.017	147.9	1.43	0.18	0.45
9	0.013	0.010	0.011	6.289981	4.760734	14.0	0.011	95.7	0.92	0.11	0.26
10	0.013	0.012	0.014	6.290161	4.760387	16.5	0.013	113.1	1.10	0.14	0.35
11	0.015	0.014	0.013	6.290649	4.759260	16.5	0.014	121.8	1.176	0.15	0.38
12	0.010	0.011	0.011	6.290648	4.758547	11.0	0.011	95.7	0.92	0.11	0.26
13	0.120	0.015	0.014	6.291131	4.758181	11.5	0.020	174.0	1.68	0.21	0.53
14	0.012	0.011	0.010	6.291063	4.758833	12.0	0.011	95.7	0.92	0.11	0.26
15	0.020	0.017	0.018	6.291519	4.759004	9.5	0.018	156.6	1.51	0.19	0.48
16	0.013	0.011	0.016	6.291860	4.759236	23.5	0.013	113.1	1.10	0.14	0.35
17	0.015	0.015	0.016	6.291751	4.759740	9.5	0.015	130.5	1.26	0.16	0.40
18	0.020	0.022	0.020	6.291568	4.760286	6.0	0.021	182.7	1.76	0.22	0.55
19	0.013	0.011	0.014	6.291404	4.760900	7.5	0.013	113.1	1.10	0.14	0.35
20	0.015	0.013	0.016	6.291748	4.761777	6.5	0.015	130.5	1.26	0.16	0.40
21	0.017	0.016	0.018	6.290858	4.761734	10.0	0.017	147.9	1.43	0.18	0.45
22	0.016	0.013	0.018	6.290535	4.761789	9.5	0.016	139.2	1.34	0.17	0.43
S/No	R1	R2	R3	Longitude	Latitude	Height	Average Exposure(m	Absorbed Dose (nGyh-	Equivalent Dose (mSvy-	AEDE (mSvy-1)	ELCR (x10-3)

	(mR/hr)	(mE/hr)	(mR/hr)	(o)	(o)	(m)	Rh-1)	1)	1)		
23	0.020	0.020	0.019	6.290468	4.762234	12.0	0.020	174.0	1.68	0.21	0.53
24	0.020	0.018	0.019	6.290633	4.762712	8.5	0.019	165.3	1.60	0.20	0.50
25	0.019	0.020	0.018	6.290433	4.76271	12.0	0.019	165.3	1.60	0.20	0.50
26	0.017	0.020	0.016	6.289715	4.762568	12.0	0.018	156.6	1.51	0.19	0.48
27	0.020	0.016	0.017	6.288032	4.763435	13.0	0.018	156.6	1.51	0.19	0.48
28	0.017	0.015	0.016	6.287471	4.763309	12.5	0.016	139.2	1.34	0.17	0.43
29	0.021	0.020	0.021	6.286961	4.763313	13.0	0.021	182.7	1.76	0.22	0.55
30	0.015	0.016	0.016	6.286595	4.763191	12.0	0.016	139.2	1.34	0.17	0.43
31	0.016	0.013	0.015	6.287779	4.764378	10.0	0.015	130.5	1.26	0.16	0.40
32	0.011	0.016	0.015	6.288665	4.764946	6.0	0.014	121.8	1.18	0.15	0.38
33	0.012	0.016	0.015	6.311730	4.764858	8.0	0.014	121.8	1.18	0.15	0.38
34	0.010	0.011	0.010	6.294632	4.770268	13.0	0.010	87.0	0.84	0.10	0.25
35	0.013	0.011	0.016	6.311730	4.785844	9.0	0.013	113.1	1.10	0.14	0.35
	Average						0.016	141.7	1.37	0.171	0.43

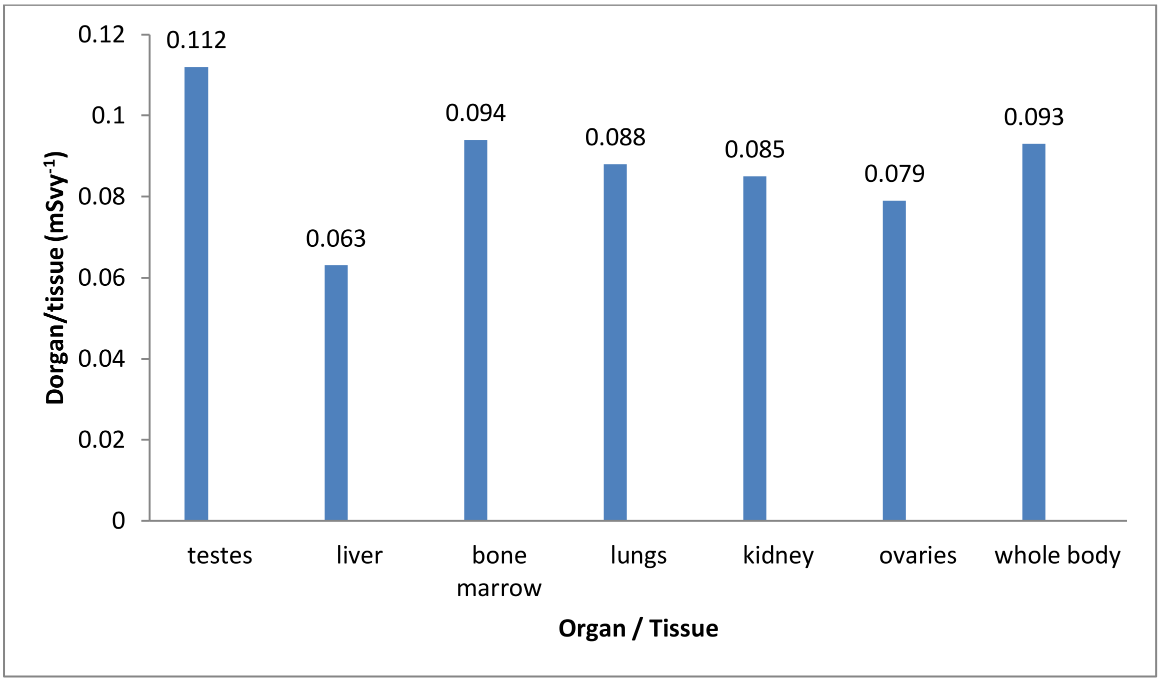

Fig. 4: Chart of Effective dose to Human Organ or Tissue

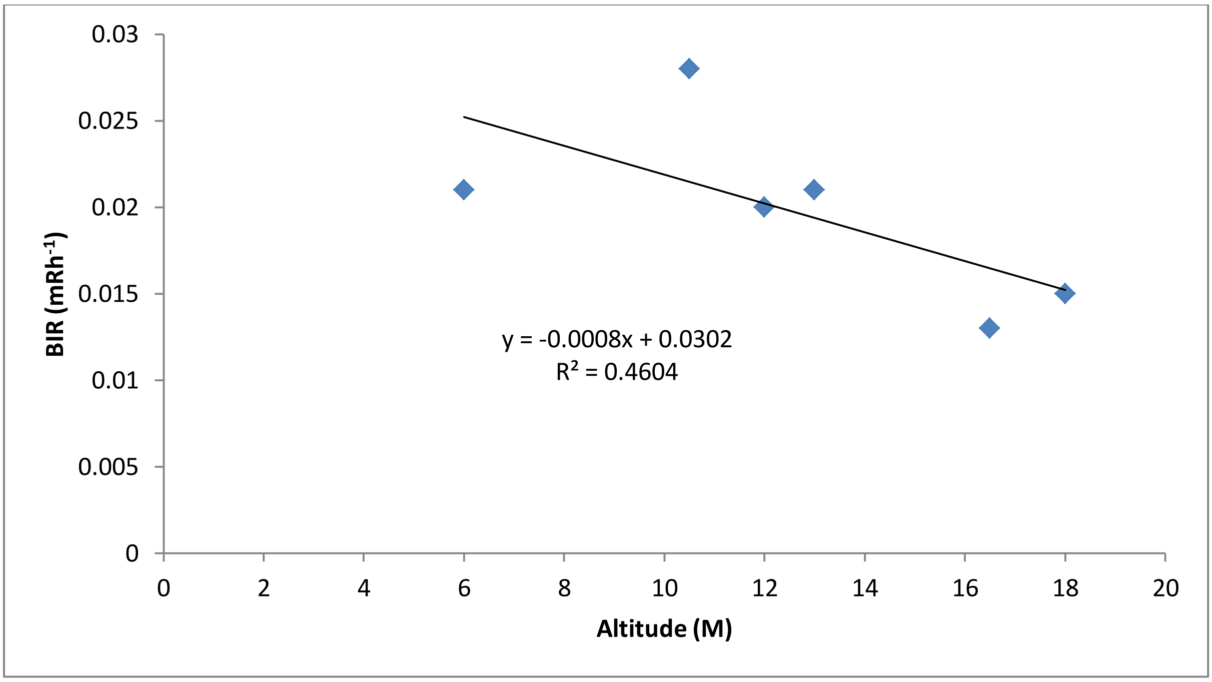

Fig. 5: Correlation between Exposure rate and the Elevation

Acknowledgement
Doumo-Spiff, Ayebanoa is hereby acknowledged for liaising with SMV Company.

REFERENCES

Ali, S., Tufail, M., Jamil, K., Ahmad, A. and Klian, H.A. (1996). Gamma ray activity and dose rate of brick samples from some arrears of North West Frontier Province, Pakistan. *Total Environ.* 187, 247-252

Anekwe, U.L. and Ibe, S.O. (2017). Estimation of Radiation Risk Due to Exposure toTerrestrial Radiation. Archives of Current Research International 9(4): 1-10, 2017; Article no. ACRI.36 318 ISSN: 2454-7077

Anekwe, U.L. and Uzoekwe, S.A. (2008). Assessment of Environmental Radioactivity in the Federal University Otuoke, Bayelsa State, Nigeria. *International Journal of Advanced Research in Physical Science (IJARPS),* Volume 5, Issue 1, 2018, PP 12-18.

Awosika, L. F. (1995). "The West African Coastal Zones: a regional approach to the process of integrated coastal zone management". In Beukenkamp, P. et al. (eds) "*World coast conference proceedings". Coastal zone management center,* The Hague, vol. 2, 697-704.

Cember, H. (1996). Introduction to Health physics, 3rd Edition. McGraw Hill, Inc, Toronto pp.220-231.

Chen, C.J., Weng, P.S. and Chu, T.C.(1993). Radon exhalation Rate from various building materials. *Health Phys*. 64 (6), 613-619.

DuBois, R. and Towle, E. (1985). Coral harvesting and sand mining management practices. In: Clark, J. (ed.) Coastal resources management: development case studies. *Coastal Publication, Research Planning Institute*, Columbia. SC, 3: 203-289.

Garba, N.N., Rabiu, N., Yusuf, A.M., Abubakar, A.K., Yamusa, Y.A. and Ismail, A. (2008)."How safe is a Radiation dose". Proceedings of International Conference on Research and Development. 2(8), pp. 43-48.

Hart, D. and Wall, B.F. (2002). Radiation Exposure of the UK Population from Medical and Dental X-Ray examinations. National Radiological Protection Board, Uk.

ICRP. (2007). ICRP Publication 103 Recomm-endation of the International Commission on Radiological Population 103 Oxford, New York.

ICRP.(2008). Radiation dose to patients from radiopharmaceuticals. Addendum 3 to ICRP Publication 53. ICRP Publication 106. Ann. ICRP 38: 1-2.

Kathren (1991). Radioactivity in the Environment. Taylor and FrancisPublishers, USA.

Khatibeh, A.J., Mal'ly, A., Ahmad, N.(1997). Natural Radioactivity in Jordanian Construction. *Radiation Protection Documentary*, Vol 69 (2) 143-147

Kumar, A, Kumar, M, Singh, B. and Singh, S. (2003). Natural Activities of 238U, 232Th and 40K in some Indian building materials. *Radiat. Meas*, 36: 465-469

Kuroda, P.K. (1991). Estimation of Burnup in the Oklo Natural Nuclear Reactor from Ruthernium Isotopic Composition. *Journal of radioanal. Nucl. Chem., Lett*., 155: 107-113

Laogun, A.A., Ajayi, N.O. and Agaja,S.A. (2006). Variation in wellhead gamma radiation levels at the Nigeria Petroleum development company oil field, Ologbo Edo State, Nigeria. *Nig. J. Phys*, 18(1):135-140.·

Mehra, R., Kumar, S., Sonkamade, R., Singh, N.P., and Babhan, K. (2009). Analysis of terrestrial naturally occurring radionuclides in the soil samples from some areas of Sirsa district of Haryana, India. *Environmental earth Sciences*, (59) :1159-1164

Nazoroff, W.W. (1992). Radon Transport from Soil to Air. Review of Geophysics30(2):137-160

UNSCEAR.(2000). Annex – Dose Assessment methodologies pp23.

UNSCEAR.(2006). United Nations Scientific Committee on the Effects of Atomic Radiation (2006). "Annex E Sources-to-effects assessment for radon in homes and workplaces. Effects of Ionizing Radiation (http://www.unscear. org/docs/ reports/2006/09-81160_Report_

UNSCEAR. (2008). Sources and Effects of Ionizing Radiation.(http://www.unscear.org/unscear/en/publications/2008_1.html

Wall, B.F. and Hart, D. (1997). Revised radiation doses for typical X-ray examinations. Report on a recent review of doses to patients from medical X-ray examinations in the UK by NRPB, National Radiological Protection Board. British Journal of Radiology 70(833) 437-439.

WHO, (2006). Global initiative on Radiation Safety in Health Care Settings, Geneva.

Xinwei, L. and Xiaolan, Z. (2006). Measurement of natural radioactivity in sand samples collected from the Baoji Weihe Sand Park, China. Environ Geol 50: 977-982

Zaid O., Ababaneh Khled, M., Aljarrah, A., Ababneh, M. and Abdalmajeid, M.A. (2010). Measurement of natural and artificial radioactivity in powder milk corresponding annual effective dose. *Radiat. Prot. Dosim.* 138(3): 278-283.

ISSN 2488-8648

APPENDIX 1: Pictures of the Sand Mine valley site

APPENDIX 2: Radalert^{100} Universal Radiometer, GPSInfo^{TM} GUI on BB z10 screen