Estimation of the Level of Indoor Radon in Sokoto Metropolis

[1]Yusuf Ahijjo Musa, [2]Adamu Nchama Baba-Kutigi

[1]Department of Phyiscs, Usmanu Danfodiyo University, Sokoto, Sokoto State, Nigeria.
[2]Department of Phyiscs, Federal University, Dutsin-Ma, Katsina State, Nigeria.
Email: [1]yusuf4abodia@yahoo.com, [2]nchama3101@yahoo.com

Abstract — Indoor radon-222 concentration was estimated in thirty randomly selected homes and workplaces carried out within Sokoto metropolis (a Semi-Arid Extreme North-west of Nigeria). The studies which may help understand the potential danger posed by radon-222 activity concentration known for its lung cancer potency. The city's metropolis was gridded into thirty grids over which thirty samples were collected using statistical random sampling; with the aid of Activated Charcoal Detectors (ACDs). The gamma-ray spectrometric analysed result by Sodium Iodide detector (NaI (Tl)) revealed that indoor radon concentration ranges from 358.81 to 542.30 Bq/m^3 with a mean value of 448.98 Bq/m^3 for homes and workplaces.

I. INTRODUCTION

Radon-222 is a naturally occurring radionuclide, a chemically inert gas, and has a suitable half-life of 3.82 days [1]. Recently, high levels of ^{222}Rn have been reported in dwellings of many countries around the world. It is estimated that indoor ^{222}Rn exposure may be responsible for more than 10% of the lung cancer incidence [2]. Inhalation of the radioactive decay products of radon (^{222}Rn), a naturally occurring gaseous decay product of radium, present in all soil has been linked to an increased risk of lung cancer [3]. Every square mile of surface soil, to a depth of 6 inches (2.6 km^2 to a depth of 15 cm), contains approximately 1 gram of radium, which releases radon in small amounts to the atmosphere on a global scale, it is estimated that 2,400 million curies (90 TBq) of radon are released from soil annually [4]. Nearly 50% of annually radiation dose absorption of human is due to radon which is one of the main causes of cancer to respiratory and digestive systems [5]. Its concentration varies greatly with season and atmospheric conditions. For instance, it has been shown to accumulate in the air if there is a meteorological inversion and little wind [6]. In deciding if remedial measures have to be taken and where these measures should be taken the wide indoor radon survey is to be carried out. A ^{222}Rn detector of the passive alpha track type was used in the measurements of indoor radon in Indian dwelling. The estimated measured activities from an individual detector for a month-long exposure were 18% at 500 Bq.m^{-3} and 13% at 1000 Bq.m^{-3} respectively [7].

II. THE STUDY AREA

Sokoto metropolis is the study area. Sokoto lies on the Latitude 13.0833333^0, Longitude 5.25^0, and Altitude 895 (feet). The time zone in Sokoto is Africa/Lagos, sunrise at 06:27 and sunset at 18:46. It is located in the extreme northwest of Nigeria, bordering Niger and Benin Republics in West Africa. It has an annual average temperature of 33.3^{o}C. Sokoto state is highly endowed with the wealth of limestone which attracted the chosen site of one existing cement company, and this limestone also contains some fairly significant amount of radon-222 [8]. It is no longer doubtful that low concentration of ^{222}Rn can as well deliver the radiation dose which can cause internal hazards to humans [9].

A. Materials and Methods

This research was conducted on the use of a commercially purchased activated charcoal detectors (ACDs). ACDs are passive devices deployed for 1-7 days to obtain indoor radon sample before Laboratory analysis. The principle of detection is radon adsorption on the active sites of the activated carbon [10]. An electronic chemical balance of Shimadzu Corporation, assembled by SPM Japan, which is capable of measuring between 0.1mg to 320g, was used to measure 40g of ACDs needed in the canister. A plastic can was purchased in Sokoto market (Kasuwan Kara), and constructively improvised to ascertain the required dimensions. This is to enhance fixing of smaller dimension cylinder (canister) inside the lager one for the sample collection. Their dimensions were carefully determined as shown in the figure 1 and 2 below, so that they can conveniently fit into the Sodium Iodide detector geometry (7.62cm x 7.62cm) for better resolution. An electronic Chassis Model (GP 214) manufactured by Graffin England was used to perforate the lid of the plastic cylinder to allow radon gas adsorption into the canister. The side of the perforated lid was sealed round by the application of candle wax and Vaseline jelly to greatly lay barrier for any unwanted cross-ventilation as radon concentration can easily be affected by air flux [10]. Since the same ACDs

were used throughout this research, the probable variation in the result of radon activities is a function of possible variation in structures of the sampled points.

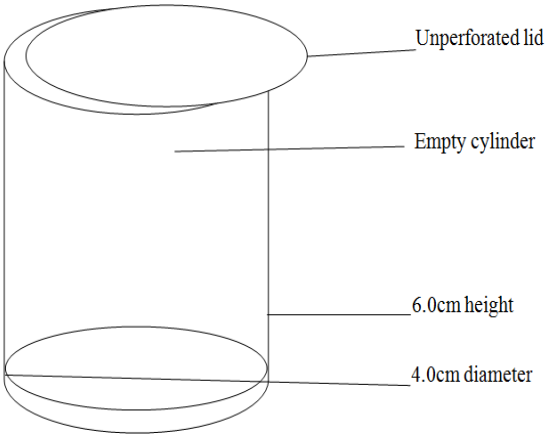

Fig-1 Schematic Illustration of a Constructed, Cylinder (Canister).

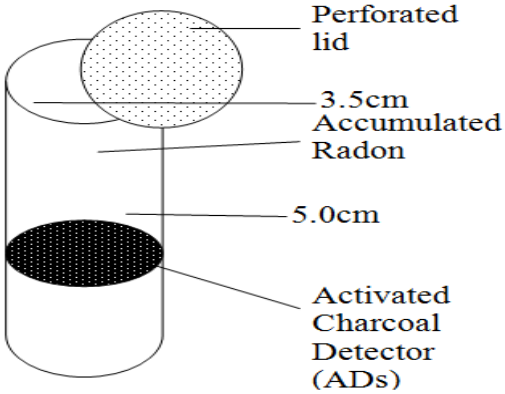

Fig-2 Schematic Illustration of a Constructed ACDs Canister with Accumulated Radon.

B. Theory of Adsorption and Absorption

Adsorption, which is often confused with absorption, refers to the adhesion of molecules of gases and liquids to the surface of porous solid. Adsorption is a surface phenomenon; while absorption is an intermingling or interpenetration of two substances [11]. The relatively large surface area of the absorbent allows absorbate atoms, ions or molecule to be taken up. In some cases the atoms of the absorbate share electrons with atoms of the absorbent surface, forming a thin layer of chemical compound. Absorption occurs when the molecules of the absorbate penetrate the bulk of the solid or liquid absorbent. Adsorption denotes absorption of a gas or a solute by a surface or an interface. Adsorption implies action at the surface .It is a spontaneous process accompanied by reduction of surface free energy of the adsorbing surface. Adsorption is a type of adhesion which takes place at the surface of a solid or a liquid in contact with another medium, resulting in an accumulation or increased concentration of molecules from that medium in immediate vicinity of the surface for example if freshly heated charcoal is placed in an enclosure with ordinary air, a condensation of certain grasses occurs upon it, resulting in a reduction of pressure; or if it is placed in a solution of unrefined sugar, some of the impurities are likewise adsorbed, and thus removed from the solution [12]. Charcoal when activated (i.e. freed from adsorbed matter by heating) is especially effective in adsorption, due to it great surface area presented by it porous structure. The adsorption of dirt on one's hand results from the unequal distribution of dirt between the skin of the hand and the air or solid with which the skin comes in contact. Water is frequently ineffective in removing the dirt. The efficacy of soap in accomplishing its removal is due to the unequal distributing of dirt between skin and soap solution, this time favouring the soap and leaving the hands clean. At a given fixed temperature, there is a definite relation between the number of molecules adsorbed upon a surface and the pressure (if a gas) or the concentration (of a solution) which may be represented by an equation or graphically by a curve called the adsorption isotherm.

The freundlich or classical adsorption isotherm is of the form.

$$\frac{x}{m} = k\rho^{\frac{1}{n}} \qquad (1)$$

[13].

Where x is the mass of gas adsorbed

m is the mass of adsorbent

ρ is the gas pressure

k, n are constant for the temperature and system.

In certain system it is necessary to express this relationship as

$$\frac{x}{m} = k\left(h\gamma\right)^{\frac{1}{n}} \qquad (2)$$

Where h is the relationship of the partial pressure of the vapour to it saturation value and r is the surface tension. Numerous isotherm equations have been proposed. The lagmuir adsorption isotherm is of the form stated below.

$$\frac{x}{m} = \frac{\kappa_1 \kappa_2 \rho}{1 + \kappa_1 \rho} \qquad (3)$$

The degree of adsorption depends on following factors, viz:

- The composition of the adsorbing material
- The condition of surface of the adsorbing material
- The material to be adsorbed
- The temperature
- The pressure (of a gas) [13].

C. Gamma ray Spectrometry

The concentration of radon in the air is measured in units Becquerel's per cubic meter (Bq/m^3). One Bq corresponds to one disintegration per second. One pCi/L is equivalent to 37 Bq/m^3 [14]. Gamma ray spectrometry technique was utilised in the spectral collection of the 30 prepared samples after the equilibration period. Background measurements were performed by measuring unexposed canister which gave an average concentration of 1.5Bq/m^3. This is because radon-222 is present relatively everywhere, as a natural radionuclide. Each data is corrected by subtracting the background that measures the gamma decay of the short lived ^{222} decay products once equilibrium has been reached [15]. In this experiment we need no manual conversion due to the task embedded in the MAESTRO-23 software. The principle of detection in NaI (Tl) detector is that the output pulse amplitude from the radioactive source detector is proportional to the energy deposited by the source. So the pulse-height spectrum from such a detector contains a series of full-energy peaks superimposed on a continuous background, the spectrum can be quite complicated and difficult to analyze. It contains much useful information about the energies and relative intensities of the type of radioactive sources [15].

III. RESULT

The analysed results of thirty (30) samples within the gridded map of Sokoto metropolis from CERT Zaria is shown in Table 1 and 2 below. The result is a spectrum of the analysed thirty (30) samples within the gridded map of Sokoto metropolis from CERT, Zaria, ranging from Pottasium-40, Radium-226, Thorium-232, and Radon-222. But the activity concentration of Radon-222 which is the radioactive isotope of interest is tabulated on table 2 as shown below. Although, the significance of this research focuses on estimating indoor radon gas concentration since there is strong epidemiological evidence that ionizing radiation increases cancer risks [16].

TABLE: 1. sPOLIS.

Number of Samples	Sample Points Identity	Count Rate of Rn-222 (CPS)	Conc. of Rn-222 (Bq/m^3)
1.	1sok	0.0510	358.8100
2.	2Sok	0.0641	446.2301
3.	3Sok	0.0640	410.0911
4.	4Sok	0.0721	479.3100
5.	5Sok	0.0721	479.3100
6.	6Sok	0.0721	479.3100
7.	7Sok	0.0641	445.1001
8.	8Sok	0.0641	446.7114
9.	9Sok	0.0830	512.3992
10.	10Sok	0.0721	479.3100
11.	11Sok	0.0771	443.3551
12.	12Sok	0.0641	446.7114
13.	13Sok	0.0641	446.7114
14.	14Sok	0.0641	446.7114
15.	15Sok	0.0641	445.1001

TABLE: 2. RESULT OF RN-222 RADIOACTIVE DECAY OF SOKOTO METROPOLIS CONTINEUED.

Number of Samples	Sample Points Identity	Count Rate of Rn-222 (CPS)	Conc. of Rn-222 (Bq/m^3)
16.	16Sok	0.0982	446.7114
17.	17Sok	0.0641	542.3030
18.	18Sok	0.0611	446.7114
19.	9Sok	0.0640	410.0911
20.	20Sok	0.0640	410.0911
21.	21Sok	0.0641	410.0911
22.	22Sok	0.0600	409.8105
23.	23Sok	0.0641	446.7114
24.	24Sok	0.0641	446.7114
25.	25Sok	0.0600	407.1901
26.	26Sok	0.0730	480.6742
27.	27Sok	0.0641	446.7114
28.	28Sok	0.0831	511.0072
29.	29Sok	0.0600	410.0911
30.	30Sok	0.0720	479.3100

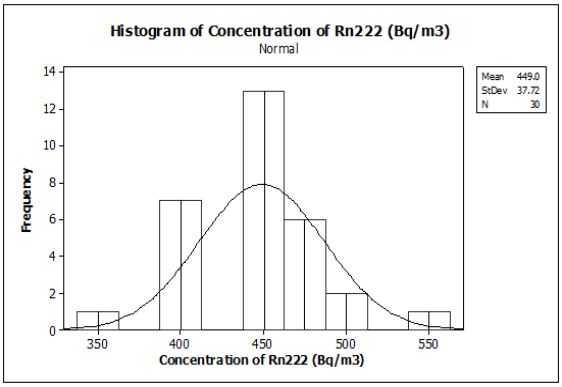

Fig-3 Histogram of Indoor Rn-222 Concentration from Different Sample Points within Sokoto Metropolis.

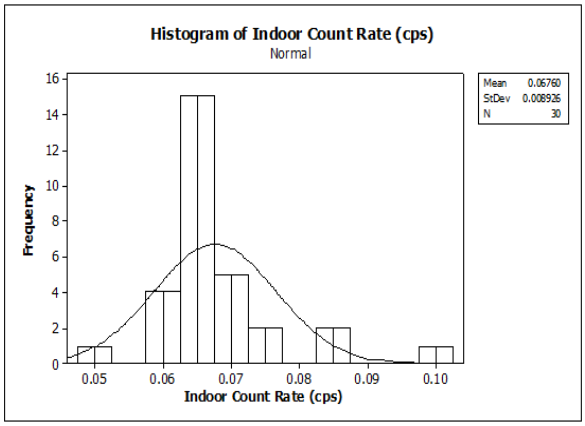

Fig-4 Histogram of Indoor Count Rate from Different Sample Points within Sokoto Metropolis.

IV. CONCLUSION

It has been shown from the result of this work, that with the aid of ACDs, the concentration of Rn-222 has be determined and following a careful observation, this research have been able to unveil two possible ionizing radiation parameters i.e. activity concentration and dose rate of Rn-222 in home and workplaces within Sokoto metropolis. The radon level in most of the houses was found to be fairly above the levels of other work in the southern-Nigeria due to vast difference in weather conditions, with mean value of 448.98Bq/m^3 for this perceive method. Hence, research should be intensified in this direction to employ other methods. The hotness and dryness nature of the weather in Sokoto could account for significantly distinct result from other research in this direction.

V. ACKNOWLEDGEMENT

This research was successfully achieved due to the painstaking effort of the following persons:

Dr. Mitshelia, Head, Department of Pharmacy, Usmanu Danfodiyo University Sokoto

Mallam Adam S. Sa'idu an Academic Technologist, Centre for Energy Research and Training, Zaria

Mallam A.A Musa Chief Academic Technologist, (Chief Co-ordinator Physics Laboratories), Usmanu Danfodiyo University Sokoto

Mallam Awalu Ibrahim a Principal Academic Technologist, (Head of Electronics unit of Physics Laboratory), Usmanu Danfodiyo University Sokoto

REFERENCES

[1] Dorr, H., Kromer, B., Levin, I., Mu¨nnich, K.O., Volpp, H.J., CO2 and Radon-222 as tracers for atmospheric transport. J. Geophys. 1983, pp. 1309–1313.

[2] Dr.Maria Neira of WHO. Handbook or Indoor Radon: A public Health perspective.2009, pp.12, 50-51.

[3] Fabricant, J.I., Radon and lung cancer: the BEIR IV report. Health Phys. 1990, pp. 59, 89–97.

[4] Agency for toxic Substances and Discease Registry, U.S. Public Health Service. In collaboration with U.S. Environmental Protection Agency. 2000, pp. 40-49

[5] Li X, Zheng B, Wang Y, Wang X. A study of daily and seasonal variations of radon concentrations in underground buildings. J. Environ. Radioactivity. 2006, pp. 101-106.

[6] Steck DJ, Field RW, Smith BJ, Brus CP, Fisher EL, Neuberger JS, Platz CE, Robinson RA, Woolson RF, Lynch CF: Residential Radon Gas Exposure and Lung Cancer: The Iowa Radon Lung Cancer Study, American Journal of Epidemiology 2000, pp.1091-102.

[7] A.J. Khan. A study of indoor radon levels in Indian dwellings Influencing factors and lung cancer risks, Radiation Measurements. 2000, pp. 87-92.

[8] Adediran JA, Oguntoyinbo FI, Omonode R and RA Sobulo. Agronomic evaluation of phosphorus fertilizers. 1998, pp. 12-16.

[9] Field RW, Krewski D, Lubin JH, Zielinski JM, Alavanja M, Catalan VS, Klotz JB, Letourneau EG, Lynch CF, Lyon JI, Sandler DP, Schoenberg JB, Steck DJ, Stolwijk JA, Weinberg C, Wilcox HB, Residential Radon and Risk of Lung Cancer: A Combined Analysis of 7 North American Case-Control Studies,Epidemiology16(2):2005,pp.37-45.

[10] Oikawa S, Kanno N, Sanada T, Abukawa J, Higuchi H J Environ Radioact. 87(3): 2006, pp. 239-45.

[11] Peter, B. N. Encyclopedia Vol. 9. Encylopedia Britannica Inc. London 77(20): 1994, pp. 4280.

[12] Barnard L Cohen and Richard Nason. A diffusion Barrier Adsorption Collection for Measuring Radon Concentration in indoor air, Health Physics vol. 50(14): 1986, pp. 30.

[13] Ducan. Advance Physics Field Waves and Atoms. John Murray (Ltd) London. 1981, pp 890.

[14] International Commission on Radiological Protection (ICRP). The Recommendations of the International Commission on Radiological Protection. 2007, pp. 67:20-22.

[15] Centre for Energy Research and Training (CERT) Zaria, Kaduna, Nigeria. Two Weeks Documentation Trip to CERT, 21st January to 2nd February, 2013.

[16] Preston DL, Brenner DJ, Doll R, Goodhead DT, Hall EJ, Land CE, Little JB,Lubin JH, Preston RJ, Puskin JS, Ron E, Sachs RK, Samet JM, Setlow RB, Zaider M. Cancer risks attributable to low doses of ionizing radiation: assessing what we really know. Proc Natl Acad Sci USA. 2003, 100: pp. 13761–13766.

◈◈◈