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ESTIMATION OF INDOOR AND OUTDOOR EFFECTIVE DOSES FROM GAMMA DOSE RATES OF RESIDENTIAL BUILDINGS IN EMELOGU VILLAGE IN RIVERS STATE, NIGERIA

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ABSTRACT: *The health implications of exposure to radon gas (^{222}Rn) by humans in the indoor environment is a major public concern worldwide. The aim of this paper is the measure the indoor and outdoor exposure rate at different heights and determines the annual effective dose and lifetime cancer risk of residents of six different settlements in Emelogu Community of Odua /Abua local Government Area of Rivers State. In-situ measurements of indoor and outdoor exposure rate of six different settlements were done using a well calibrated radiation Alert-100. The highest indoor and outdoor exposure rate of 0.0237 ± 0.014mRh^{-1} and 0.0181±0.002mRh^{-1} respectively were recorded in mud houses. The indoor annual effective dose ranges from 0.54mSvy^{-1} for concrete not plastered houses to 0.949mSvy^{-1} recorded in mud houses. Resulting average of the annual effective dose is 1.06 mSvy^{-1}, which is large as compared to the worldwide average of the annual effective dose 0.48 mSv. Whereas outdoor effective doses calculated ranges from 0.204mSvy^{-1} in burnt mud house to 0.253mSvy^{-1} recorded around mud houses which results in total mean outdoor effective dose of 0.48mSvy^{-1}. . Estimated excess lifetime cancer risk (ELCR) from indoor AEDE ranges from 1.90 x 10^{-3} to 3.32 x 10^{-3} recorded in CNP and MD respectively and ELCR from outdoor ranges from 0.715x 10^{-3} to 0.887x 10^{-3} recorded burnt in mud house. Resulting average of the excess lifetime cancer risk is 4.21 x 10^{-3}, which is large as compared to the resulting worldwide average 0.29 x 10^{-3}. The reduction coefficients were obtained by taking the ratio of the indoor and outdoor dose rates. This paper shows that outdoor dose rates decreased as the measurement height increased, whereas the indoor dose rates increased as the height increased and that indoor dose rates at the centers of each houses were lower than other locations on this same room. Therefore residents should spend more time at the centers of their homes and also use smaller windows to reduce their exposure.*

KEYWORDS: Excess lifetime cancer, Radiation-Alert, Emelogu, Effective dose, Exposure rate

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INTRODUCTION

The natural terrestrial gamma radiation dose rate is an important contribution to the average dose rate received by the world's population. Estimation of the radiation dose distribution is important in assessing the health risk to a population and serve as the reference in documenting changes to environmental radioactivity in soil due to anthropogenic activities (Senthilkumar *et al.*, 2010). Human beings are exposed outdoors to the natural terrestrial radiation that originates predominantly from the upper 30 cm of the soil (Senthilkumar *et al.*, 2010). The cosmic sources include radiations from extra terrestrial origin. Terrestrial background ionizing radiations are essentially derived from ^{40}K, and radionuclides belonging to ^{238}U and ^{232}Th series present in the earth crust (Karunakara et al (2014), UNSCEAR (2000). These radionuclides are common in the rocks and soil, in water, plants and air that make up our planet and in our building materials (Gupta *et al*., 2010), UNSCEAR (2000). The variation of terrestrial radiation is typically larger than that of cosmic radiation (Karunakara *et al*., 2014).

The health impact of exposure to radon (^{222}Rn), inhalation by humans in the indoor environment isa major public concern worldwide. The exposure is due to emanation ofradon gas from the decay chains of radioactive thorium (^{232}Th) and uranium (^{238}U), which are present in soil layers (Mohammed et al., 2014) and indoor construction materials especially granite (Kabeissi et al., 2013). The 238U decay chain contains the most important radioactive element such as protactinium (^{234}Pa), radium (^{226}Ra), radon (^{222}Rn) and bismuth (214Bi). The element 226Ra, with a half-life of 1600 years, decays to 222Rn by emitting α- particles followed by γ-radiation. This means that the concentrated in any home space. The element 222Rn is the most important radioactive element due to its properties as an emitter of α-particles with energy levels of 5.48Mev, its half lives of 3.82 days and its ability to penetrate through the ground and structural materials to reach the outdoor atmosphere and indoor spaces (Muhammed et al., 2014).

The dose rate depends on the geology and geographical conditions and appears at different levels in the soil of each region of the world (Abusini et al., 2007; Mitiullah et al., 2004; Ali et al., 2014). Higher radiation levels are associated with igneous rocks such as granite and lower levels with sedimentary rocks. However some shale and phosphate rock have relatively high content of those radionuclides (Tzortzis and Tsertos, 2004). Radon enters a home through the lowest level in the home trhat is incontact with open ground such as cracks in solid foundations, construction joints, cracks in walls, gaps in suspended floors, gaps around service pipes, cavities inside walls and the water supply (USEPA, 2012). Radon concentrations in the same location may differ by a factor of two over a period of one hour. Also the concentration in one room of a building may be significantly different from the concentration in an adjoining room (USPHS, 19901). If a material rich in uranium lies close to the surface of the earth , there can be high radium exposure hazards (Grupta, 2010). Soil is an important environmental material used for marking bricks and building raw materials. Previous works show that dwelling with mud wall registered high value of radon than dwellings with brick and Portland cement (Arif et al., 2014; Ashok et al., 2012; Sathish et al., 2009; Sivakuma, 2010; Rakesh et al., 2006).

Researchers have revealed that residents spend more time in houses, offices and schools than in outdoor activities at work and school and playing outdoors. The outdoor activities add up to approximately 5 to 6 hours per day. For the rest of time, approximately 18-19 hours per day, residents stay indoors for activities such as sleeping, working, studying and taking meals. The indoor radiation environment differs from outdoors. The exposure doses of residents are evaluated using the reduction coefficient for radiation levels in houses and buildings. The International Atomic Energy Agency (IAEA) , provides the reduction coefficient which is the ratio of indoor and outdoor ambient dose equivalent rates for evaluating indoor exposure doses (Masashi et al., 2014).

The residents' exposure dose rate is evaluated using the outdoor and indoor dose rates and the number of hours of outdoor activity. The provided reduction coefficient is 0.4 with a range of 0.2-0.5 for wooden houses; for concrete and brick houses, the coefficient is 0.2 with a range of 0.04-0.4. These values are evaluated based on European house style and radioactive contamination (IAEA, 2000). To estimate the residential dose due to gamma dose rate, it is necessary to study the radiation environment and reduction coefficient in Emelogu houses. In this study the effective dose and excess lifetime cancer risks due to gamma dose rate of residential buildings in Emelogu Community of Abua/Odua Local Government Area of Rivers State, was estimated from the indoor and outdoor exposure dose rates. There result of this study will serve as a baseline data since there have been no radiological work done in the area.

MATERIALS AND METHODS

The study area is Emelogu-Odual in Abua/Odual Local Government Area which lies between longitudes 6^{o} 24’ and 6^{o} 50’ latitudes 4^{o} 40’ and 5^{o} 55’ (Figure 1). This area is located at central part of the Niger Delta. Abua/Odual Local Government Area is divided in two major parts Abua and Odual by the Orashi River flowing in the north – south direction. The Odual axis is full of Saka-Creek distributries forming streams and fresh water swamps. The area falls within the coastal belt dominated by low lying coastal plains which structurally belong to the sedimentary formations of the recent Niger Delta (Short and Stauble, 1967). Its surface geology consists of fluvial sediments. The area is characterized by swamp tidal basins, mud flats and sandbars, composed of gentle rolling coastal plains and low lands.

A digilert-100 nuclear radiation monitoring meters containing a Geiger- Muller tube capable of detecting α- particles β-particles, γ- rays and x-rays within the temperature range of -10^{0}C to 50^{0}C were used to measure the indoor and outdoor exposure rates. The digilert -100 nuclear radiation monitor was characterized for environmental measurement. The tube of the of the radiation meter was raised to the standard height of 1.0m above the ground (Ononugbo, *et al.*, 2011) with its window facing the site to be measured and then vertically downward. The GM-tube generates a pulse of electrical current each time radiation passes through the tube and causes ionization and each pulse is electronically detected and registered as a count. In –situ measurement of background ionizing radiation was done in six different types of residential houses: mud house(MD), burnt mud house(BMD), dirty block house (DB), concrete plastered but not painted (CPNP) and Concrete plastered, painted (CPP) and concrete not plastered(CNP).

Readings were obtained between the hours of 1300 and 1600 hours, because the exposure rate meter has a maximum response to environmental radiation within these hours (Ononugbo *et al.*, 2011). For each location two measurements spanning over 2 minutes were carried out and these measurements were then averaged to single value. Data obtained for the indoor and outdoor exposure rate in mR/h was converted into absorbed dose rate nGy/h using the conversion factor (Muhammad *et al.*, 2014):

$$1\ \mu R/h = 8.7\ nGy/h = 8.7 \times 10^{-3} \mu Gy/(1/8760)yr = 76.212 \mu Gyy^{-1} \quad \ldots\ldots\ldots\ldots\ldots..(1)$$

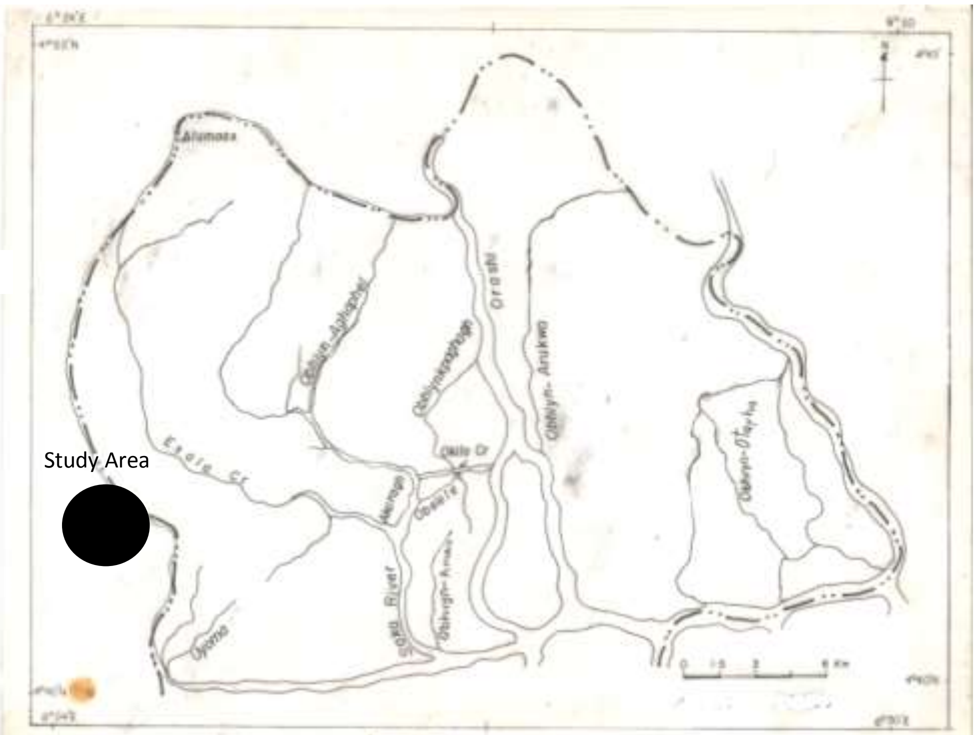

FIG. 1·2, DRAINAGE MAP OF STUDY AREA

RESULT AND DISCUSSION

Indoor and outdoor Radiation environment

The indoor exposure dose rates were measured at the centers of different residential houses and at the several locations in the rooms at varying heights using hand held radiation survey meters. Outdoor dose rates were also measured outside/surrounding of those residential houses at Emelogu Community of Odua/Abua Local Government. The indoor dose rates depended on the location in the houses and the type of residential houses with the lowest appearing at the center of each of the houses. Table 1 shows the result of indoor and outdoor measured dose rates and the calculated effective doses and excess lifetime cancer risk due to exposure to indoor and outdoor radiations. Table 2 is the comparison of the mean dose rates of the various residential houses and their associated excess lifetime cancer risk. The indoor exposure dose rate is plotted versus the outdoor exposure dose rate in Figure 1. The highest indoor and outdoor exposure dose rate of 0.0237±0.140mRh^{-1} and 0.0181±0.002mRh^{-1} respectively were measured in mud houses while the least indoor exposure rate of 0.0134±0.001 mRh^{-1} was recorded in concrete not plastered (CNP) houses. The indoor and outdoor exposure dose rates of all the sampled residential houses exceeded the ICRP, 2003 standard value of 0.013mRh^{-1}.

The indoor and outdoor dose rates in six different residential houses in Emelogu Community were measured at several heights to observe the height dependence of dose rates. The heights cover 0.5 to 3m in all the sampled houses. The outdoor dose rates decreased with increasing height while indoor dose rates increased with increasing height. This could be attributed to different shields around the houses but further investigation is required. It was observed that dose rates at the centers of each house were lower than other locations of the same house.

The Annual Effective Dose Equivalent (AEDE)

Absorbed gamma dose rates were used to calculate the annual effective dose equivalent (AEDE) received people living in the surveyed houses and its environment. For calculating AEDE we have used dose conversion factor of 0.7Sv/Gy and the occupancy factor for indoor and outdoor was 0.75 and 0.25 respectively. Occupancy factor for indoor and outdoor situation were calculated based upon interviews with peoples of the area. People of the study area spent almost 6h in outdoor and 18hours in indoor environment. The annual effective dose is determined using the following equations (Muhammad et al., 2014).

$\mathrm{AEDE}_{\mathrm{outdoor}}$ (mSvy^{-1}) = Absorbed dose rate (nGy/h) × 8760h ×0.7Sv/Gy × 0.25 (2)

$\mathrm{AEDE}_{\mathrm{Indoor}}$ (mSvy^{-1}) = Absorbed dose rate (nGy/h) × 8760h ×0.7Sv/Gy × 0.75 ………. (3)

In the UNSCEAR, 1993 report, the committee used o.7Sv/Gy for the conversion coefficient from absorbed dose in air to effective dose received by adults. Estimated values of annual effective dose equivalent for indoor AEDE ranges from 0.54mSv/y for concrete not plastered house to 0.949 mSv/y recorded in mud houses. Resulting average annual effective dose is 1.06mSv/y, which is large compared to the worldwide average of 0.48mSv (Mohammad et al., 2014).

Excess Lifetime Cancer Risk (ELCR)

Based upon calculated values of AEDE, excess lifetime cancer risk (ELCR) is calculated using equation (4):-

ELCR = AEDE × Average duration of life (DL)× Risk factor (RF) -----------------(4)

Where AEDE, DL and RF is the annual effective dose equivalent, duration of life(70 years) and Risk factor or fatal cancer risk per sievert. For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses values of 0.05 for the public exposure. Estimated excess lifetime cancer risk (ELCR) around the quarry site ranges from 0.81×10^{-3} to 1.09×10^{-3} with mean value of 0.91×10^{-3} while for plastic industry, it ranges from 0.84×10^{-3} to 0.95×10^{-3} with mean value of 0.88×10^{-3} . ELCR calculated for paint industry ranges from 0.74×10^{-3} to 1.26×10^{-3} with mean value of 1.022×10^{-3} while that from road construction site ranges from 0.74×10^{-3} to 1.07×10^{-3} with mean value of $0.90 \times 10^{-3.}$ Resulting average of the excess lifetime cancer risk is 3.71×10^{-3} which is higher than the standard value of 0.29×10^{-3} (Taskin et al., 2009).

Table 1: Indoor and Outdoor Exposure Rate and Effective dose for six Different Residential Houses.

Sample Site Code	Indoor Exposure Rate (mRh-1)	Absorbed Dose rate (nGyh-1)	Effective Dose (mSvy-1)	ELCR × 10-3	Outdoor Exposure rate mRh-1	Absorbed Dose rate (nGyh-1)	Effective Dose (mSvy-1)	ELCR × 10-3
CPP1	0.0155±0.006	134.85	0.620	2.17	0.0146±0.003	127.02	0.195	0.683
CPP2	0.0157±0.004	136.59	0.628	2.20	0.0164±0.004	142.68	0.219	0.767
CPP3	0.0151±0.002	131.37	0.604	2.11	0.0163±0.004	141.81	0.217	0.760
CPP4	0.0161±0.003	140.07	0.644	2.25	0.0167±0.001	145.29	0.223	0.781
CPP5	0.0147±0.003	127.89	0.588	3.50	0.0154±0.004	133.98	0.205	0.718
Mean	0.0154±0.003	134.15	0.617	2.45	0.0159±0.01	138.16	0.212	0.742
CPNP1	0.0151±0.004	131.37	0,604	2.11	0.0174±0.002	151.38	0.232	0.812

CPNP2	0.0127±0.001	110.49	0.508	1.78	0.0162±0.002	140.94	0.216	0.756
CPNP3	0.0153±0.005	133.11	0.612	2.14	0.0159±0.005	138.33	0.212	0.742
CPCP4	0.0168±0.001	146.16	0.672	2.35	0.0173±0.001	150.51	0.231	0.809
CPNP5	0.014±0.006	121.80	0.560	1.96	0.0152±0.006	132.24	0.207	0.725
Mean	0.0148±0.01	128.59	0.591	2.06	0.0164±0.03	142.68	0.220	0.769
CNP1	0.0141±0.006	122.67	0.564	1.97	0.0173±0.004	150.51	0.231	0.809
CNP2	0.0133±0.001	115.71	0.532	1.86	0.0168±0.001	146.16	0.224	0.784
CNP3	0.0133±0.007	115.71	0.532	1.86	0.0170±0.001	147.90	0.227	0.795
CNP4	0.0143±0.001	124.41	0.572	2.00	0.0149±0.004	129.63	0.199	0.697
CNP5	0.0129±0.001	112.23	0.516	1.81	0.0149±0.004	127.89	0.196	0.686
Mean	0.0136±0.001	118.15	0.543	1.90	0.0161±0.03	140.42	0.215	0.754
MD1	0.0225±0.001	195.75	0.900	3.15	0.0201±0.001	174.87	0.268	0.938
MD2	0.0249±0.001	216.63	0.995	3.48	0.0167±0.001	145.29	0.223	0.781
MD3	0.0240±0.002	208.80	0.960	3.36	0.0198±0.001	172.26	0.264	0.924
MD4	0.0214±0.003	186.18	0.856	3.00	0.0171±0.001	148.77	0.228	0.798
MD5	0.0258±0.001	224.46	1.032	3.61	0.0213±0.001	185.31	0.284	0.994
Mean	0.0237±0.02	206.36	0.949	3.32	0.019±0.001	165.30	0.253	0.887
BMD1	0.0176±0.003	153.12	0.704	2.46	0.0162±.001	140.94	0.216	0.756
BMD2	0.0171±0.001	148.77	0.684	2.39	0.0140±.001	121.80	0.187	0.655
BMD3	0.0188±0.001	163.56	0.752	2.63	0.0158±0.001	137.46	0.211	0.735
BMD4	0.0167±0.008	145.29	0.763	2.67	0.0152±.002	132.24	0.203	0.711
BMD5	0.0209±0.008	181.83	0.955	3.34	0.0154±0.001	133.98	0.205	0.718
Mean	0.0182±0.01	158.51	0.772	2.70	0.0153±0.002	133.28	0.204	0.715
DB1	0.0205±0.001	178.35	0.820	2.87	0.0168±.001	146.16	0.224	0.784
DB2	0.0181±0.001	157.47	0.724	2.53	0.0166±0.003	144.42	0.221	0.774
DB3	0.0189±0.001	164.43	0.756	2.65	0.0149±0.001	129.63	0.199	0.697
DB4	0.0197±.002	171.39	0.788	2.76	0.0156±0.001	135.72	0.208	0.728
DB5	0.0187±.002	162.69	0.854	2.99	0.0182±.002	158.34	0.243	0.851
Mean	0.0192±0.01	166.87	0.788	2.76	0.0164±.002	142.85	0.219	0.767

CPP= Concrete plastered and painted, CPNP= Concrete plastered and not painted, CNP= concrete not plastered, MD=mud, BMD= burnt mud, DB= dirty block house

Table 2: Comparison of the Mean Indoor and Outdoor Exposure Rate and Effective Dose.

Code	Indoor Exposure Rate(mR/h)	D (nGy/h)	AEDE mSv/y	ELCR $\times 10^{-3}$	Outdoor Exposure Rate(mR/h)	D (nGy/h)	AEDE mSv/y	ELCR $\times 10^{-3}$	Redox. Coeff.
CPP	0.0154	134.15	0.617	2.45	0.0159	138.16\	0.212	0.742	0.97
CPNP	0.0149	128.59	0.591	2.06	0.0164	142.68	0.220	0.769	0.91
CNP	0.0134	118.15	0.543	1.90	0.0161	140.42	0.215	0.754	0.83
MD	0.0237	206.19	0.949	3.32	0.0190	165.30	0.253	0.887	1.25
BMD	0.0182	158.34	0.772	2.72	0.0153	133.28	0.204	0.715	1.19
DB	0.0192	166.87	0.788	2.76	0.0164	142.85	0.219	0.767	1.17

Reduction Coefficient

The average reduction coefficient was obtained by fitting the distributions of the ratio of the indoor and outdoor dose rates with Gaussian distributions. The distributions were separately analyzed according to the type of the residential houses. Reduction coefficients of 0.97, 0.91, 0.83, 1.25, 1.19 and 1.17 corresponding to CPP, CPNP, CNP, MD, BMD and DB respectively were obtained as listed in Table 2. From the reduction coefficients at the centers of all the residential houses, the average reduction coefficient at the centers of the houses range from 0.84 to 1.28. These coefficients are slightly higher than 0.4 provided by the IAEA, although the dose rate measurement were performed in European houses. The comparison with calculation of the reduction coefficient provided by the IAEA indicates that there could be different building pattern of the Europeans and Africans. The reduction coefficients in areas other than the centers of houses have never been provided by the IAEA. These reduction coefficients obtained at the several locations in each room and in toilets and bathrooms are larger than those at the centers of the houses. The dose ratio depends on the window sizes (Masashi et al., 2014). In toilets and bathrooms, the dose ratios are small; however in living rooms with large windows, the dose ratios are large because of the small shielding against photons entering the rooms. Walls are effective photon shields. To reduce the exposure doses, residents should spend more time at the center of the living rooms and in rooms with small windows.

The indoor and outdoor ambient dose equivalent rates were measured at a height of 1m above the floor level in the houses and above the ground respectively. Several measurement of indoor and outdoor dose rate at several heights in order to observe the height dependence of dose rates. The heights in the houses are defined from the ground, including the floor height. The outside dose rates decreased as the measurement height increased, whereas the indoor dose rates increased as the height increased. This may be due to shielding effect of wall.

The annual indoor effective dose equivalent ranges from 0.54mSvy^{-1} for CNP houses to 0.949mSvy^{-1} recorded in mud houses. The annual outdoor effective dose ranges from 0.204mSvy^{-1} recorded in burnt mud house to 0.253 mSvy^{-1} recorded around mud houses which resulted in a total mean outdoor dose of 0.48mSvy^{-1}. The lifetime cancer risk calculated from indoor effective doses in all the residential houses ranges from 1.90×10^{-3} to 3.32×10^{-3} while that from outdoor effective dose ranges from 0.75×10^{-3} to 0.887×10^{-3}. Mud and burnt mud houses recorded the highest dose rates, effective doses and lifetime cancer risk than other types of residential houses which includes concrete houses (concrete plastered and painted (CPP), concrete not plastered and not painted (CNPNP) and concrete plastered not painted (CPNP)). This could be as a result of high radionuclide content in clay soil being the major component of mud houses and also cracks that permits photon entrance into the houses. Comparison of the exposure rates measured in all the six residential houses with the ICRP standard as shown in Figure 2 shows that the dose rates measured in all the houses exceeded the ICRP standard. The result showed that the indoor and outdoor dose rates are higher than the safe levels.

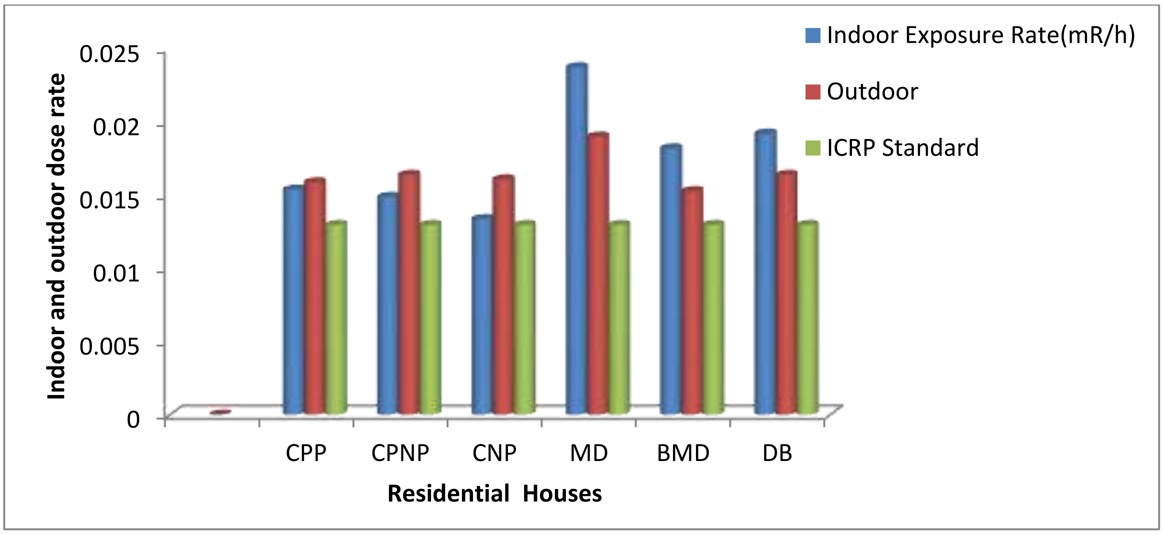

Fig.2: Comparison of indoor and outdoor dose rate of six residential houses.

CONCLUSION

In-situ measurements of indoor and outdoor exposure rate of six different settlements were done using a well calibrated radiation Alert-100. The highest indoor and outdoor exposure rate of 0.0237 ± 0.014mRh^{-1} and 0.0181±0.002mRh^{-1} respectively were recorded in mud houses while the lowest mean exposure rate was recorded in concrete not plastered houses. The indoor annual effective dose ranges from 0.54mSvy^{-1} for concrete not plastered houses to 0.949mSvy^{-1} recorded in mud houses. Resulting average of the annual effective dose is 1.06 mSvy^{-1}, which is large as compared to the worldwide average of the annual effective dose 0.48 mSv. Whereas outdoor effective doses calculated ranges from 0.204mSvy^{-1} in burnt mud house to 0.253mSvy^{-1} recorded around mud houses which results in total mean outdoor effective dose of 0.48mSvy^{-1}. Estimated excess lifetime cancer risk (ELCR) from indoor AEDE ranges from 1.90 x 10^{-3} to 3.32 x 10^{-3} recorded in CNP and MD respectively and ELCR from outdoor ranges from 0.715x 10^{-3} to 0.887x 10^{-3} recorded in burnt mud house. Resulting average of the excess lifetime cancer risk is 4.21 x 10^{-3}, which is large as compared to the resulting worldwide average 0.29 x 10^{-3}.

The average reduction coefficients were obtained from the ratio of the indoor and outdoor dose rates. These reduction coefficients obtained at the several locations in each room and in toilets and bathrooms are larger than those at the centers of the houses. It was observed that outdoor dose rates decreased as the measurement height increased, whereas the indoor dose rates increased as the height increased. Also indoor dose rates at the centers of each house were lower than other locations on this same room due to the shielding effect of the walls and also it is dependent on the size of the window as dose rate measured inside toilet with smaller windows were smaller than other locations of the rooms with wider windows. To reduce the exposure doses, residents should spend more time at the center of the living rooms and in rooms with small windows.

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