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SOIL GAS RADON MONITORING IN ODO ONA AS AN INDIRECT PROBE FOR LOCATION OF GEOLOGICAL FAULT ZONES

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Abstract

Radon (Rn-222) gas, a leading cause of lung cancer, second only to cigarette smoking was investigated in Odo Ona, Ibadan, (which lies within Latitude 3˚50' 0' to Latitude 3˚55'0', and Longitude 7˚15'0' to Longitude 7˚25'0') a population of about 741 405 people. Four monitoring stations were randomly selected where soil gas radon were monitored using CR 39 detectors for about four months. Average soil gas radon exhalation from these sites which ranged from 531.85 Bq/m^3 to 970.35 Bq/m^3 were significantly higher the USEPA recommended action level which was adopted by the Standard Organisation of Nigeria. The paper concludes with the health risks associated with these facts about radon exhalation in the area and concludes with useful recommendations.

1.0 Introduction

Radon (Rn) is a radioactive gas (Lewis 2001) that naturally occurs in different forms known as isotopes. Radon is a chemically and biologically inert noble gas. Its nucleus is heavily neutron-rich, making it radioactive. Radon's half-life is 3.8 days. Radon is present in air, water, and soil. Radon will undergo radioactive decay in the environment. Each parent atom (thorium-234 or uranium-238) decays several times to become a radium atom (Ra-224 or Ra-226), then radon (Rn-220 or Rn-222), and several more times through a series, creating radioactive substances known as radon daughters or progeny. The atom finally decays into a stable lead atom. As radon progeny undergo radioactive decay, radiation is released in forms that include high-energy alpha particles, Beta particles, and Gamma radiation. Once formed, radon's noble gas nature releases it from chemical bonds in rock, soil, water, and building materials. Radon's half-life provides sufficient time for it to diffuse from its origin and into the atmosphere. This allows for entry into buildings and homes, where further disintegration produces radon progeny. These progeny tend to be electrically charged and tend to attach to dust particles. Radon progeny include four isotopes with half-lives of fewer than 30 minutes. These are the major source of human exposure to alpha radiation (high-energy, highmass particles, each consisting of two protons and two neutrons). Alpha radiation may—directly or indirectly—damage DNA and other cell components, which could result in radon-induced lung diseases or cancer.

Radon and its progeny are measured in different terms for environmental /residential and occupational exposures. Environmental/residential radon is usually measured in terms of its quantity of radioactive material, or activity (in units of curies or becquerels). A curie (Ci) is the amount of air, soil, or other material in which 37 billion atoms transform each second, and 1 Ci = 3.7×10^{10} Bq. A Becquerel (Bq) is the amount of material in which 1 atom transforms each second. Prefixes are often used with these units, [e.g., pCi or picocurie (10^{-12} curie)].

Occupational radon is measured in terms of "working levels" or the total amount of energy imparted to tissue from radon progeny. EPA recommends limiting indoor residential radon concentrations to 4pCi/L, which is generally about a 0.016 working level.

Radon gas has been identified as a leading cause of lung cancer, second only to cigarette smoking (ACS 2006; EPA 2013a). Radon gas is responsible for an estimated 21,000 deaths from lung cancer annually (NCI 2004; EPA 2013b). The risk of cancer due to radon exposure is increased for smokers, as the radiation emitted by tobacco synergizes when in the presence of radon gas.

2.0 Materials and Methods

2.1 Research Procedure

The systematic approach to this research involves the following:

2.1.1 Field Work: The field work involves:

(i) **Mapping out of the study area**: The study area (Odo Ona region) lies within Latitude $3^0 50' 0'$ to Latitude $3^0 55' 0'$, and Longitude $7^0 15' 0'$ to Longitude $7^0 25' 0'$ and spans four Local Governments regions namely- Ibadan North West, Ibadan South

West, Ido and Oluyole Local Government Areas of Oyo State. The population distribution of the area of research is as follow :

Local Govt.	Population	male	female
Ibadan North West	152834	75311	77523
Ibadan South West	282585	139515	143070
Ido	103261	51750	51511
Oluyole	202725	102220	100505

The area account for about 13.259% (741405 inhabitants) of the total population.

2.1.2 **Location of Monitoring Stations**:

Based on consultation with the dwellers in the region, four monitoring stations were randomly selected and their location noted using the GPS device

a. Station 1- Odo Ona Elewe river with
   GPS Location.

b. Station 2- with
   GPS Location N 7.39930, E3.87086.

c. Station 3- with
   GPS Location N 7.33160, E 3.84679.

d. Station 4- with
   GPS Location N 7.28410, E 3.85009.

Station Name	*GPS Coordinate*	*male*	*female*
Odo Ona Elewe	152834	75311	77523
Orita/ Odo Ona Junction	282585	139515	
Asipa Telecommunication	103261	51750	
Ratcon Quarry area	202725	102220	

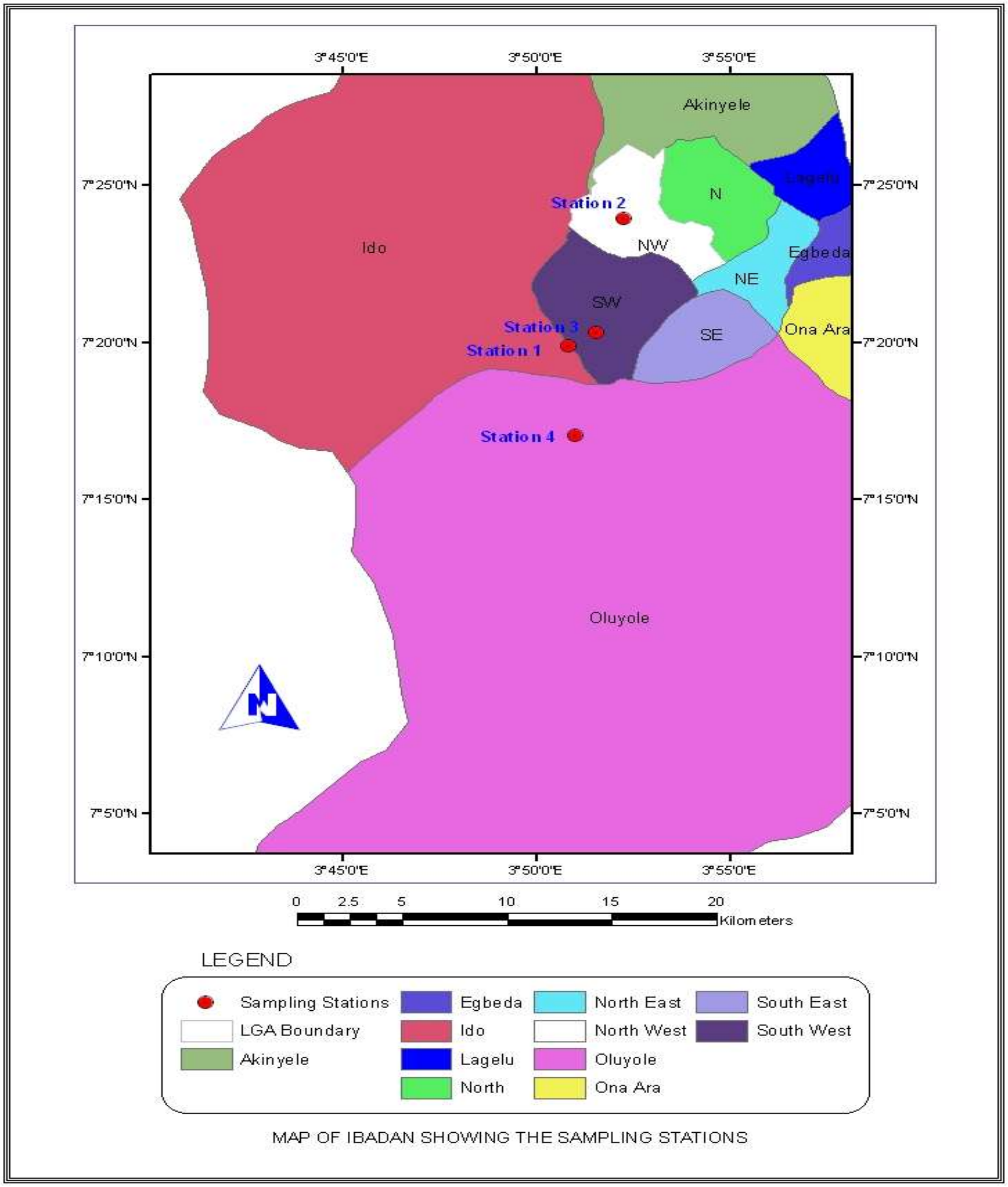


Fig 2.1. The Geographical Map of The Study Area Showing Measuring Stations

3.0 Experimental method

The method that has been applied here is track etch technique using CR-39 detectors. The choice of CR-39 as the Solid State Nuclear Tract Detectors (SSNTD) used for this research is its excellent sensitivity over a wide range of particle energies, and its good chemical and electrochemical properties. For ᶐ-particle measurement, CR-39 detectors are sensitive over the range 0.1-40 MeV which makes them an excellent choice for these types of measurements. The CR-39 detectors and cups used for this research work were donated by I.N.F.N., Italy. The detectors of 1cm^2 area were already fixed in the cups and the cups were sealed in a radon tight foil. The foils were only removed at the sites and consequently, for the CR-39 detectors to be exposed to radon. The cups were 4.7 cm in height and 6.3 cm in diameter.

A P.V.C. pipe with upper and lower sides open was placed inside the hole of 70 cm deep below the earth surface. The cup was placed within the P.V.C. pipe in the hole. Silica gel was placed in the hole surrounding the cup to absorb moisture there. This is showed in Fig. 3. 6. The upper end of the P.V.C. pipe that was almost in the level of the upper ground surface was covered with a lid. The arrangement reduced the effect of external meteorological effect on radon flow.

Each CR-39 plate was exposed for 4days (96h) in such an undisturbed condition. On completion of the exposure time, the detector was removed and another detector was placed in the same manner. After exposing, chemical etching of the detectors was done.

3.1 Chemical Etching

In this process, the plates were etched in 6.25M NaOH solution for 2 hrs at 90^{o}C. The temperature was carefully maintained at constant value. The detectors were first washed under running water and left in distilled water. This was done to stop the activity of the etchant.

3.2 Method of Analysis

The CR 39 slides after being etched were analysed using the Image J software. The tracks in the plates formed due to alpha particles were counted under an optical microscope with x 40 magnification. The digital camera attached to the Microscope captures the images on a screen through the USB Cord connected to the Laptop with the aid of VIMICRO USB PC Camera (ZC0301PL) software. Image J software deduces the number of holes from each image

38 detectors were exposed and removed at the four Monitoring stations from 27th March to 10th May, 2013 and etched; from which their respective radon concentrations were determined.

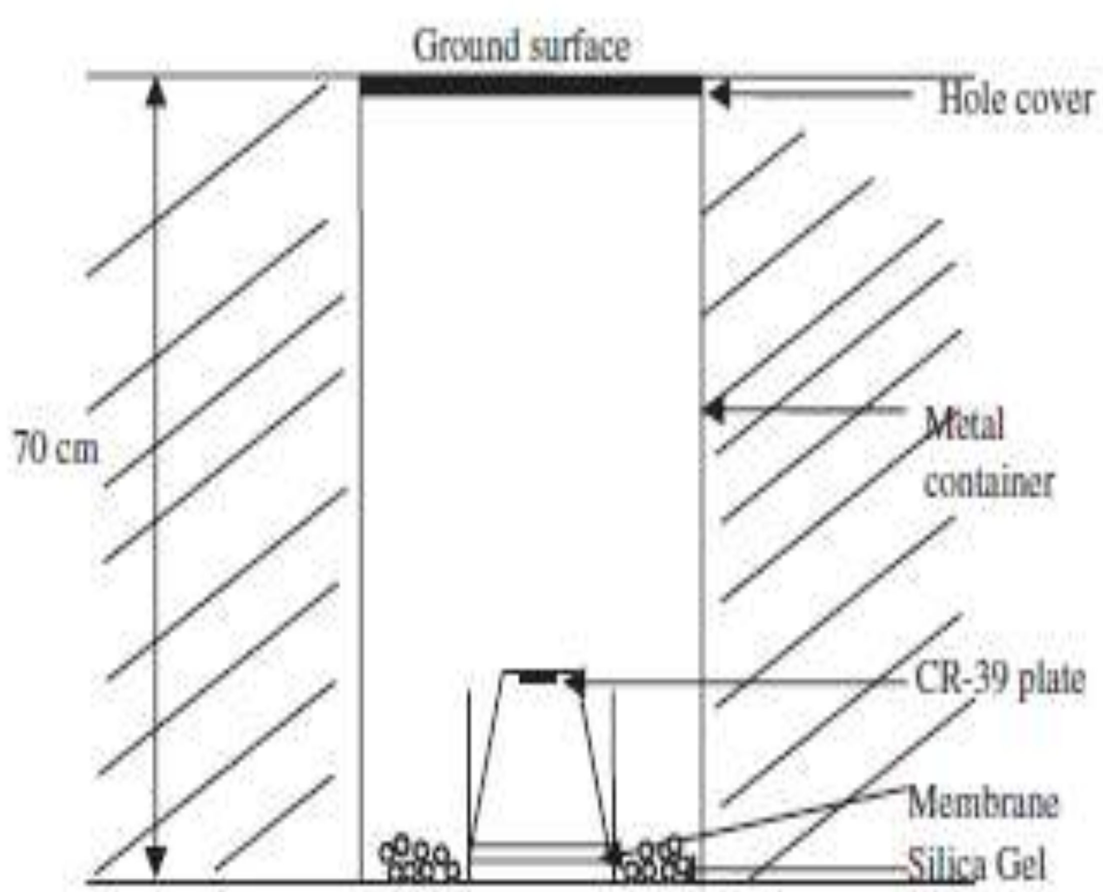


Fig. 3.1. The experimental set-up during the measurement of radon concentration.

4.1 Results

At the start of the experiment there was a problem of moisture accumulation over the membrane. This was overcome by placing silica gel in the shallow borehole and the problem was greatly reduced. There was no significant change in the atmospheric pressure (753± 1mm of Hg) during the period of investigation. The radon concentration was measured in Bq/m^3 using Image J software and a designed Spreadsheet. The result of the monitoring stations is detailed below:

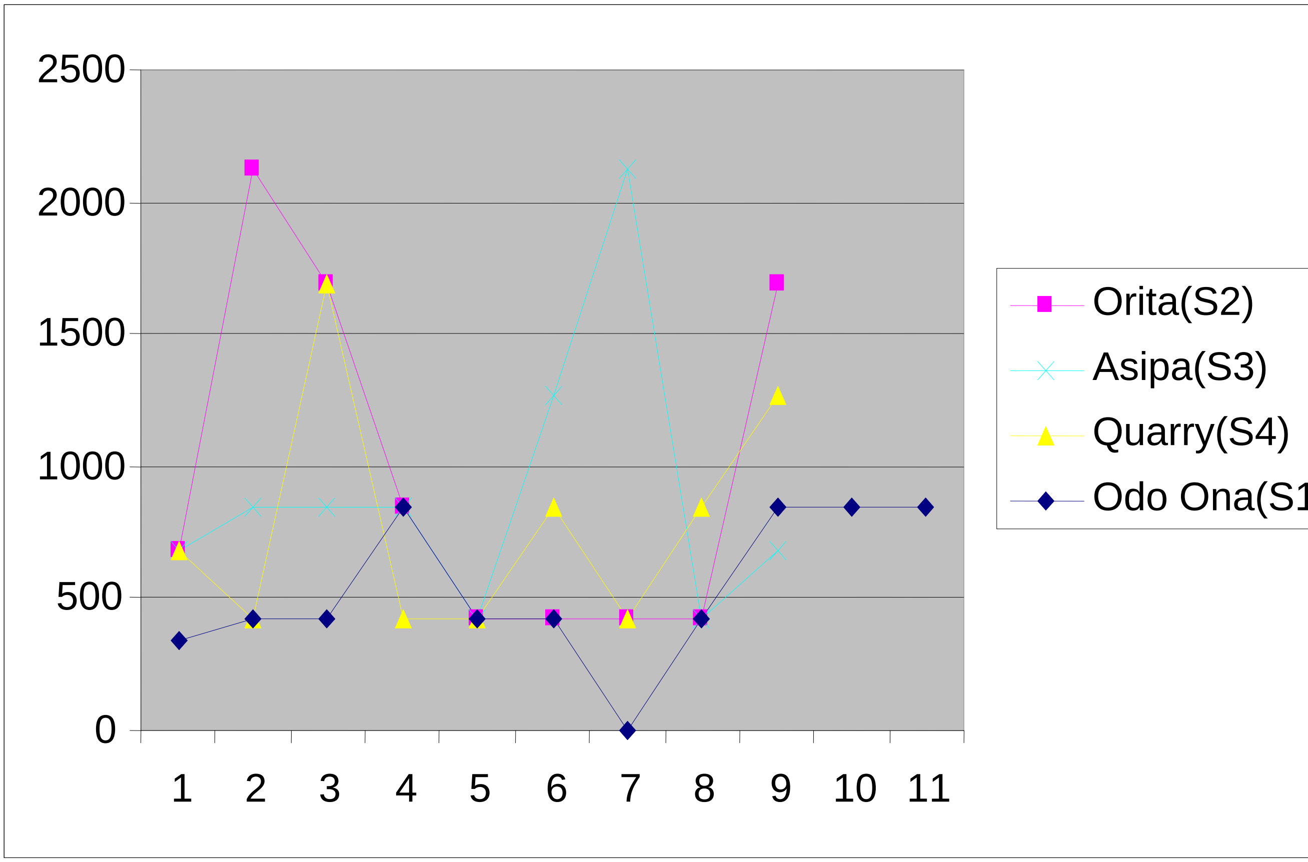
Table 4.1 : **The result of the monitored stations**

ID Dosemeter [number]	Rn Conc, [Bq/m^3]	Error (±) [Bq/m^3]	Error (±) [Bq/m^3]	Error (±) [Bq/m^3]	Error (±) [Bq/m^3]
Radon Concentration for Detectors Exposed At Odo Ona Monitoring Station (S1)			**Radon Concentration for Detectors Exposed At Orita Challenge Monitoring Station (S2)**		
I95082	424	85	I95028	678	136
I96221	424	85	I95059	2120	424
I96604	424	85	I95088	1696	339
I 96706	848	170	J 11359	848	170
J 11297	424	85	J 54918	424	85
J 55103	424	85	J 54988	424	85
J 55105	0	0	J 55038	424	85
J 55205	424	85	J 55205	424	85
I 96538	848	170	J 55307	1696	339
J 55227	848	170	I 95029	678	136
I 96671	678	136	I 95030	13	136

Table 4.2: The result of the monitored stations

ID Dosemeter [number]	Rn Conc, [Bq/m^3]	Error (±) [Bq/m^3]	Error (±) [Bq/m^3]	Error (±) [Bq/m^3]	Error (±) [Bq/m^3]
Radon Concentration for Detectors at Exposed At Asipa Monitoring Station (S3)			**Radon Concentration for Detectors at Exposed At Ratcon Quarry Monitoring Station (S4)**		
I95016	678	136	I95069	678	136
I95037	848	170	I95082	424	85
I95037	848	170	I95088	1696	339
I95648	848	170	I95675	424	85
I 96684	424	85	I95676	424	85
I 96900	1272	254	I96622	848	170
I 99385	2120	424	I 96837	424	85
I 95017	424	85	J 54976	848	170
J 54858	678	136	J 55101	1272	254
I95016	678	136	I95069	678	136
I95037	848	170	I95082	424	85

Fig. 4.1 Overview of radon undulation observed in all the Monitoring Stations



4.2 Discussions

(i) Odo Ona Monitoring Station

The deduced Radon concentration ranges from 0 to 848 Bq/m^3.

The average Radon concentration for the monitoring Station within the period of investigation is 531.85 Bq/m^3

The standard deviation is 278.86 Bq/m^3

$X_{radon} > n\sigma$

Where n =1,2,3……..

X_{radon} = mean Radon concentration

σ = standard deviation

For station 1, $X_{radon} > 1.5\sigma$

Peak radon anomaly 848 $Bq/m^3 > 3\sigma$ was recorded on 21^{st} day of investigation. (13/4/2013)

(ii) Orita Challenge Monitoring Station

The deduced Radon concentration ranges from 424 to 2120 Bq/m^3.

The average Radon concentration for the monitoring Station within the period of investigation is 970.35 Bq/m^3

The standard deviation is 677.12 Bq/m^3.

For station 2, $X_{radon} > 1.4\sigma$

Peak radon anomaly 2120 $Bq/m^3 > 2.5\sigma$ was recorded on the 9^{th} day of investigation (5/4/2013)

(iii) Asipa Monitoring Station

The deduced Radon concentration ranges from 424 to 2120 Bq/m^3.

The average Radon concentration for the monitoring Station within the period of investigation is 904.40 Bq/m^3

The standard deviation is 522.67 Bq/m^3.

For station 3, $X_{radon} > 1.7\sigma$

Peak radon anomaly 2120 $Bq/m^3 > 4\sigma$ was recorded on 29^{th} day of investigation (25/4/2013)

(iv) Ratcon Quarry Monitoring Station

The deduced Radon concentration ranges from 424 to 1696 Bq/m^3.

The average Radon concentration for the monitoring Station within the period of investigation is 781.93 Bq/m^3

The standard deviation is 448.209 Bq/m^3

For station 4, $X_{radon} > 1.7\sigma$

Peak radon anomaly 1696 Bq/m^3 > 3.5σ was recorded on 13th day of Investigation (9/4/2013)

From the result of the data shown above, it can be clearly seen that Radon concentration is significant in each of the regions under investigation with the following ranking:

Orita Monitoring station	Highest (970.35 Bq/m^3)
Asipa Monitoring station	Very High (904.40 Bq/m^3)
Ratcon Quarry Monitoring station	High (781.93 Bq/m^3)
Odo Ona Monitoring station	Fairly High (531.85 Bq/m^3)

The discovery confirms that Radon concentration levels are based not on artificial activities of Quarries that periodically but regularly blasts causing ground vibrations but are rather caused by the tectonic nature of the lithosphere regions under investigation. It therefore, shows a correlation between the seismicity which is a product of earthquakes and radon exhalation.

Radon Safe limit

In the UK, there are action levels (200 Bq/m^3) and target levels (100 Bq/m^3) set for the average radon concentration in homes (over a 3 month period for detectors in a bed room and a living room). I don't know the details of the derivation of these levels, but they relate to dose to residents.

As for whether these levels are "safe", that rather depends on what you mean by "safe". There is a probability of radon exposure causing health effects that increases with increased radon concentration (with various adjustments for lifestyle, age etc). There is no scientific basis for a safe/unsafe threshold. There is a threshold between acceptable and unacceptable probability of health effects, which is derived as much from political considerations as it is from hard science.

5.1 CONCLUSION

The following conclusion could be made from this research work:

(i) The study offers an overview of radon anomaly in the region of study using the CR 39 Solid State Nuclear Tract Detector (SSNTD) for about two months.

(ii) The average radon measurement in soil gas at Orita Monitoring station ranked highest as 970.35 Bq/m^3 while the peak radon anomaly 2120 Bq/m^3 was recorded on the 9th day of investigation. (5/4/2013).

(iii) The average radon concentration for Asipa monitoring Station within the period of investigation is 904.40 Bq/m^3, while the peak radon anomaly 2120 Bq/m^3 was recorded on the 29th day of investigation (25/4/2013)

(iv) The average Radon concentration for Ratcon Quarry monitoring Station within the period of investigation is 781.93 Bq/m^3, while the peak radon anomaly 1696 Bq/m^3 was recorded on the 13th day of Investigation (9/4/2013).

(v) The average Radon concentration for the monitoring Station within the period of investigation is 531.85 Bq/m^3, while the peak radon anomaly 848 Bq/m^3 was recorded on the 21st day of investigation. (13/4/2013).

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