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Assessment Of Natural Radioactivity Concentration and Associated Radiological Hazards of Commercial Wall Paints and Plaster of Paris Cements Commonly used in Nigeria

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ABSTRACT: Plaster of paris (POP) is quick-setting gypsum plaster while certain commercial wall paints contains chemolumnicence materials. These building materials are most likely to emit radiation. Hence, the objectiveof this paper is to assess the natural radioactivity concentration and associated radioloical hazards of commercial wall paints and plaster of paris cements commonly used in Nigeria using standard measurement techniques. Data obtained reveals high average levels of the activity concentration (AC) of ^{40}K, ^{232}Th and ^{226}Ra were observed in emulsion paints (174.73, 56.98 and 58.18 Bq/kg) and POP (149.59, 64.51 and 63.49 Bq/kg) respectively. For oil paint, the mean result of the test elements ^{40}K, ^{226}Ra and ^{232}Th were 119.66, 37.86 and 44.66 Bq/kg respectively. From results, the study concluded that all investigated emulsion, oil paints and POP available in Nigeria have low level radioactivity concentrations which pose no significant radiological risk to users. However, the result from average excess lifetime cancer risk of these surface coatings presented higher value greater than the recommended limit. Consequently, this paper proposes constant monitoring of POP and raw materials used for paint production in Nigeria as well as quality assurance and control.

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Some of the raw materials deployed in industries for production of surface coatings have innate natural occurring radioactive materials (NORMs) in them base on their origin. The NORMs which include elements such as ^{40}K, ^{226}Ra and ^{232}Th are the main sources of both internal and external radiation exposure to individuals within any environment these surface coatings are used (Agbalagba *et al.* 2014). Furthermore, Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) also adds to internal and external radiation exposures as a result of human manipulation and modification of source materials used in the production of surface coatings additives. These surface coatings include paints, cements, Plaster of Paris (POP) also known as white cements, marbles, ceramic tiles; these products are deployed to enhance aesthetics of structures in residential buildings. External radiation exposures are usually generated through gamma emitting radionuclides; typical examples are ^{232}Th, ^{40}K, ^{226}Ra and their progenies. However, internal radiation exposures are majorly generated by ^{222}Rn, and marginally by ^{220}Rn emitted from surface coatings into the room (Joel *et al*, 2018). The radioactive decay of

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^{238}U into its progenies produce ^{226}Ra which is mostly used as reference isotope instead of ^{238}U. Hazardous gamma radiation which is an ionizing radiations are emitted from these radionuclides and discharged in the air, inhaled and absorbed in human lungs (Stoulos *et al*, 2003). Ionizing radiations, whether from surface coatings or other sources cause damage to human body or biological material by damaging the DNA in the body cells. Research have shown that continuous and prolong exposure to radiation can cause burns, hair loss, rise in risk of leukaemia and thyroid cancer (AAP, 1998). The degree of these effects is majorly dependent on radiation dose individual is exposed to overtime (AAP, 1998). Base on diverse sources of raw materials deployed in production of paint, white cement as well as other surface coatings, and the negative impact of ionizing radiation on biological molecules; it is essential to evaluate the concentration of natural radioactive in these surface coatings. Secondly, since most human beings spend about 80% of their time in houses, offices, etc which are mostly coated with assorted surface coatings (ICRP, 1999). The study of the concentration of radioactivity in paints and white cement allows one to understand, investigate and also explore possible radiological hazard inherent in the use of these surface coatings. This will enable regulatory agencies to develop policies, guidelines and standards for the safe management and production of paints and other surface coatings in Nigeria. Paints are referred to as pigmented semi-fluid materials that are usually applied on the surface of built structures to improve the aesthetics of that structure as well as to preserve and protect the structures (Echeweozo et al, 2022). Oil and emulsion paints are two major types of paints. On the other hand, white cements / Plaster of Paris (POP) cements are powdered cement-like material made from gypsum, Kaolin, and high-grade limestone used for coating of building walls and ceilings. In Nigeria, usually interior decorators combine paints and white cement for wall screed basically to ensure the magnificence of structures and houses not minding composition or the percentage of radioactive element present in the source material. The source material deploy in the making white cement and paints are blend of both inorganic and organic sources extracted from the earth crust that have some level of radioactivity elements present in it. (Echeweozo, and Igwesi, 2021). In Nigeria markets, there are many popular brands of surface coating products used for both interior and exterior decoration of built structures. However, there is little or no information on radioactive concentration of these popular brands of emulsion, oil and white cement which is the focal point in the current study. In the past, radiological hazard assessments have been carried out to evaluate specific activity or concentrations of radioactive elements in some building materials which include ceramics tiles, marbles, cement and sand (Joel *et al* 2018; Abojassim *et al*, 2014; Echeweozo, and Igwesi, 2021) however, limited work have been have done to assess the level of radioactive element present in the popular surface coating products found in Nigeria Market. Hence, the objective of this paper is to assess the natural radioactivity concentration and associated radioloical hazards of commercial wall paints and plaster of paris cements commonly used in Nigeria

MATERIALS AND METHOD

Sampling: Samples of oil and emulsion paints were collected from ten popular brands. Furthermore, four (4) different popular white cement samples were collected from different building materials' markets, located in the following populated cities; Lagos, Onitsha, and Kano Aba. This make the total number of the samples twenty (24). All the samples were deliberately selected because of their reputation and volume of sales as obtained from the marketers through oral interviews. Samples were collected from 10^{th} to 20^{th} December 2022. Paint samples were oven-dried for 12 hours at 35°C to fully change them to solid samples by removing the water content in these samples. The relatively low and longer time of temperature treatment was to circumvent ignition of samples since some of these paints contain some volatile material like turpentine. The white cement samples were also oven-dried for five (5) minutes to eliminate moisture. Each sample were individually pulverized into fine powdered and sieved using industrial grade sieve (10 µm) mesh size. Then, 300g of each sample was weigh out, package and labelled in a sterilized bottle (Marinelli beaker) hermetically wrapped to avoid 222Rn escape. Samples were carefully packed in a sealed carton and transported to Ahmadu Bello University, Nigeria precisely at environmental radiation laboratory, Center for Energy Research. Each sample had the following clearly labelled on the container body; date of acquisition, code name and net weights of sample. In the environmental radiation laboratory, each sample was kept for 28 days to enable radionuclides as well as their series progenies to reach secular equilibrium inside the container. After that, the concentration of radioactivity of ^{226}Ra, ^{232}Th, and ^{40}K in each of the samples were accurately measured and recorded.

Radiometric analysis: A 3' x 3' NaI(Tl) detector crystal which was connected to a photomultiplier tube optically was employed as the detector system. An 8 cm thick Lead material combined alongside an internal shield (made from a cadmium and copper material) was employed to reduce scattering effects of the background radiations. The following elements ^{137}Cs, ^{57}Co, ^{60}Co, and ^{241}Am, were used as a standard for Gamma radiations sources for the calibration of energy and full-energy photopeak efficiency. All necessary reference materials needed for verifying the calibrations were used in the course of these experiments. The calibration processes as published in IAEA/AL/314 report for the assessment of radioactive element in Food and Environment were stringently followed.

The ambient background counts of the test sample were measured using blank container of the same shape. Taking into account the long decay rates and also low photons emission of ^{238}U and ^{232}Th, their specific short-lived decay daughters in the samples were used in the determination of the respective AC after achieving secular equilibrium (Saleh *et al,* 2018; Echeweozo and Okeke 2021; Khandaker *et al,* 2019).

The mean values of gamma lines 351.9 and 295.1 keV from ^{214}Pb to 1764.5 and 609.3keV gamma lines from ^{214}Bi were applied in the determination of AC of ^{226}Ra. The AC of 232Th was ascertained with the average value of gamma lines 238.6 keV obtained from ^{212}Pb, 968.9 keV obtained from ^{228}Ac, 2614 and 583.1 keV from ^{208}Ti. The AC of ^{40}K was obtained directly from 1461 keV peak of the gamma ray spectrum. Each sample was measured twice and the average net count determined. All spectra collected were analyzed with Genie 2000 software.

In each of the sample, the AC of ^{40}K and ^{226}Ra, ^{232}Th in Bq/kg were estimated using Equation (1).

$$A_i\left(\frac{Bq}{kg}\right) = \frac{NA_i}{E_r x_M x T_s x Y_d} \qquad (1)$$

NA_i = counts (net peak) of the ith radionuclide, E_γ the absolute efficiency of the detector at energy, M = mass of the each of sample measured in kg, T_s = counting time measured in sec. Y_d= gamma decay intensity (absolute value) for the specific energy photopeak of the ith radionuclide.

During measurement, uncertainties and errors were defined as the standard deviation, σ and estimated using Equation 2. These uncertainties resulted from error in statistical counting, calibration error, area determination error.

$$\sigma = \sqrt[2]{\left[\frac{N_s}{T_s^2} + \frac{N_b}{T_b^2}\right]} \qquad (2)$$

Where N_s is the sample counts recorded in time T_S, N_b represents total background counts recorded in time T_b. The standard deviation $\pm 2\sigma$ which were recorded in count per seconds (*cps)* was converted into AC in Bq/kg. 1cps = 1 Bq/kg (Khandaker *et al,* 2019; Abuqubu 2016).

Equation 3 was used to obtain the lower limits of the detection (LLD) for for^{40}K, ^{226}Ra, and ^{232}Th as indicated in Table 1 (Abuqubu, 2016; Khandaker *et al,* 2019). The LLD of the detector system without test sample was also ascertained using equation 3 from the background count spectrum (Abuqubu, 2016). Table 1 gives LLD of the detector system

$$LLD = 4.65\,\frac{\sqrt{C_b}}{t_b}k \qquad (3)$$

where C_b represents the corresponding photopeak of background count. t_b represents background counts time (s) and k represents the conversion factor from counts per second (cps) to AC in Bq/kg. The overall experimental uncertainties found in these results caused by error in area measurement, statistical counting error, calibration error etc, was generally less than 6%.

Table 1: Represents the LLD values for radionuclide in Bq/kg using 82000 s as detection time, mass of 1 kg dry mass with confidence levels α=5%, β= 5%

LLD(Bq/kg)	Radionuclides
0.01	^{40}K
0.5	^{228}Ra
0.01	^{226}Ra
0.02	^{214}Pb
0.13	^{212}Pb
0.34	^{214}Bi

Values below LLD were considered to be below detection limit (BDL) of the detection system

RESULTS AND DISCUSSION

Radioactivity concentration (A_i) Assessment of hazard and radiological exposure risk: The calculation of hazard was carried out to determine the radiation exposures levels of these surface coatings. These evaluated radiation exposure levels were further compared with the recommended boundaries for of public health and environmental protection. Activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th calculated for all paints and white cements brands were shown in Table 2. Where results show that that maximum activity concentrations were seen in samples of white cement. However, emulsion paints were gave higher radioactivity concentrations when compared to oil paints. From the studied samples, the deviation of NORMs resulting from the mineral composition of raw materials deployed in the manufacturing of these paints and white cements were determined. Emulsion paints gave average values of ^{40}K (174.73 ±

5.18Bq/Kg), ^{226}Ra (58.18 ± 2.51 Bq/Kg) and ^{232}Th (56.98 ± 2.32 Bq/Kg), while oil paints gave average values of ^{40}K (119.66 ± 3.69 Bq/Kg), ^{226}Ra (44.66 ± 2.39 Bq/Kg) and ^{232}Th (37.86 ± 1.85 Bq/Kg). White cements gave average values of ^{40}K (149 .59 ± 3.47 Bq/Kg) ^{226}Ra (63.49 ± 3.66 Bq/Kg) and ^{232}Th (64.51 ± 3.56 Bq/Kg). It was generally observed that average values for emulsion paints and white cements gave radioactivity concentrations marginally above the recommended values in terms of ^{226}Ra and ^{232}Th as stipulated in (UNSCEAR, 2002). This portends a caution indicator for paint's handlers and regulatory agencies. Distribution of activity concentration in all investigated samples were uneven.

Therefore, statistical (descriptive) analysis was additionally carried out to evaluate the degree of variation of concentrations of ^{40}K, ^{226}Ra and ^{232}Th in paints and white cement samples.

Table 2: Concentration of naturally occurring radioactive materials (NORMs) in commercial paints and Plaster of Paris used in Nigeria

Paint Brand	**Paint type**	**Product code**	**Location**	**^{40}K ± error (Bq/Kg)**	**^{226}Ra ± error (Bq/Kg)**	**^{232}Th ± error (Bq/Kg)**
Dulux	Emulsion paint (EP)	K1	Onitsha	198.47 ± 6.68	57.85 ± 0.71	49.83 ± 1.35
	Oil paint (OP)	K2		145.42 ± 4.55	54.65 ± 0.67	38.44 ± 1.17
Berger	EP	M1	Lagos	184.44 ± 4.91	82.14 ± 4.57	63.22 ± 2.35
	OP	M2		127.61 ± 3.70	50.66 ± 3.63	41.69 ± 0.47
Mayer	EP	N1	Kano	195.58 ± 6.75	51.66 ± 3.63	89.61 ± 2.47
	OP	N2		139.98 ± 4.39	39.43 ± 3.27	28.97 ± 0.82
Saculux	EP	O1	Aba	161.51 ± 3.12	67.92 ± 3.43	77.23 ± 3.70
	OP	O2		123.39 ± 3.50	37.87 ± 1.15	37.45 ± 1.61
International	EP	P1	Lagos	185.60 ± 4.29	58.29 ± 2.47	46.31 ± 1.61
	OP	P2		122.77 ± 3.30	35.97 ± 2.47	45.79 ± 2.59
Premium	EP	Q1	Onitsha	133.19 ± 3.00	58.05 ± 4.07	25.72 ± 1.33
	OP	Q2		89.12 ± 2.25	48.22 ± 3.83	18.72 ± 0.23
Portland	EP	R1	Lagos	147.90 ± 6.84	51.36 ± 1.04	56.06 ± 1.25
	OP	R2		109.02 ± 4.04	43.32 ± 2.38	36.78 ± 4.79
Eagle	EP	S1	Kano	193.74 ± 6.33	62.45 ± 2.05	52.79 ± 2.45
	OP	S2		136.11 ± 4.02	51.74 ± 3.15	23.37 ± 2.34
Clover	EP	T1	Aba	197.62 ± 5.77	50.72 ± 1.03	38.13 ± 1.19
	OP	T2		103.03 ± 4.11	45.59 ± 2.11	22.00 ± 2.34
Premier	EP	U1	Onitsha	149.28 ± 4.10	41.40 ± 2.12	70.92 ± 5.57
	OP	U2		100.18 ± 3.08	39.15 ± 1.03	57.24 ± 2.14
Mean value for EP				**174.73 ± 5.18**	**58.18 ± 2.51**	**56.98 ± 2.32**
Mean values for OP				**119.66 ± 3.69**	**44.66 ± 2.39**	**37.86 ± 1.85**
Plaster of Paris (POP)	Portman brand	W1	Lagos	147.90 ± 3.84	75.36 ± 5.04	50.06 ± 3.25
	JK brand	W2	Kano	139.02 ± 3.10	63.32 ± 3.38	76.78 ± 3.79
	Dangote brand	W3	Onitsha	158.98 ± 3.62	59.41 ± 3.22	83.00 ± 4.26
	ABS brand	W4	Aba	152.09 ± 3.32	55.85 ± 2.99	47.67 ± 2.80
Mean values for Plaster of Paris				**149 .59 ± 3.47**	**63.49 ± 3.66**	**64.51 ± 3.56**
World average (UNSCEAR, 2000)				**412.00 ± 0.00**	**45.00 ± 0.00**	**32.00 ± 0.00**

The Radium Equivalent Activity: Radium equivalent activity (Ra_{eq}) describes the combined specific activities of (^{232}Th, ^{226}Ra and ^{40}K). It is applied in the assessment of external exposure to the public population. It was calculated with Equation (4) (UNSCEAR, 2013; El-Taher *et al,* 2010) .

$$Ra_{eq} = 0.077A_K + A_{Ra} + 1.43A_{Th} \qquad (4)$$

Where A_{Ra}, A_k, A_{Th} gives specific activities or radioactive concentration of 226Ra, 40K and 232Th respectively in Bq/kg. Radium equivalent activity represents the external gamma dosage linked to any radioactive material.

Radium equivalent activity provides combined activity concentrations of ^{232}Th, ^{226}Ra and ^{40}K in any radioactive material and this activity must not be greater than 370 Bqkg^{-1} to maintain the minimum permissible external dose of 1.5 mGy/yr (Joel *et al*, 2018; (Echeweozo and Okeke, 2021; Jibiri and Emelue, 2009). From Table 3, the average values of radium equivalent in emulsion paints, oil paints and Plaster of Paris are 153.11 Bq/Kg, 108.01 Bq/Kg and 167.05 Bq/Kg respectively. Fig 1 clearly displayed higher radium equivalent activities in white cement than in oil and in emulsion paints. This gives higher natural radioactivity in white cements when compared to paints.. However, results from radium equivalent values for emulsion paints, oil paints and white cements were lower than the threshold value of 370 Bq/Kg regarded as the maximum admissible value (UNSCEAR, 2013; UNSCEAR, 2008). This means that all studied samples do not foretell major radiological hazard to users of these surface coatings.

Table 3: Radiological hazard and indoor exposure risk Assessment of commercial paints and Plaster of Paris used in Nigeria.

Product code	Radium equivalent activity index Raeq (Bq/Kg)	Absorbed dose rate D_{in} (nGy/h)	Annual effective dose rate AEDE (indoor) (mSv)	Excess lifetime cancer risk (*E*-03) indoor	Internal hazard index H_{in} (mSv/y)	External hazard index H_{ex}(mSv/y)	Gamma index Iγ (Bq/Kg)
K1	144.39	124.11	0.61	2.14	0.55	0.39	0.51
K2	120.82	104.34	0.51	1.79	0.47	0.33	0.42
M1	186.75	160.05	0.79	2.77	0.73	0.50	0.65
M2	120.10	102.80	0.50	1.75	0.46	0.32	0.42
N1	194.86	152.98	0.75	2.63	0.65	0.53	0.69
N2	91.63	79.48	0.39	1.36	0.33	0.25	0.32
O1	190.80	160.52	0.78	2.73	0.70	0.52	0.67
O2	100.92	86.03	0.42	1.47	0.37	0.27	0.35
P1	138.80	119.60	0.59	2.07	0.50	0.37	0.49
P2	110.90	97.20	0.48	1.68	0.53	0.30	0.39
Q1	105.08	92.49	0.45	1.58	0.44	0.26	0.37
Q2	81.72	72.17	0.35	1.23	0.35	0.22	0.28
R1	142.90	120.90	0.59	2.07	0.52	0.31	0.50
R2	104.31	89.14	0.44	1.54	0.40	0.28	0.36
S1	152.86	131.24	0.64	2.24	0.58	0.41	0.54
S2	95.64	84.33	0.41	1.44	0.40	0.26	0.33
T1	120.46	104.61	0.51	1.79	0.46	0.33	0.43
T2	84.98	74.49	0.37	1.30	0.35	0.23	0.30
U1	154.31	128.19	0.63	2.21	0.26	0.41	0.54
U2	128.72	107.15	0.53	1.86	0.45	0.35	0.45
Mean	**128.54**	**109.59**	**0.54**	**1.88**	**0.46**	**0.34**	**0.45**
W1	158.33	72.04	0.35	1.23	0.63	0.57	0.55
W2	183.82	82.73	0.41	1.44	0.67	0.58	0.64
W3	190.34	85.62	0.45	1.47	0.67	0.58	0.67
W4	135.73	61.74	0.30	1.05	0.52	0.46	0.48
Mean	**167.05**	**75.53**	**0.37**	**1.29**	**0.62**	**0.55**	**0.58**

Table 4: Discriptive statistical analysis of radioactivity concentration of NORMs in Paints and Plaster of Paris samples

	EP			OP			Plaster of Paris		
Statistical Variables	^{40}K	^{226}Ra	^{232}Th	^{40}K	^{226}Ra	^{232}Th	^{40}K	^{226}Ra	^{232}Th
Max	198.47	82.14	89.61	145.42	54.65	57.24	158.98	75,36	83.00
Min	133.19	41.40	25.72	89.12	35.97	18.72	139.02	55.85	47.67
Mean	174.73	58.18	57.98	119.66	40.66	37.86	149.00	65.61	65.33
SD	24.41	11.12	18.92	18.66	6.53	11.93	8.34	8.48	18.12
SEM	7.72	3.51	5.98	5.90	2.06	3.77	4.17	4.24	9.06
CV%	0.14	0.19	0.33	0.15	0.14	0.34	0.05	0.13	0.28
Skewness	-0.63	0.91	0.14	-0.24	0.15	0.33	-0.33	1.27	0.08
Kurtosis	2.99	6.06	4.14	3.22	2.88	4.06	13.87	15.15	8.16

Standard deviation (SD); Standard error of the mean(SEM); Coefficient of Variance (CV)

Hazard Indices Assessment: External radiation exposure which is the total radiations dose due to the presence of, ^{232}Th, ^{226}Ra and ^{40}K is evaluated by external hazard index, H_{ex}. It is evaluated with Equation (5) (Sharma *et al*, 2016).

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (5)$$

The internal exposure gives exposure from radon and its series progenies. It was calculated with the internal hazard index, (H_{in}) as displayed in Equation (6) (El-Taher *et al*, 2010).

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (6)$$

External and internal hazard indices are degrees of hazardous effect from radon and its progenies to human respiratory organs. It was calculated with Equation 5 and 6 respectively. H_{ex} and H_{in} of nontoxic surface coatings should not be greater than one (Sharma *et al*, 2016; El-Taher *et al*, 2010). The average values of internal hazard index for white cements and paints were 0.62 mSv/y and 0.49 mSv/y respectively.

In Fig 2 the External and Internal hazard index were compared. Consequently, the internal hazard index gave lower values with respect to the external hazard index. Generally, the internal hazard index values obtained from investigated samples gave values below one, which is the recommended limit. This means that the external and internal hazard indices of investigated samples were within a safe region (UNSCEAR, 2008; UNSCEAR, 2013; Senthilkumar *et al*, 2014).

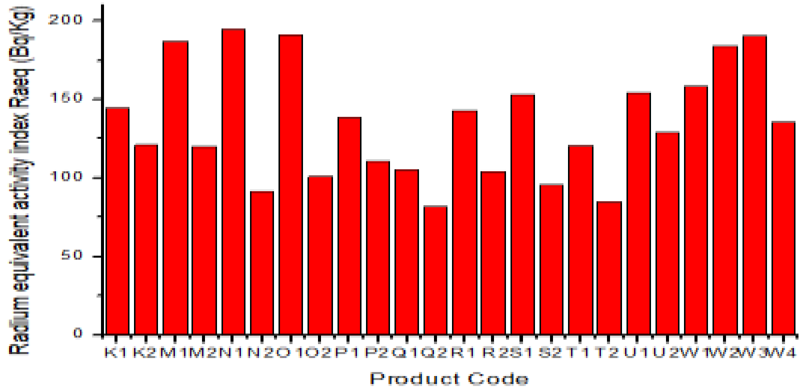

Fig 1: Represents the variation in Radium equivalent activity index for all the samples

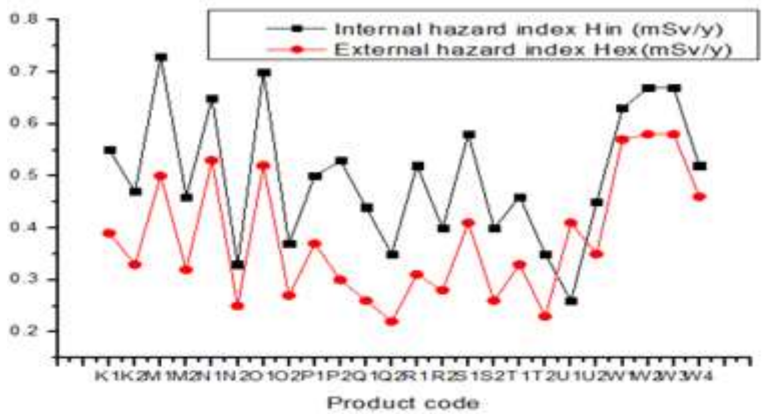

Fig 2: Comparison between Internal and External hazard index of the paints and Plaster of Paris samples.

Table 5: Contrast in the mean radioactive contents of paints and Plaster of Paris alongside other building materials deployed in the building houses in Nigeria and their mean radium equivalent values.

Material	**No. of samples**	**Mean radioactivity concentration (Bq/kg)**			**Mean Radium equivalent (Bq/kg)**	**Reference**
		^{40}K	^{226}Ra	^{232}Th		
Sand (Nigeria)	5	60.55	12.07	13.02	35.35	(Ugbede , 2020)
Ceramics Tiles (China)	-	530.0	55.5	126.9	277.77	(Lu X *et al*, 2014)
Ceramics Tiles (Nigeria)	-	514.7	61.1	70.2	201.12	(Olarinoye *et al*, 2014)
Cement (Dangote)	1	289.7	33.9	32.5	102.68	(Olarinoye *et al*, 2014)
Cement (BUA)	1	295.8	46.3	32.5	115.68	(Olarinoye *et al*, 2014)
Cement (UNICEM)	1	297.5	43.3	30.1	109.25	(Olarinoye *et al*, 2014)
Wood	5	9	6	1.2	8	(Brgido *et al*, 2008)
Blocks (Ave)	32	430.70	31.85	38.65	113.5	(Brgido *et al*, 2008)
Emulsion Paint	10	174.73	58.18	56.98	153. 11	Present study
Oil paint	10	119.66	44.66	37.86	108.01	Present study
Plaster of Paris	4	149 .59	63.49	64.51	167.05	Present study

Assessment of absorbed dose rate: Absorbed dose rate (D) measured in (nGy/h) for indoor air was calculated with Equation 7

$$D = 0.0417A_k + 0.462A_{Ra} + 0.621A_{Th} \qquad (7)$$

The gamma absorbed dose rate of any material that is safe must be lower than 70 nGy/h which is the recommended average value (Abojassim *et al*, 2014; NEA-OECD, 1979). Results show that, the maximum value of the absorbed dose rate was gotten from paints with average value of 109.59 $nGyh^{-1}$, while white cement gave an average value of 75.53 $nGyh^{-1}$. It is significant to note that for all samples few of the estimated results of absorbed dose rate gave values higher than 55 $nGyh^{-1}$ and 84 $nGyh^{-1}$ by which are recommended limits by UNSCEAR, (2000) and UNSCEAR, (1998) respectively.

Assessment of annual effective dose exposure: Annual effective dose exposure (AEDEs) for outdoor exposure and indoor exposure were calculated by applying Equations 8 and 9 (UNSCEAR, 2013).

$$AEDE_{outdoor}(mSv) = D\ x\ 8760\left(\frac{h}{y}\right) x\ 0.7\ x\ 10^{-6}\ x\ 0.2 \quad (8)$$

$$AEDE_{indoor}(mSv) = D\ x\ 8760\left(\frac{h}{y}\right) x\ 0.7x10^{-6}\ x\ 0.8 \quad (9)$$

Were D is measured in $nGyh^{-1}$. 0.7 in $SvGy^{-1}$ gives the conversion factor from absorbed dose in air to effective dose received by adults. 0.2 and 0.8 in Equation 8 and 9 are time fraction spent outdoors and indoors also known as occupancy factors (UNSCEAR, 2013) The global range of annual effective dose is between 0.3 - 0.6 mSv with an average of 0.48 mSv. For human infants the value is between 10% and 30% higher than the adults value (Ugbede and Echeweozo, 2017). This resulted from the increase in the value of conversion factor from absorbed dose in air to effective dose. In this study, the estimated indoor annual effective dose exposure values gave mean value of 0.54 mSv for paints samples and 0.37 mSv for white cements samples. These values were considerably usual and do not constitute significant hazard or risk.

Excess life time cancer risk assessment: Excess lifetime cancer risk (ELCR) which gives extra possibility of an individual having cancer during his or her lifetime due to exposure to different kinds of radiations. It was estimated with Equation (10) (Abojassim *et al*, 2014; UNSCEAR, 2013).

$$ELCR_{in} = AEDE_{in}\ x\ DL\ x\ RF \quad (10)$$

Where AEDE represents annual effective dose exposure, DL represents the duration of life which was giving as 70 years (UNSCEAR, 2013) and RF is (0.05 Sv^{-1}) which gives the fatal cancer risk per Sv.

An average value of 1.90×10^{-3} for paints and 1.30×10^{-3} for white cements were obtained from the deduced results. These values were higher than the estimated world average of 0.29×10^{-3} (Jibiri *et al*, 2014; Echeweozo and Okeke, 2021; Ugbede and Echeweozo, 2017). This implies that constant and prolong exposure to this paints and white cements portent danger because people have higher probability of having cancer over a life time when constantly exposed to these paints and white cements over a long period of time.

Gamma index (I_γ): Gamma index is the gamma-radiation hazard related to natural radionuclide in a sample. The gamma index (I_γ) is assessed using Equation (11) (Abuqubu, 2016).

$$I\gamma = \left(\frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_k}{3000}\right) Bqkg^{-1} \quad (11)$$

Results of (I_γ) were also displayed in Table 3. The average values for paints and white cement were 0.45 $mSvy^{-1}$ and 0.58 $mSvy^{-1}$ respectively which is below the world average of 1 $mSvy^{-1}$. In this research, investigated gave comfortable level of gamma index value. However, it is greatly advised that gamma emission dose of all decorative surface coatings like paints, gray cements, white cement, tiles and marbles should not go beyond 1 $mSvy^{-1}$ when compared with outdoor background values.

Conclusion: In this study, a baseline information has been established on natural radioactivity status and inherent radiological risk from paints and POP materials available in Nigeria. The study also compared the value of activity concentrations of NORMs POP and paints with values of activity concentration obtained for other materials used for building. Results and activity concentration values from this study shall serve as reference material for monitoring of paints and POP products used in Nigeria. It will motivate regulatory agencies to monitor the radiological hazards of these surface coatings.

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