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TERRESTRIAL RADIATION LEVEL IN SELECTED ASPHALT PLANTS IN PORT HARCOURT, NIGERIA.

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ABSTRACT
An environmental radiation survey in asphalt processing plants in Rivers State was been carried out using a well calibrated Radalert survey meter. Measurements were carried out in four different locations of asphalt processing plants at different strategic points. Measured average values of 0.0223 ± 0.0017 mR/hr, 0.0225 ± 0.0023 mR/hr, 0.0180 ± 0.0030 mR/hr and 0.0189 ± 0.0009 mR/hr respectively were recorded. These results revealed the average doses equivalent obtained are higher than the safe radiation limit of (≤) 20mSv/yr recommended by UNSCEAR. The radiation level within these facilities in the plants is significantly higher than the standard background radiation level. Therefore the results show significant radiological risk.

Keywords: Effective dose, natural radioactivity, asphalt

INTRODUCTION
Radionuclides are present in the air, the food and terrestrial water consumed by man (Ciezkowski and Przylibski, 1997; Hakonson-Hayes et al., 2002). Foland et al. (1995) reported that human activities that have led to the depletion of the ozone layer increased the cosmic rays reaching the earth thereby affecting the background radiation. The Construction and maintenance of roads in order to reduce the problem of urban migration has lead to astronomical increases in the Construction of roads and walk way. It has been established that the activities of constructing firms include the use of quarrying, aggregating and the asphalt in the process and production of the material for tarring of roads (Brian Jones, 2007). There are two major types of road pavement in Nigeria. Those finished with asphalt wearing course, are referred to as flexible pavement roads, while those finished with a reinforced concrete, and are referred to as rigid pavement roads. More than 90 percent of all the roads constructed in Nigeria are of the flexible pavement type. A release by the Federal Ministry of Works and Housing, Highways Management Services Division in 1994 showed that of all the 32,097km of Federal Highways, 18,250km are of asphalt concrete wearing course carriage and another 7,877km are made up of asphalt surface dressing, both types being flexible pavement (FMWH, 1994).The remaining 5970km are the then yet to be constructed earth roads.

The production of hot asphalt concrete is done at an Asphalt Plant also known as Hot Mix Asphalt (HMA) facility. Hot mix asphalt is used primarily as paving material and consists of a mixture of aggregate (i.e. inert mineral materials such as sand, gravel, crushed stone, slag, rock dust or powder))and liquid asphalt cement (bitumen), which are heated and mixed in measured quantities in an assembly of mechanical equipment called Hot Mix Asphalt facility. (Momoh and Fred, 2010).

Hot Mix Asphalt facility can be constructed as a permanent plant, a skid-mounted (easily relocated) plant, or a portable plant. Asphalt plants are numerous in Nigeria. Every major road project has an asphalt plant installed for asphalt production by the construction company. Some construction companies, on the other hand, have their HMA facility centrally located in their area of operation and hence feeds more than one road project with asphalt from the one centrally located plant Hot Mix Asphalt facilities are comprised of the same basic environmental pollution sources. These are the dryer, burner-blower, exhaust fan, dust collection system, asphalt cement heating and storage, and reclaimed asphalt paving components. Hot mix asphalt facilities can be broadly classified as either drum mix plants or batch mix plants, according to the process by which the raw materials are mixed. In a batch mix plant, the aggregate is dried first, and then transferred to a mixer where it is mixed with the liquid asphalt. In a drum mix plant, a rotary dryer serves to dry the aggregate and mix it with the liquid asphalt cement. After mixing, the HMA generally is transferred to a storage bin or silo, where it is stored temporarily. From the silo, the HMA is emptied into haul trucks, which transport the material to the job site. Most of the pollutants emitted from Hot Mix Asphalt facilities are particulates. Sulphur dioxide, carbon monoxide, nitrogen oxides and volatile organic compounds (VOC) are gaseous emissions that are also emitted. Gaseous emissions come from the burner-blower, exhaust fan, asphalt storage, storage silos, heating systems, loading and transportation.

Organic vapour (asphalt fumes) and its associated aerosol may also be emitted directly into the atmosphere as process fugitives during truck loading from the asphalt storage tanks or storage silos, and from the truck during transportation to the job site (OSHA, 2002). However, a lot more of the asphalt fumes are emitted during discharge of the already mixed asphalt from the truck to the road paving plants on the job site (WSDNR, 2001).

Each operation can be a potential source of pollution if controls are not employed. The impact of development projects (such as road construction and maintenance) on our physical environment and human well-being is attracting serious attention throughout the world (UNCED, 1992). Asphalt is at least 80% carbon, which explains its deep black colour. Black surfaces absorb significantly more electromagnetic radiation, and cause the surfaces of asphalt roads and highways to heat (Brian, 2007).In most of these sectors, radioactive materials and radiation generators are used. The activities of the solid mineral mining industries can cause increases in radiation to the environment during mixing and breaking of soils, rocks with crude oil for production of asphalt and other applied products which are radioactive encapsulates in the rocks are released into the air (Avwiri, 2011).The stages involved in processing and usage of asphalt with the constituent such as mixture contain element of radioactive, measurement of natural radioactivity in such environment is very important to determine the amount of change in natural background with time as a result of any radioactive release. The complete plant operation is monitored from the control house of the plant.

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However, the impact (gaseous and radioactive pollution) of Hot Mix Asphalt plants on the physical and socioeconomic environment of host communities in Nigeria is yet to be addressed. Monitoring of any release of radioactivity to the environment is important for environmental protection since effect of radiation on the human body depends on the type of radiation, dose, duration and the sensitivity of the part of the body exposed to it (UNSCEAR, 1988, Ike, 2008). Excessive exposure of construction plant worker's, inhabitants to ionizing radiation could result to health side effects. Background studies of radiation levels in these plants are lacking, hence the need to properly document the level of background ionizing radiation of these areas and provide a baseline for future studies and also estimate radiological burden on the construction plant worker's, populace and environment.

MATERIALS AND METHODS

Study Area:

The study area Port Harcourt is a cosmopolitan city with numerous networks of roads under construction. This was necessitated by the presence of oil and gas multinational firms which attracted migrations to the city. The roads under construction in turn attract construction and asphalt firms and the accompanied increase in radiation level which justifies this research. The use of a radiation survey meter to detect and measure the radiation absorbed dose rate is a rapid and insitu method of assessing the intensity of radiation but will give the exposure rate in a mixed field. A portable scintillating survey meter was used to examine the mean source of radiation emission at the Asphalt plants. The meter measures in mR/hr so as to assess minimum level of radiation. At each location, the meter was held 1.0 m above the ground level (Ademola, 2008), switched on and mR/hr unit was selected. Since, radioactivity process or measurement is statistical, three readings were taken on each point at five different strategic locations of each plant and the average of the readings was calculated.

The absorbed dose in mR/hr was converted to Sv/hr using the relation

$$1\ R = 0.11933\ Sv \quad (1)$$

The absorbed dose rate was determined using the conversion form

$$1\ R/hr = 1.1933 \times 10^{-1}\ Sv/hr, \quad (2)$$

The conversion factor to convert from R to Sv, k = 0.11933 Sv/R.

$$\delta = \text{counter reading} \times \text{conversion factor, } k\ (Sv/hr) \quad (3)$$

The annual dose from each location was determined using

$$D = \delta \times 24 \times 365.25\ Sv/yr \quad (4)$$

RESULTS AND DISCUSSION

Table 1: Plant 1-H & H Engineering Company

S/N	POSITIONS	Counter Readings in mR/hr				Equivalent dose rate mSv/yr
		Counter1	Counter2	Counter3	Average	
1	Entrance	0.0164	0.0178	0.0196	0.0179±0.0013	18.7
2	Generator house	0.0206	0.0281	0.0214	0.0234±0.0034	24.5
3	Heaped Gravel	0.0288	0.0268	0.0299	0.0285±0.0016	29.8
4	Control unit	0.0156	0.0170	0.0116	0.0147±0.0005	15.4
5	Mixing Plant	0.0248	0.0271	0.0285	0.0268±0.0015	28.0
Average					0.0223±0.0017	23.3

Table 2: Plant 2-AUC Constructing Company

S/N	Positions	Counter Readings in m R/hr				Equivalent dose rate (mSv/yr)
		Counter1	Counter2	Counter3	Average	
1	Security House	0.0194	0.0162	0.0173	0.0176±0.0013	18.4
2	Storage Bin	0.0220	0.0271	0.0265	0.0252±0.0023	26.4
3	New Coal tar	0.0195	0.0244	0.0253	0.0231±0.0025	24.2
4	Centre	0.0202	0.0248	0.0225	0.0225±0.0033	23.5
5	Mixing Section	0.0212	0.0268	0.0249	0.0243±0.0023	25.4
Average					0.0225±0.0023	23.5

Table 3: Plant 3 – Skemco Nigeria Limited

S/N	Positions	Counter Readings in m R/hr				Equivalent dose rate mSv/yr
		Counter1	Counter2	Counter3	Average	
1	Office	0.0190	0.0171	0.0223	0.0195±0.0021	20.4
2	Mixing Drum	0.0200	0.0236	0.0196	0.0211±0.0068	22.1
3	Concrete	0.0165	0.0141	0.0162	0.0156±0.0011	16.3
4	Old Asphalt	0.0210	0.0198	0.0144	0.0184±0.0043	19.2
5	Control unit	0.0150	0.0158	0.0147	0.0152±0.0005	15.9
Average					0.0180±0.0030	18.8

Table 4: Plant 4 – JCC Engineering Company

S/N	Positions	Counter Readings in m R/hr				Equivalent dose rate mSv/yr
		Counter1	Counter2	Counter3	Average	
1	Security House	0.0160	0.0171	0.0164	0.0165±0.0005	17.3
2	Office	0.0175	0.0152	0.0163	0.0163±0.0009	17.1
3	Heaped Gravel	0.0262	0.0250	0.0268	0.0260±0.0007	27.2
4	Generator house	0.0161	0.0180	0.0205	0.0182±0.0020	19.0
5	Control unit	0.0177	0.0176	0.0167	0.0173±0.0173	18.1
Average					0.0189±0.0009	19.8

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Table 5: Mean Exposure Rate Percentage Deviation from ICRP Standard

S/N	Plants	Mean Plant Exposure (mR/hr)	% Deviation from ICRP
1	H-H ENG.	0.0223	95.6
2	AUC	0.0225	97.4
3	SKEMCO	0.0180	57.9
4	JCC	0.0189	65.8

Tables 1-4 show the counter readings, absorbed dose rate and the total annual absorbed dose rate in each of the asphalt plant. The table shows the range of counter readings for different locations. The values obtained range from 0.0225±0.0023 to 0.0180 ± 0.0030 mR/hr for the exposure rate and 23.5 to 18.8 mSv/yr for dose equivalent. In Plant 1, a minimum value of 15.4 mSv/yr is obtained in the control unit while a maximum value of 29.8 mSv/yr is obtained around the Heaped Gravel with a mean value of 23.3 mSv/yr. In Plant 2 a minimum value of 18.4 mSv/yr is obtained in the Security House and a maximum value of 26.4 mSv/yr is obtained in Storage Bin with a mean value of 23.5 mSv/yr. In plant 3, a minimum value of 15.9 mSv/yr is obtained in the control unit and a maximum value of 22.1 mSv/yr is obtained in the Mixing Drum with a mean value of 18.8 mSv/yr. A minimum value of 17.1 mSv/yr is obtained around the Office in Plant 4 while a maximum 27.2 mSv/yr is obtained in the Heaped asphalt with a mean value of 19.8 mSv/yr.

The mean value of 0.0223± 0.0023 $mRhr^{-1}$ was recorded at the Plant 1, H-H Eng. which gives a 95% deviation from the ICRP recommended permissible limit of 0.013 $mRhr^{-1}$ for normal background levels, which indicates a significant elevation over the normal background radiation level. Measurements at Plant 2 AUC Construction in Table2, shows the radiation levels of values ranged between 0.0176± 0.0013 to 0.0252 ± 0.0023 $mRhr^{-1}$ with a mean value of 0.0225 ± 0.0023 $mRhr^{-1}$. This value is higher than the range of mean background exposure arte of 0.017 $mRhr^{-1}$ recorded in Denver, USA, which is an area of relatively high background radiation (USCF, 2002). These values are very close to the mean value for Plant 1 and are higher than the external background radiation for approximately,0.007-0.015 $mRhr^{-1}$, 0.014 $mRhr^{-1}$, 0.015 $mRhr^{-1}$ and 0.0099 $mRhr^{-1}$ obtained for individual area, Ikot Ekpene, Akwa Ibom State (Akpabio *et al*, 2005), Rivers State, Nigeria (Ebeniro and Avwiri, 1998), Conway and New-York City, USA respectively (Shapiro, 1981). Also a deviation of 97.4% of the mean value from the ICRP limit for normal background, which is a very significant elevation. The elevation of the background radiation is at a higher level in the sections of heaped gravel which could be attributed to its constituents of granite rock for its nature occurrence in the igneous formations (Bishop et al, 1999). Due to the presence of U-238, Th-232 and K-40, igneous rocks emit gamma photons (Shapiro, 1981) which are harmful radiations that can damage the chemicals in the living cell of a critical organ. From table 3, the results obtained show that the value ranges from 0.0152± 0.0005 to 0.0211± 0.0068 $mRhr^{-1}$ with a mean value of 0.0180± 0.003 $mRhr^{-1}$ recorded at the Skemco Nigeria limited plant. This was the minimum mean exposure rate recorded relative to the other surveyed plants and gives a deviation of 57.9% relative to the ICRP limit. The higher values are obtained from the mixing drum which could be linked to the fact that Bitumen extracted from oil and gas production contains naturally occurring radioactive elements (uranium and thorium) and their daughter products (Ra-226 and Ra-228). This mixing sections activities involved contain carbon and shale-potassium as an essential constituent, the mixture of hydrocarbons (bitumen) and granite which are basic raw materials has contributed to the elevation of the naturally occurring radionuclide which abounds in the earth crust and human body, and hence contributes to man the highest radiation dose from injection (Tchokossa et al, 1999).

According to the United States Environmental Protection Agency (www.epa.gov./radiation), surveys have shown that oil production may have very high Ra-226 concentration, and on disposal exposes the environment to associated radioactive contaminants. The plant 4 at the JCC company result presented in Table 4, shows values ranged from 0.0163$\pm$ 0.0009 to 0.0260$\pm$ 0.0007 mRhr^{-1}with a mean value of 0.0189$\pm$ 0.0009 mRhr^{-1}. Also this mean value gives a deviation of 65.8% relative to the ICRP limit. This relatively high count rate could be attributed to the fact that natural aggregates comes from different rock types –igneous, metamorphic and sedimentary rocks, these radionuclides produce an elevation in external radiation field to which all asphalt plant workers and human beings are exposed. These results show that the radionuclides are present naturally in the rocks (gravel) upon decay mixed with tar from crude oil as an aggregate (asphalt), which has extreme viscosity used as binder can be injurious to health and is cancerous to humans (IARC, 1980).

The estimated annual mean exposure rates for the workers for the Plants shown in the table above were found to be exceeded in Plant 1 and Plant 2 the recommended dose limit to the whole body of 20mS/yr for individual members of public from all man-made sources (ICRP, 2007).

Fig 1 shows explicitly that these measured values are higher than 0.013 mR/hr recommended by the International Commission for Radiological Protection (ICRP, 1990) as maximum permissible exposure limit for members of the public.

CONCLUSION

The radionuclide content in and around the asphalt processing plant has been studied. The result shows that the radiation exposure in the asphalt processing plant is high and hence there should be fear of hazard from radiation exposure. These exposure levels are far higher than the range of those measured on worldwide scale reported by other authors cited. The result indicates some level of impartation of the environment and a significant elevation from the standard background radiation level of 0.013mR/hr. These measured radiation exposure levels could yield some future radiological health side effects to the processing plant workers, the communities and the environment.

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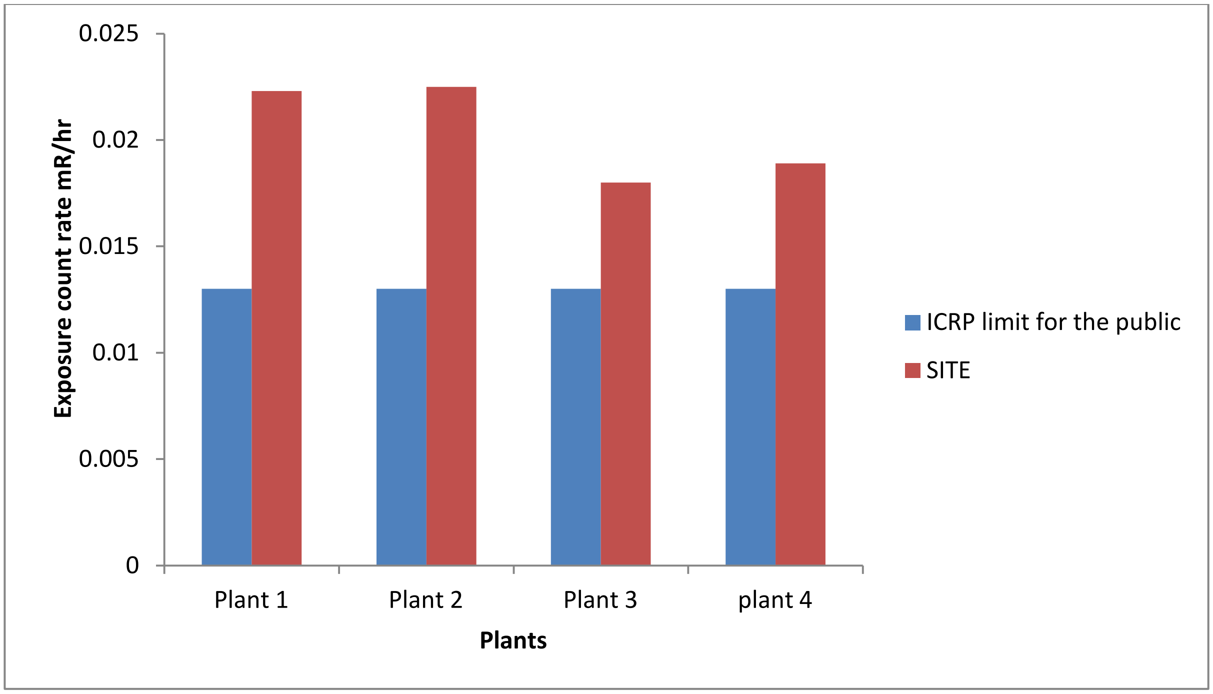

Fig 1: Measured count rate compared with count rate of standard

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