SYNERGISMS OF RN-222 REDUCTION EMANATIONS WITH DIFFERENT THICKNESS PLASTER FROM INTERLOCKING BLOCK

by

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DECLARATION

I declare that this thesis entitled “SYNERGISMS OF RN-222 REDUCTION EMANATIONS WITH DIFFERENT THICKNESS PLASTER FROM INTERLOCKING BLOCK” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

Name : ______________________________

Date : ______________________________

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ABSTRACT

Radon is radioactive materials which exist in human surrounding and it dangerous to human and environment because it is tasteless, invisible, touchable colourless and odourless. It is a decay product of Ra-226 and ultimately of U-238, both of which are naturally contain in soil and rocks which produce from the Earth's crust. Rn-222 originated from rock and soil which can enter any building through cracks, construction joint and also from materials that build it. Rn-222 also is a second lead lung cancer disease besides smoking because of the inhalation of radon gas in high concentration is dangerous that can affect the organ and tissue inside human body due to the alpha particles that contain in radon. So, the measurements of radon concentrations were done in prototype room at material laboratory, Universiti Malaysia Kelantan, Jeli due to the effect of hazard and the different thickness of plaster from interlocking block were chosen. In this research, Radon Sentinel 1030 Model was used to measure the radon concentrations thus investigate the radon emanation produce and effect from interlocking block with different plaster as well as to study the factor that influence radon emanation in environment. The different thickness of plaster which consist layer 1 with thickness (0.5 – 1.0) cm, layer 2 (1.0 – 1.5) cm and layer 3 (1.5 – 2.0) cm was placed in the prototype room with its measurement 40 cm height x 40 cm long x 40 cm wide to control the factors that can affect the radon produce. The research runs in four days per layer. Layer 1 has the most radon concentrations than layer 2 and layer 3. For layer 1, the maximum Rn-222 concentration detected is 0.2 pCi/L, for layer 2 is 0 and also for layer 3 is 0. Thickness of plaster play important rule that can affect to Rn-222 emanation. This is due to the alpha particle properties which are alpha particles has short travel distance and can blocked by sheet of paper. Environmental factors also can affect the emanation of Rn-222 such as humidity, temperature, and pressure. The result show less Rn-222 because of the brief monitoring. To get the better result, this research must run at least 6 month. At the nut shell, radiation properties, thickness of layer, environmental factors and time monitoring in this research can affect the emanation of Rn-222.

SINERGISMA RN-222 TERHASIL DARIPADA BATA INTERLOCKING DENGAN KETEBALAN PLASTER YANG BERBEZA

ABSTRAK

Radon adalah bahan-bahan radioaktif yang wujud dalam persekitaran manusia dan ia berbahaya kepada manusia dan alam sekitar kerana ia adalah, tidak kelihatan, tidak dapat disentuh, tidak berwarna dan tidak berbau. Ia adalah produk pereputan Ra-226 dan akhirnya U-238, kedua-duanya secara semula jadi terhasil daripada tanah dan batu-batu yang dikeluarkan dari kerak Bumi. Rn-222 berasal dari batu dan tanah yang boleh memasuki mana-mana bangunan melalui retakan, pembinaan bersama dan juga dari bahan-bahan yang membinanya. Rn-222 juga boleh menyebabkan penyakit kanser paru-paru kedua merbahaya selain merokok kerana menyedut gas radon dalam kepekatan yang tinggi adalah berbahaya dan boleh memberi kesan kepada organ dan tisu dalam badan manusia kerana zarah alfa yang terdapat dalam radon. Jadi, ukuran kepekatan radon telah dilakukan di dalam bilik prototaip di makmal bahan, Universiti Malaysia Kelantan, Jeli menyebabkan oleh kesan bahaya dan ketebalan plaster yang berbeza dari blok yang sama telah dipilih. Dalam kajian ini, Radon Sentinel 1030 Model digunakan untuk mengukur kepekatan radon, menyiasat hasil radon emanasi dan kesan dari bata interlocking dengan plaster yang berbeza dan juga untuk mengkaji faktor yang mempengaruhi emanasi radon dalam persekitaran. Ketebalan yang berbeza daripada plaster yang mempunyai lapisan 1 dengan ketebalan (0.5-1.0) cm, lapisan 2 (1.0 - 1.5) cm dan lapisan 3 (1.5 - 2.0) cm diletakkan di dalam bilik prototaip dengan yang berukuran 40 cm ketinggian x 40 cm panjang x 40 cm lebar untuk mengawal faktor-faktor yang boleh memberi kesan kepada terhasilnya radon itu. Kajian ini berjalan selama empat hari setiap lapisan. Lapisan 1 mempunyai kepekatan radon paling tinggi berbanding lapisan 2 dan lapisan 3. Untuk lapisan 1, kepekatan Rn-222 maksimum dikesan adalah 0.2 pCi / L, untuk lapisan 2 adalah 0 dan juga untuk lapisan 3 ialah 0. Ketebalan plaster memainkan peranan penting yang boleh memberi kesan kepada terbitan Rn-222. Ini adalah kerana sifat-sifat zarah alfa yang mempunyai jarak perjalanan yang pendek dan boleh disekat oleh sehelai kertas. Faktor-faktor persekitaran juga boleh mempengaruhi kesan dari Rn-222 seperti kelembapan, suhu, dan tekanan. Keputusan menunjukkan kurang Rn-222 kerana pemantauan kajian yang sekejap dan ringkas. Untuk mendapatkan bacaan yang lebih baik, kajian ini perlu menjalankan sekurang-kurangnya 6 bulan. Kesimpulannya, sifat sinaran, ketebalan lapisan, faktor persekitaran dan pemantauan masa dalam kajian boleh memberi kesan kepada terhasilnya Rn-222.

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NO		
i	pCi/L	Picocuries
ii	°C	Degree Celcius
iii	Pa	Pascal
iv	Rn-222	Radon-222
v	Ra-226	Radium-226
vi	U-238	Uranium-238
vii	EPA	Environmental Protection Agency
viii	WHO	World Heath Organization

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In our environment have radioactive that can harm human health. Radioactive are produce from all construction materials such as soil and stone. Naturally occurring alpha-particle radiation is ubiquitous in the environment, its primary source being radon (Rn-222) gas. Radon is a decay product of radium (Ra-226) and ultimately of uranium (U-238), both of which are naturally found in soil and rocks (Chauhan, Howland, Kutzner, et al., 2012) which emanate radioactive in small quantities and havor in atmosphere not on purpose can risk human life.

For example of the radioactive that contain in environment is Radon. It is radioactive and common isotopes in environment (Garver & Baskaran, 2004). The radon is present in the air which people can inhale it through human's nose. The radon contain in buildings can pose a risk to human health. The environment that contain high concentration of radon can cause lung cancer. 222Rn exposure and associated lung cancer risk over the past decade (Chauhan, Howland, Mendenhall, et al., 2012)

Regarding to this issue, the investigation on the concentration of radon in different construction material have been clame. Due to this, concentration of radon wil be measured in interlocking block with different plaster. This research will be done to determine which plaster produce the more or lower of radon from interlocking block and will describe which plaster is safe from high amount of radon clearly.

Interlocking block is one of the construction material that use to build any buiding and it also has strong chemical and physical properties. It commonly use in Malaysia. Interlocking block is make from small soil and added by cement and water. Then the interlocking block was gived dome pressure to it to be contructed to strong properties. This block also is very high resistant to heat and can avoid from fire hazard. It mix from clay, cement, soil, and water. The interlocking block made to build strong building and it difficult to collapse.

The factors that involve in the ractivity of radon concentration are temperature, humadity, pressure, human activity and ventilation. Radon concentration levels are measure using Radon Sentinel Model 1030. This model will help to record the reading of humadity, pressure and temperature of radon. Then the reading of radon concentration for different plaster is compared.

Alpha particle is the particle that contain in radon and public receives approximately half of its exposure to natural radiation. Epidemiological studies have found a positive correlation between exposure to Rn-222 and lung carcinogenesis (Chauhan, Howland, Mendenhall, et al., 2012). Alpha particles is very dangerous to human beacause it is not smelly, can’t be seen with our eyes, and can’t touch it. This can approve the alpha particles is very dangerous to human life. Besides, alpha particles also can easily through human body but it can’t easily through material such as paper, coating and other materials that protect human in life.

The measurement of radon concentration is picocuries per liter (pCi/L). This measurement is source from Environmental Protection Agent (EPA) which the limit of radon concentration average in a year-long is not more than 4 pCi/L. If the radon concentration is higher, it can risk human health.

1.2 PROBLEM STATEMENT

Nowdays, concreate widely used for buiding and house. The high level of radon concentration in the construction material can affect the human health and can cause lung cancer. So in this research, the Radon Sentinel Prototype is use to avoid from the factors that can affect the concentration of radon. The study carried out the concentration of radon with different plaster from interlocking block. Different plaster can cause the amount of radon concentration produce from interlocking block. Which is more thick the plaster, the radon concentration is lower.

1.3 OBJECTIVE

1. To investigate the radon emanation produce and effect from interlocking block with different plaster.
2. To study the factor that influence radon emanation in environment.

1.4 EXPECTED OUTCOMES

The concentration on radon in construction material will be reduced to less than 4.0 pCi/L. The measurement was assigned by Environmental Protection Agent (EPA). Radon concentration on the interlocking block will be lower if the plaster has close structure and the thickness of plaster is more thick. The alpha particle cannot tunnel the close structure of plaster. In this research different thickness of plaster is use. The plaster used also must less porosity and high resistant to chemical and physical interaction. it can prevent from the radon concentration to tunnel the plaster.

1.5 SCOPE OF RESEARCH

The research is include the interlocking block, Rn-222, different plaster, protocol room and alpha particles. In this research, the thickness of plaster is different which has three layer. In theoritical, the different of thickness are affect the emanations of radon produce from the interlocking block. If the plaster more thick, amount of radon concentration produce to the environment is less. This is because of the structure of plaster. It more dense and no space are provide to the radon gas out through the plaster. The structure are more close. In the other hand, interlocking block that use in this experiment also have the same size and types. This way is to avoid from the amount of radon gas produce are same and constant. Size of interlocking block also currently affected the amount of radon gas produce. The interlocking block are made from clay, cement, soil and water. This ingredients are the main items of the radon gas produces. Futhermore, prototype perpective room is the main play important role in this experiment because want to get the constant humadity, pressure and temperature. This prorototype model room had been made up to control the factor of the radon concentration from others source.

CHAPTER 2

LITERATURE REVIEW

2.1 Type of Radiation

Energy that propagate through the space in the form of waves or particle called radiation. Radiation is the most higher energy that can give human long term desease and harm to human DNA due to the presence of alpha particles which can affect human health. There has been much evidence over the years of biological effects in cell and animal models as well as in humans exposed to alpha particles (Chauhan, Howland, Kutzner, et al., 2012).

There are three types of radioactive decays in the radiation. First is alpha decay which occurs when the particles from the nucleus were ejected by atoms that consist two neutron and two proton. When this process happens, the atomis number exceed by 2 and also the mass decreases by 4. Radium, radon and thorium are the examples of alpha emmiters.

Meanwhile strontium-90, carbon-14, tritium and sulphur-35 will be irridiate a beta decay. The basic beta decay is when a neutron was turned into a proton and an electron is emmited from the nucleus. This also happen when the atomic number increase by one but the mass only decrease slightly.

Lastly is gamma decay. Gamma decay is the wave and takes place when there is residual energy in the nucleus following alpha or beta decay, or after neutron capture (type of nuclear reaction) in a nuclear reactor. This will happen when the gamma release the residual energy as a photon. The mass of atomic number of radio isotope from gamma decay generally does not affected because gamma is only wave. Example of gamma emitters are iodine-131, cesium-137, cobalt-226 and technetium-99m.

2.2 Alpha Radiation

Figure 2.2.1 showed alpha particle radiation. When the particles with two proton and two neutrons is ejected from the nucleus of radioactive atom that occurs in radioactive process, the alpha decay produced. Alpha particles will be possible in heavy element such as uranium, thorium and radium because the atoms are contain very rich of neutron. When uranium-238 decays by alpha emmission, thorium-234 was produced because of the alpha positive charge which alpha particle contain two proton automatically they have two positive charge. So they can stable the atom.

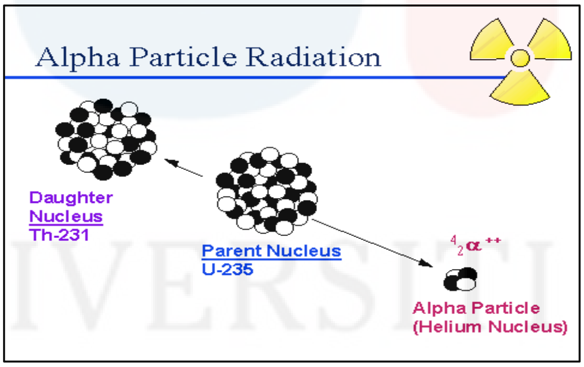

Figure 2.2 Alpha Particle Radiation

$$^{238}_{92}U \longrightarrow ^{234}_{90}Th + ^{4}_{2}He$$

Equation of Alpha Decay (Source : retrieve from 22 Mei 2016)

Alpha particle can be harmful to human if the materials are inhaled, received or absorbed through open wound. On the other hand, alpha particles can readily interact with material they encounter including air, causing many ionizations in a very short distance. Alpha particle will travel less than a few centimeters in air and will stopped by a sheet of paper.

The characteristics of alpha particles are it is not penetrating. So the instrument cannot detect the alpha radiation when it is in water, blood, dust, or other material. Besides, alpha radiation also is unable to penetrate turnout gear, cloths or a cover on a probe because of their very short travel distance through air.

2.3 Historical Background of Radon

In 1998, the epidemiological study conducted in Iowa US, showed beyond any reasonable doubt that radon decay products cause lung cancer among women who lived at least twenty years in their homes (Unit, n.d.)

Radon is a radioactive noble gas, having three naturally – occurring radioactive isotopes 219Rn (Actinon, a by-product of the Actinium Series), 220Rn (Thoron, a by-product of the Thorium Series) and Rn-222 (Radon, a by-product of the Uranium Series). Radon-222, being the most important radon isotope in terms of radiation exposure, is measured in different environments to determine its contribution to human radiation exposure. Rn-222 contributes about 55% of the annual radiation dose to the general population from all sources and 70% from natural radiation sources (George, 1998)

2.4 Radon from Construction Materials

All construction materials contain radioactive materials, albeit in small quantities. Rock and soil also contains natural radionuclides including the decay products of uranium and thorium as well as the radioactive isotopes of potassium (Ju et al., 2012). The report of the Technical Basis for a Candidate Building Materials Radium Standard released by the EPA of the US in 1996 recommends that the concentration in aggregate and cement used for concrete should not exceed 370 Bq/kg based on the Ra-226 content and the concentration in concrete itself should not exceed 180 Bq/kg (5 pCi/g) (Ju et al., 2012).

U^{238}, U^{235}, Th^{232} continuously emanate Rn-222 from the decay of the radionuclide. The isotope Rn-222, produced from the decay of U^{238}, is the main source (approximately 55%) of internal radiation exposure to human life (Salih & Aswood, 2016). Indoor radon can be attributed to different sources, such as earth-based building materials, domestic well water, and soil adjacent to the building, as reported by Nazaroff and Nero (1984) in their study of the entry of radon into residences (Tung, Niu, Burnett, & Lau, 2005). Concrete is an earth-based building material, which comprises uranium decay series products.

2.5 Radon in Sand, Rock, and Water

In raw materials such as sand, rocks and water there have many amount of radon produced that cannot been seen by human and detect it. Radon can be found in both air and water if the instrument radon sentinel was used. Uranium is a common mineral produced from the earth's crust and transfer to the raw materials such as soil, sand, rocks and water (Alharbi et al, 2014). These radioactive element exists in the form of three unstable isotopes. The existence of radon gas in the air and water because of the isotope emit alpha particle.

Radon gas is throughout from the rocks and soil are because of the formations of mineral structures that develops during the crystallization process (Unit, n.d.). Uranium are found in the crack structure on the outer rocks surface. Rocks, soil and underground water transmit the gases and liquid because of the dissolved uranium and also the radon gas move through the material that have highest permeability (Arafa, 2002).

2.6 Health Effect of Radon

Radon is a naturally occurring radioactive gas. When inhaled, radon can cause mutations which lead to lung cancer. During the Health Canada Radon Workshop [2] held in Ottawa, March 3–4, 2004, some practitioners working in the front line of radiation protection showed strong interest in having risk tables for individuals exposed to short periods, such as 10 or 20 years (Chen, 2005). Epidemiological studies conducted among uranium mine workers, as well as animal cancer studies, have found a strong correlation between 222Rn exposure and an increase in the development of lung cancer (Chauhan, et al., 2012). The results from these studies have yielded mixed data, with some studies suggesting a positive association between Rn-222 concentrations and lung cancer, while others show equivocal or negative results (Chauhan, et al., 2012).

The alpha particle in radon gases has potential to give the most damage to the human tissue (Khairul, Abdul, Hamzah, et al., n.d.). If radon hover in the air, human lung are constantly threatened with dose pf alpha radiation. The human risk against radon radiation is depends on the concentration of radon present in our home and the amount of time spend there.

However, the quality of air, humadity or dust contain and especially second hand cigarette smoke can increase the problem and help the transport of radon to higher potential exposure.

CHAPTER 3

MATERIAL AND METHODS

3.1 Research Materials

Radon Sentinel Model was used to calculate the data of this research. This instrument very sensitive to radiation, so in this research must be avoid from the factor that can cause the error. Interlocking block also is the main building material to construct the buiding.

3.1.1 Interlocking Block

Figure 3.1 : Interlocking Block (Source : retrieve from 22 March 2016)

Interlocking block that show in figure 3.1 is one of the construction material that use to build any buiding and it also has strong chemical and physical properties. It commonly use in Malaysia.

Interlocking block is make from small soil and added by cement and water. Then the interlocking block was gived dome pressure to it to be contructed to strong properties. This block also is very high resistant to heat and can avoid from fire hazard.

Clay, cement, soil, and water. The interlocking block made to build strong building and it difficult to collapse.

3.3.2 Plaster

Figure 3.2 : Plaster (Source : retrieve from 20 Mei 2016)

A soft mixture of lime with sand or cement and water for spreading on wall. Other structures to form a smooth hard surface when dried a piece of material that is put on the skin over a small wound.

3.2 Research Equipment

Vernier calipers is the instrument that use to calculate the thickness of plaster. This will be the exact value of the thickness of plaster. Second is prototype perpective box. This equipment is to cover the sample and avoid the factors of radon concentration enter the research air.

3.2.1 Radon Monitor

In this research device using for measure radon concentration is Radon Sentinel Model 1030 as shown in figure 3.1. The Radon Sentinel Model is the device created to detected the radon concentration. There are three term in reading of radon concentration, which are humidity, temperature and pressure. The unit was designed for professional inspectors to use in homes and building. This detection is continues radon monitors by that can be operated using AC adapter or four size C alkaline batteries. Then it is suitable to calculate radon levels and fluctuation over short time.

Figure 3.3: The Radon Sentinel model 1030 (Source : Sun Nuclear Corporation)

This device showed 16-characters instruction and radon reading. While the button below the display are used to enter data, set parameters, and display data value. This Sentinal also need Radon Monitor Software to be used to measure the radon gas and also connected via USB cable.

Model 1030 Radon Sentinel Specifications

Description	Value
Measurement Range	0.1 to 9999 picocuries/liter (pCi/l) or 1 becquerels per cubic meter (Bq/m**3**) to 99.99 kilo becquerels per cubic meter(kBq/m**3**)
Accuracy	±20% or 1 pCi/l, whichever is greater after 24 hours
Detector	Diffused-junction photodiode • Model 1028: quantity 1 • Model 1029: quantity 2 • Model 1030: quantity 6 Active volume: 9.4 cm3 Dome volume: 63 cm3
Measurement Interval	0.5, 1, 2, 4, 8, 12, 16, 20 or 24-hour intervals, selectable by user
Test Duration	1, 12, 24, 36, 48, 60, 72, 84, 96, 100, 999 hours, selectable by user (maximum of 720 measurements)
Sensitivity	• 1028: 3 counts per hour per picocurie per liter (cph/pCi/l) • 1029: 6 counts per hour per picocurie per liter (cph/pCi/l) • 1030: 15 counts per hour per picocurie per liter (cph/pCi/l)
Display	16-digit reflective LCD display
Status Light	Green LED (light emitting diode) indicates USB to PC connection
Environmental sensors	• Temperature: 0 to 120 ± 2 degrees F -18 to 49 ± 1 degree C) • Pressure: 10 to 15 ± 0.5 psi 69 to 104 kPa +/- 3 kPa • Humidity: 20 to 90% relative humidity ± 5%
Operating Environment	• 45 to 95° F (7 to 35° C) • 20 to 90% relative humidity, non-condensing
Keypad	6-digit membrane switches with multiple functions
Disturbance Sensor	Inertial switch; report shows “M” for motion
Storage Environment	• –22 to 122° F (–30 to 50° C) • 10 to 90% relative humidity, non-condensing
USB Data Port	USB connector allows two-way

	communication with PC
Power Supply	110-240 VAC 50-60 Hz converted to 5 VDC 500 mA USB connection/power adapter
Battery Power/Backup	Four size C alkaline (non-rechargeable) batteries supply 300+ hours of operation when AC power is not connected.
Handle	Integrated handle for carrying or for use with cable lock

Data 3.1 (Source : retrieve from 22 Mei 2016)

3.2.2 Vernier calipers

Vernier calipers is a measurement instrument to measure the thickness of object and has a consisting scaled rule with projecting arm. It attached a sliding vernier with a projecting arm that forms a jaw with the other projecting arm as shown in figure 3.4.

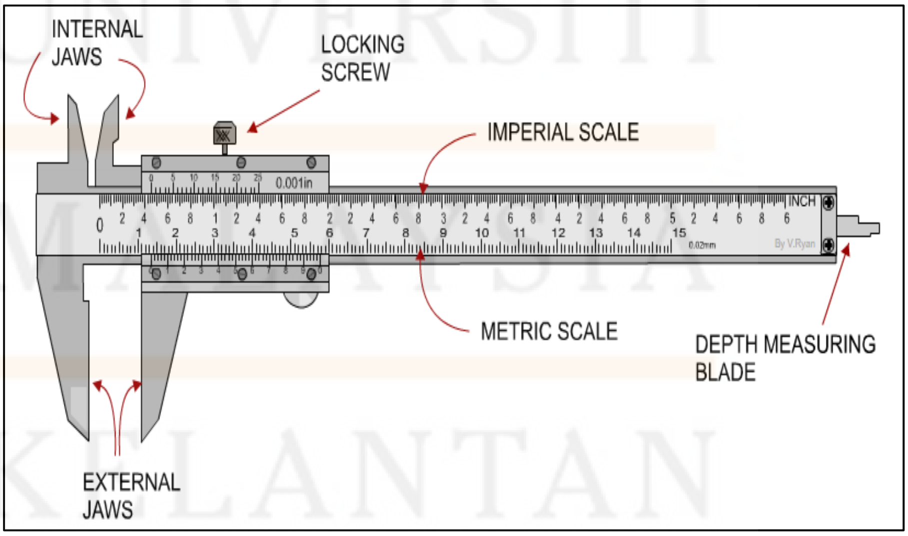

Figure 3.4 : Vernier Calipers (Source : retrieve from 22 March 2016)

3.2.3 Prototype Room

Figure 3.5 : Prototype Room

This instrument is use in this experiment to control the factors of radon like humadity, pressure, temperature. It give a constant measurement to radon because it free from air, pressure, humadity and temperature. The prototype has volume with the length, weight and thickness of 40cm, 40cm, 40cm and 1cm respectively.

3.3 METHODS

The interlocking block is the sample that want to use in this research so it is the main material to calculate the amout of radon concentration. Radon concentration will detected in this interlocking block by using sentinel model. Plaster also the material that played important role in this research because the plaster can block the radon through it. It can prevent the radon from interlocking block through out the plaster.

3.3.1 Study Area

The study will be take placed at the prototype room in material laboratory at third level building, in Universiti Malaysia Kelantan Kampus Jeli Kelantan. The radon concentration will be measured in the prototype room for 24 hours per day and 30 minutes of time interval. The radon sentinel will be take the reading of radon in picocuries per liter (pCi/L).

3.3.2 Preparation of Sample

In this research, the result is the amount of radon concentration produce from the interlocking block with different thickness of plaster so different thickness of plaster is use to cover up the interlocking block.

The interlocking block must be covered by plaster with different thickness. In the other hand, in early of this research the initial amount of radon concentration must be calculated without using the plaster. The initial amount of radon calculate only produce from interlocking block, so the result must be different after we use the plaster to cover up the interlocking block.

After the initial radon produce from interlocking block calculated, use the plaster to cover the interlocking block with first thickness of plaster and calculate it. The first layer of plaster is more thin because this reseach want to calculate the amount of radon with different of thickness. This research need three layer of plaster that want to calculate the amount of radon produce.

Every layer of plaster need to be calculated four period of times to collect the average of radon produce and for every one of the period, need 24 hours to collect the result and for every 24 hours, the result will be collect on 30 minutes per one period. There have the range of thickness for every layer which the first layer has 0.5 – 1.0 cm. For second layer is 1.0 - 1.5 cm and third layer is 1.5 – 2.0 cm. Sand and cement was mix into a small container and stir it. After that, put water to the mix and then stir the mix with water. Lastly cover the interlocking block with plaster. The steps to cover the interlocking block with plaster has shown on Figure 3.6.

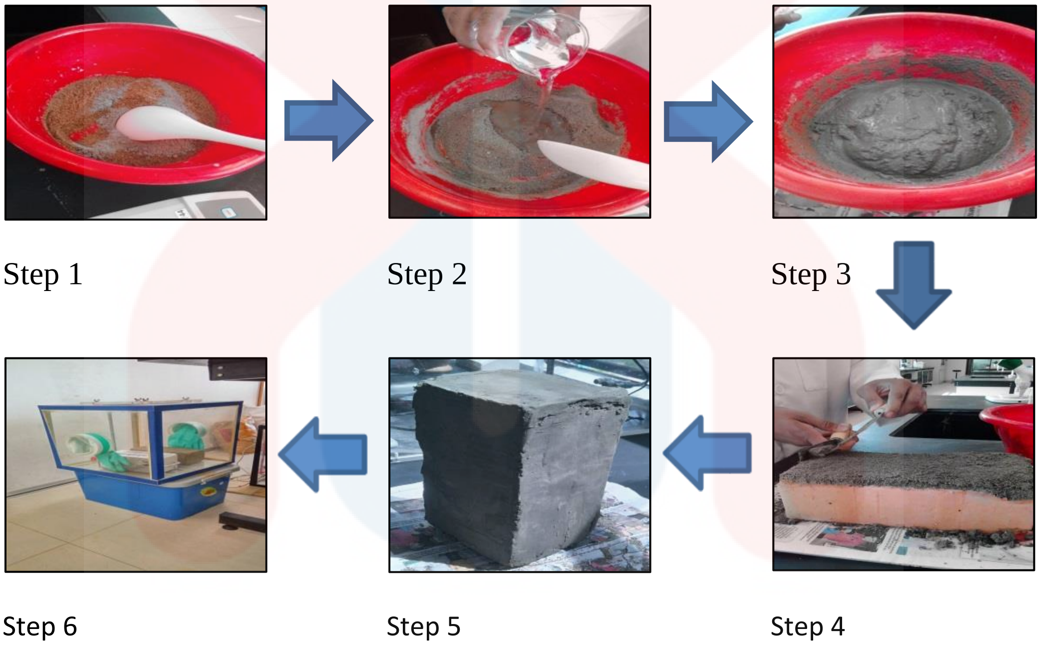

Figure 3.6 : Steps to cover the interlocking block with plaster

The ratio amount of material used in this research is 3:1 where 3 is the amount of sand use and 1 is the amount of cement use. The amount use was calculated in gram as shown in table 3.1.

Layer	Materials	Weight (g)
1	Sand Cement Water	300 g 100 g 75 ml
2	Sand Cement Water	450 g 150 g 135 ml
3	Sand Cement Water	600 g 200 g 190 ml

Table 3.1 : Weight of materials use in each layer

3.3.3 Radon Measurement

After the materials preparation, this research will continue with radon measurement. This is want to calculate the concentration of radon produce from the interlocking block using different thickness of plaster.

CHAPTER 4

RESULT AND DISCUSSION

In this research, rapid measurements have been take by using Radon Sentinel Model 1030 for the thickness of plaster from interlocking block Rn-222 simultaneously. Concentration of Rn-222 were measured for three different thickness of plaster from interlocking block which layer 1 consist of 0.5-1.0 cm, layer 2 consist of 1.0-1.5 cm and layer 3 consist of 1.5-2.0 cm and this research was run in material laboratory at third level of academic building Universiti Malaysia Kelantan. The results of the thickness from interlocking block Rn-222 concentration measured in perpective box placed in material laboratory at third level of academic building in Universiti Malaysia Kelantan Kampus Jeli are reported in Appendix A and data of raw materials in Appendix B.

4.1 The Rn-222 concentration produced from raw materials

In this research, raw materials cause Rn-222 concentration measurement. This is because the raw materials are natural part to our environment and consist the Rn-222 concentration such as interlocking block, cement, sand, prototype room, and water. Rn-222 emmited from natural source for example soil, rock and sand (Besar, at el., 2016).

Table 4.1 show the Rn-222 concentration of raw materials that measured in this research to check the initial reading before run the research.

Table 4.1 : Rn-222 concentration of raw materials

Raw Material	Average of Rn-222 concentration (pCi/L)
Interlocking Block	1.256
Prototype Room	0.977
Cement	0.881
Sand	0.788
Beaker	0.625
Water	0.342

Raw materials are the main component used in this research such as interlocking block, prototype room, cement, sand, beaker and water. Figure 4.1 show the average of Rn-222 concentrations use in this research.

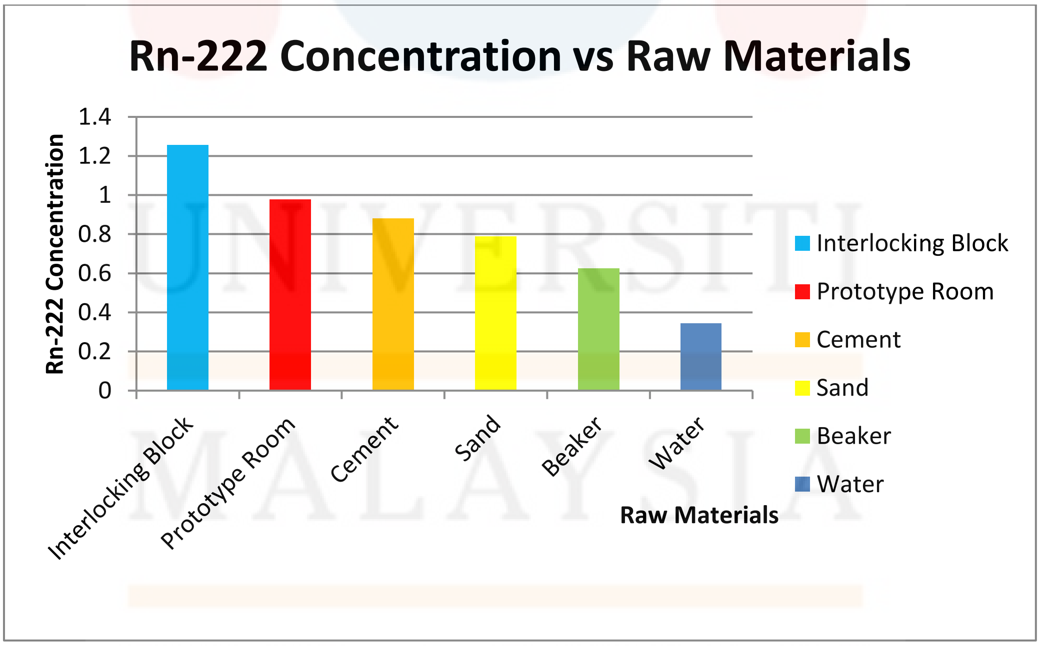

Figure 4.1 : Average Rn-222 concentrations of raw materials

4.2 Scale of Data

The data collected need to have a standard or scale to easier analysis and interpreted the data. In this research, the Rn-222 concentrations and its parameter that can cause the effect of Rn-222 such as humidity and temperature which were recorded by Radon Sentinel 1030 were set to a scale as shown on table 4.2.

Table 4.2 : Scale of the radon concentrations and its parameter

Parameter	Scale	Information
Temperature (°C)	< 26°C	Low Temperature
Pressure (pa)	< 10Pa	Low pressure
Humadity (%)	< 80.0 %	Low humidity
Concentration (pCl/L)	< 0.2 pCi/L	Low concentration

The scale was used as a reference to analyze the Rn-222 concentrations obtained from the measurements for different thickness of plaster.

4.3 Rn-222 concentrations for different thickness of plaster

The Rn-222 concentrations were obtained completely throughout for four days of each layer. The data were recorded daily within 24 hours per day to obtain 48 data series of 24 hours Rn-222 concentrations for each 30 minutes of time interval that had been set up. These 48 data series of Rn-222 concentrations recorded for layer 1 for one day. Each layer take four days reading of Rn-222 concentrations, so the data series recorded are 192. In this research, the Rn-222 concentrations are very low.

This is because of the factors involved in this research. The factors are humidity, pressure and temperature. Besides, the Rn-222 concentrations produced from interlocking block is depends on the thickness of plaster. If the plaster more thick, the existance of the Rn-222 concentrations low. It is due to the alpha particles nature which alpha particles only can travel in small radius.

4.3.1 Temperature, Pressure and Humadity Factors

Analyses of Rn-222 concentrations were also made according to the observations on the increasing and decreasing of the temperature, pressure and humadity of the concentrations as shown in table 4.3. The increasing and decreasing of the temperature, pressure and humadity were observed during the research. Concentrations of Rn-222 of layer 1 show that the increase in the evening and constantly decrease at noon and increase back at late night.

Table 4.3 : Rn-222 concentration for layer 1 for four days

Measurement	Rn-222 and ints factors	Morning	Noon	Late night
Day 1	Concentrations (pCi/L)	0.1	0.1	0.2
	Temperature (°C)	28.3	28.5	30.1
	Humadity (%)	69	68	67
	Pressure (Pa)	10	10	10
Day 2	Concentrations (pCi/L)	0.1	0.1	0.1
	Temperature (°C)	27.2	28.3	28.8
	Humadity (%)	78	80	80
	Pressure (Pa)	10	10	10
Day 3	Concentrations (pCi/L)	0.0	0.0	0.0
	Temperature (°C)	29.9	29.8	29.9
	Humadity (%)	74	69	66
	Pressure (Pa)	10	10	10
Day 4	Concentrations (pCi/L)	0.0	0.0	0.0
	Temperature (°C)	29.9	29.7	29.8
	Humadity (%)	69	68	67
	Pressure (Pa)	10	10	10

4.3.2 Rn-222 Concentrations Trends for Interlocking Block with layer 1

Based on the observations that been analyzed while considering the value of the temperature, pressure, humidity and concentrations given, Rn-222 concentrations can be related to three possible trends of weather parameters which stated in the Table 4.3.

Table 4.4 : Weather parameters for interlocking block with layer trends

Day	Weather
Morning	Temperature low, humidity high = Radon is low
Evening	Temperature high, humidity low = Radon is low
Late Night	Temperature high, humidity low = Radon is low

There are four set of data which were obtained daily based on the average temperature, humidity and pressure. Due to some uncontrollable factors such as climate rainy and unpredictable weather during the research process as well as moisture which are beyond of this research purpose, about one or three data shows some diffrences from the overall data.

4.4 The Rn-222 concentration produce and effect from interlocking block with different plaster.

In this study, the first objective is to investigate the radon emanation produce and effect from interlocking block with different plaster. The result of Rn-222 concentration produce from different thickness of plaster from interlocking block calculated by from day 1 to day 4.

The Rn-222 concentrations is calculate based on the Rn-222 concentrations by hours for each day as shown in Appendix A and B. The average of Rn-222 concentrations for 4 days in layer 1, layer 2, and layer 3 were recorded.

4.4.1. The Rn-222 concentrations produced from layer 1, layer 2 and layer 3

Table 4.5 presents the Rn-222 concentration from three different thickness of layer which are layer 1 (0.5 – 1.0) cm, layer 2 (1.0 – 1.5) cm, layer 3 (1.5 – 2.0) cm for 4 consecutive days. According to the Figure 4.2, the first layer showed that the interlocking block have Rn-222 concentration rather than layer 2 and layer 3. Layer 2 and layer 3 has no Rn-222 concentration. This conditions is due to the thickness of layer which is layer 2 and layer 3 have more thick plaster. This is because alpha particle cannot through out the thick layer of plaster.

Only the thickess of plaster for layer 1 show the maximum Rn-222 concentration with 0.2 pCi/L in four days. However, this value still less than EPA recommendation which is 4.00 pCi/L for indoor radon control in homes and buildings. From table 4.5, the maximum of Rn-222 concentrations of three different of plaster also lower than EPA action level (4 pCi/L), it means that radon to be distributed at very very low concentrations in the interlocking with plaster in the prototype room. Table 4.5 shown the maximum Rn-222 concentrations had been recorded during the research.

Table 4.5 : The maximum Rn-222 concentration for layer 1, layer 2, and layer 3.

Layer	Maximum Rn-222 concentrations (pCi/L)
1	0.2
2	0.0
3	0.0

From the Table 4.5, only layer 1 had recorded Rn-222 concentration during the research. Layer 2 and layer 3 showing no Rn-222 concentration. This is due to layer 2 and layer 3 have thick plaster covered the interlocking block.

Figure 4.2 showed the maximum Rn-222 concentration detected during this research vs time interval.

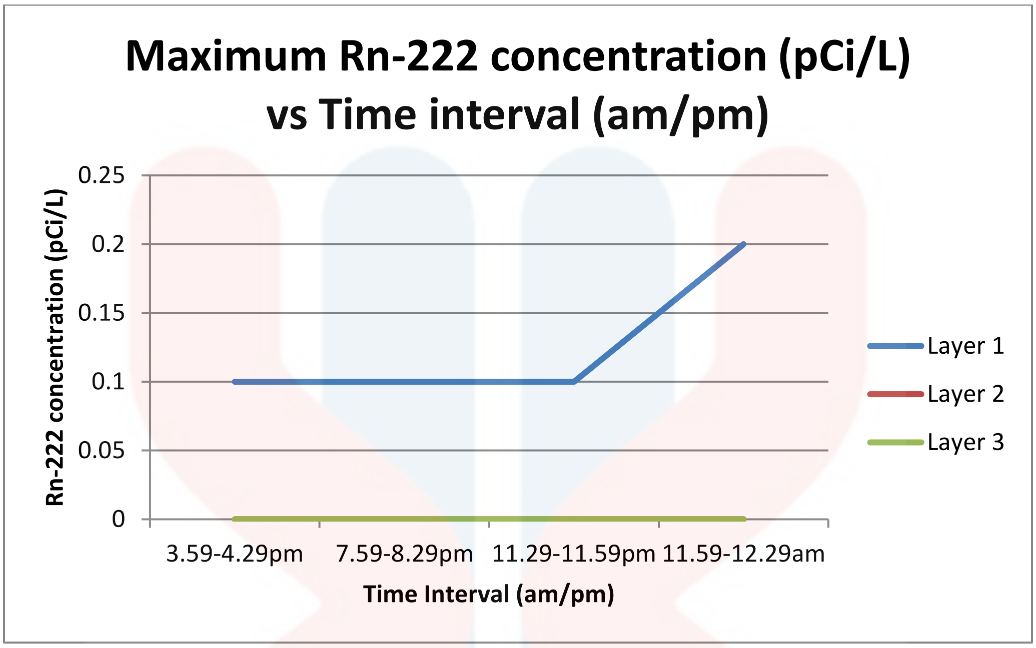

Figure 4.2 : Maximum Rn-222 concentration detected during this research vs time interval.

4.5 Other Factors Affecting Rn-222 concentrations

In general, there are several factors affecting Rn-222 concentrations such as flux density of radon exhaled (exhalation of radon gas) from the ground surface and the dispertion in the atmosphere with influence of meteorological factors such as temperature, pressure and humidity.

Alpha particles also cannot pass through the thin wall because alpha particle will travel less than a few centimeters in the air and will stopped by a sheet of paper. The characteristics of alpha particles are it is not penetrating. Besides, alpha radiation also is unable to penetrate turnout gear, cloths or a cover on a probe because of their very short travel distance through air.

For the other thickness such as layer 2 and layer 3, there are no Rn-222 concentrations detected from the interlocking block. This is because layer 2 and layer 3 have more thick plaster than layer 1. Layer 2, the range of plaster is (1.0 – 1.5) cm while for the layer 3 is (1.5 – 2.0) cm. Its showed those layer have greetest thickness and can cause the Rn-222 through those layers. Alpha particles cannot through those thickest layers because of the no space for alpha particle to past the plaster.

4.5.1. Thickness of Plaster

The interlocking block which covered with thin plaster give high concentration of Rn-222. When the thickness of layer more thick, the concentration of Rn-222 difficult to emanation from interlocking block. In this research, layer 1 show the most concentration of Rn-222 than layer 2 and layer 3.

Thickness of plaster also give the important rule to the emanation of Rn-222 to come out from interlocking block to the environment (Saidi, Jaafar, Khairul, & Abdul, 2013). This is due to the structure of plaster. If the structure of the plaster more close, the Rn-222 from interlocking block more diffilcult to emanation. This is because of the properties of a-particles.

4.5.2 Radiation Properties

Rn-222 consist of a-particle which Rn-222 is the decay product of the Ra-226. Alpha decay which occurs when the particles from the nucleus were ejected by atoms that consist two neutron and two proton. When this process happens, the atomis number exceed by 2 and also the mass decreases by 4. Radium, radon and thorium are the examples of alpha emmiters (Sharma, Singh, Esakki, & Tripathi, 2015).

Rn-222 cannot through out the thick plaster because of the alpha particle properties. Alpha particle will travel less than a few centimeters in air and will stopped by a sheet of paper and has a half-life of 3.82 days (Razab, et al., n.d.). Alpha particles are heavy and doubly charged which cause them to lose their energy very quickly in matter. They can be shielded by a sheet of paper or the surface layer of our skin. Alpha particles are only considered hazardous to a persons health if an alpha emitting material is ingested or inhaled. Beta and position particles are much smaller and only have one charge, which cause them to interact more slowly with material. They are effectively shielded by thin layers of metal or plastic and are again only considered hazardous if a beta emitter is ingested or inhaled. That's why the alpha particle cannot tunnel the thick plaster.

4.5.3 Radon Monitoring

This research was run 4-5 days for each layer. Time that run in this research are not suitable to detect the Rn-222 concentration. Rn-222 cannot detected if the research was run in brief monitoring. Brief monitoring give no result to the research because of the properties of Rn-222 which is its half life is only 3.8 days.

To get the right result of the Rn-222 concentration, the researh must run long term monitoring at least 6 month to detect the Rn-222 concentration (Razab, et al., n.d.). It avoid from half life of Rn-222 which is 3.8 days.

4.5.4 Environmental Factors

There are several environmental factors that can effect the Rn-222 concentration such as humidity, temperature and pressure. Analyses of Rn-222 concentrations were also made according to the observations on environmental factors which are humidity and temperature. For this analysis, Rn-222 concentrations with their environmental factors (temperature and humidity) were recorded in the morning, noon and at late night. Rn-222 concentrations trends recorded were varies in the morning, noon and late night where the concentrations are highly depending on environmental factors changes (Razab, et al., n.d.).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the research, the Rn-222 concentrations for layer 1, layer 2 and layer 3 for four days are different measurement and below than EPA standard (4 pCi/L). For the layer 1, Rn-222 still detected but it very low reading of Rn-222 concentration. Rn-222 concentrations vary depending on the weather parameter in addition with several factors such as ventilation and emanation from interlocking block and raw materials. The result also showed some differences in the morning, evening and late night where the Rn-222 increase in morning and late night and slowly drop in the afternoon. Here temperature and humidity plays important role in effecting the Rn-222 concentrations. Since the study area is in th prototype room at the level three in laboratory lab, the pressure can be control and constant. For the layer 2 and layer 3, there are no Rn-222 concentrations detected from interlocking block. It is because layer 2 and layer 3 have very thick plaster covered and the alpha particle cannot past the plaster because alpha particle will travel less than a few centimeters.

5.2 Recommendation

During research, there is selected place to run the experiment to control the factors that can effect the Rn-222 produced. Selection of place to run the equipment is needed to avoid reading error and disturbance from other student that uses the room. Further investigation is needed to comfirm the effect of Rn-222 concentrations to the materials laboratory and height of the building. Some technical problems such as air conditioner during class in material laboratory also can affected the result. Besides that, the window also might be open and close because of the others experiment.

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APPENDIX A

Graph Plot for Each Layer for 4 Consecutive Days

Figure A.1 : Layer 1 Day 1

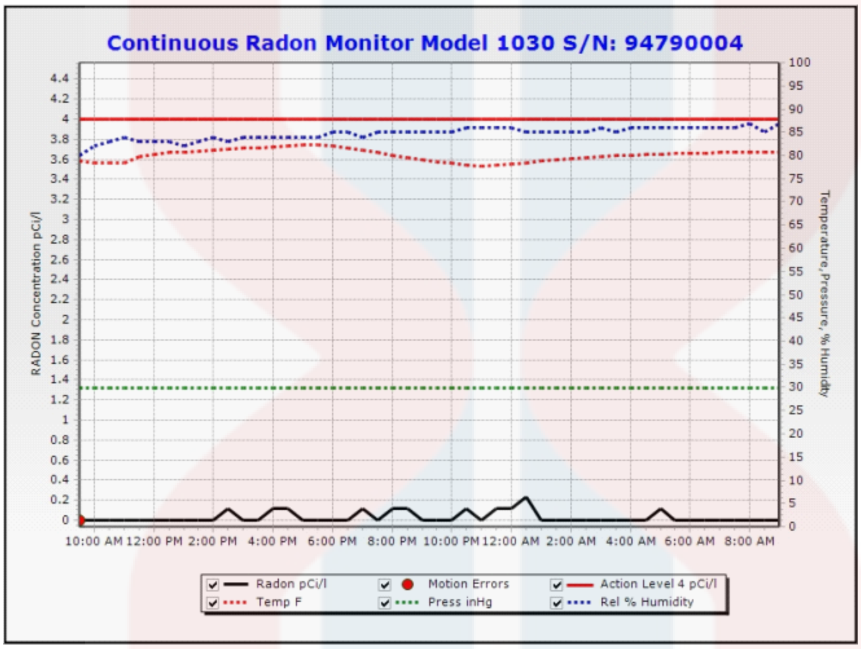


Figure A.2 : Layer 1 day 2

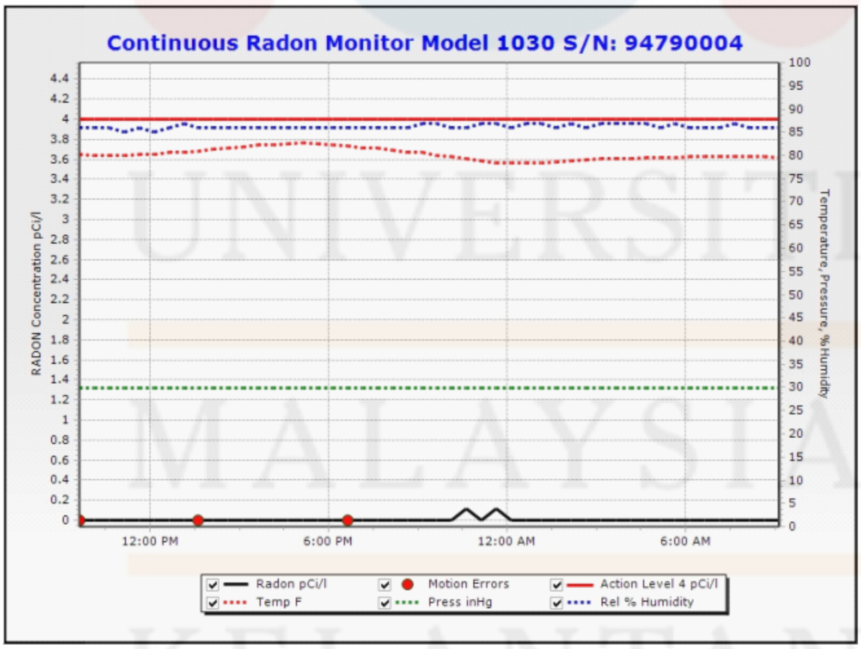


Figure A.3 : Layer 1 Day 3

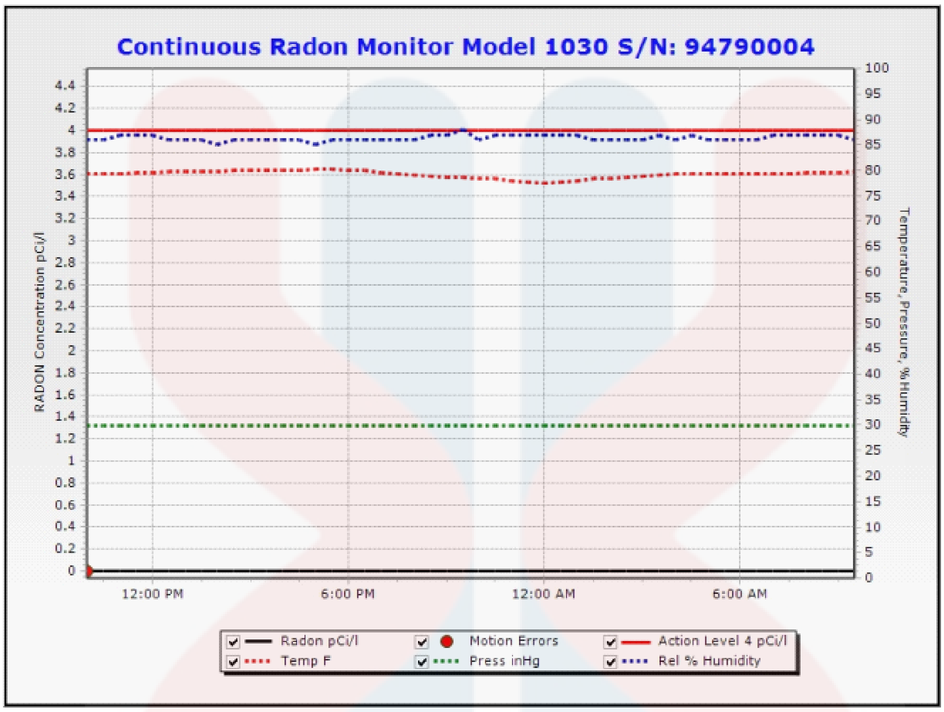


Figure A.4 : Layer 1 Day 4

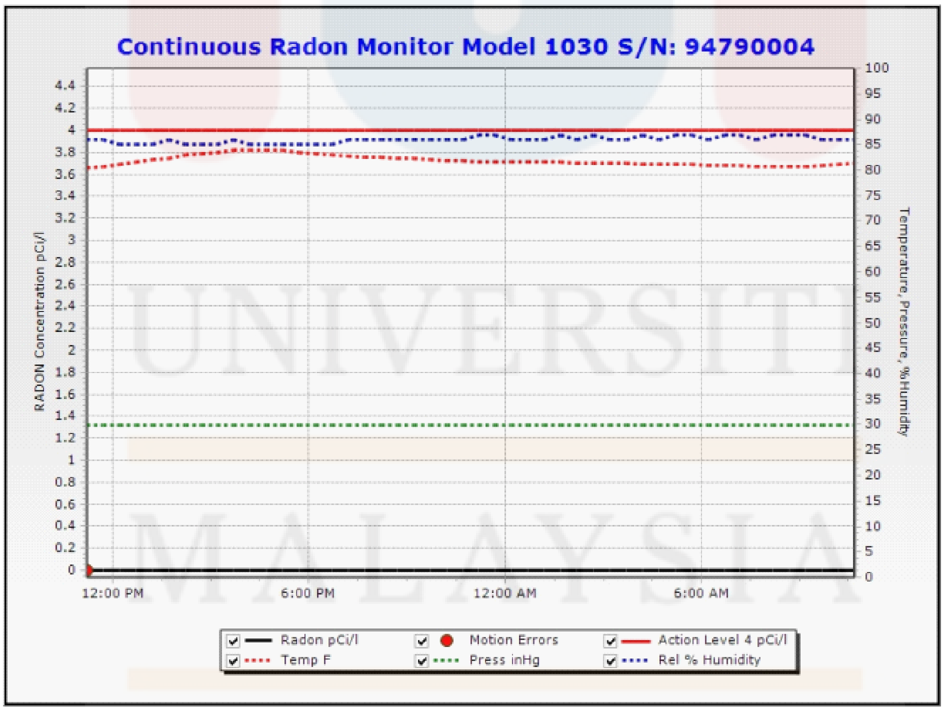


Figure A.5 : Layer 2 Day 1

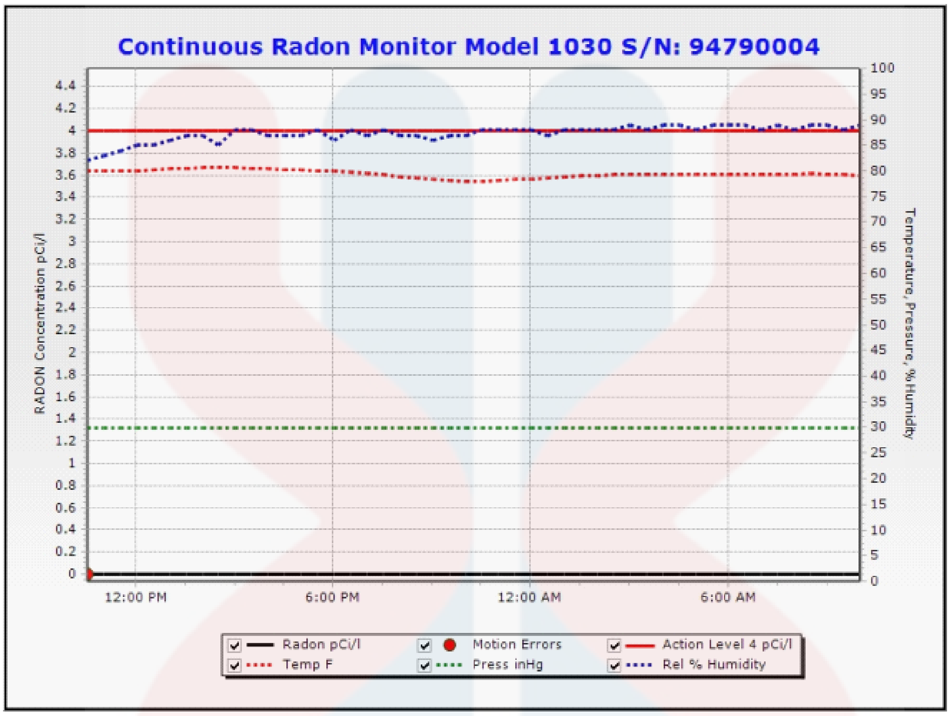


Figure A.6 : Layer 2 Day 2

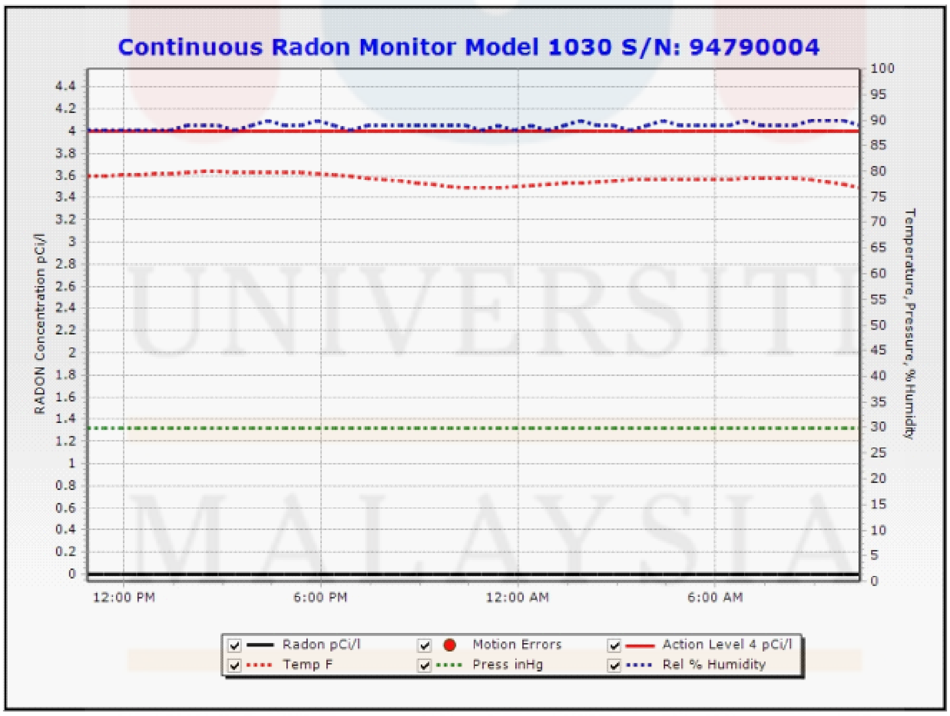


Figure A.7 : Layer 2 Day 3

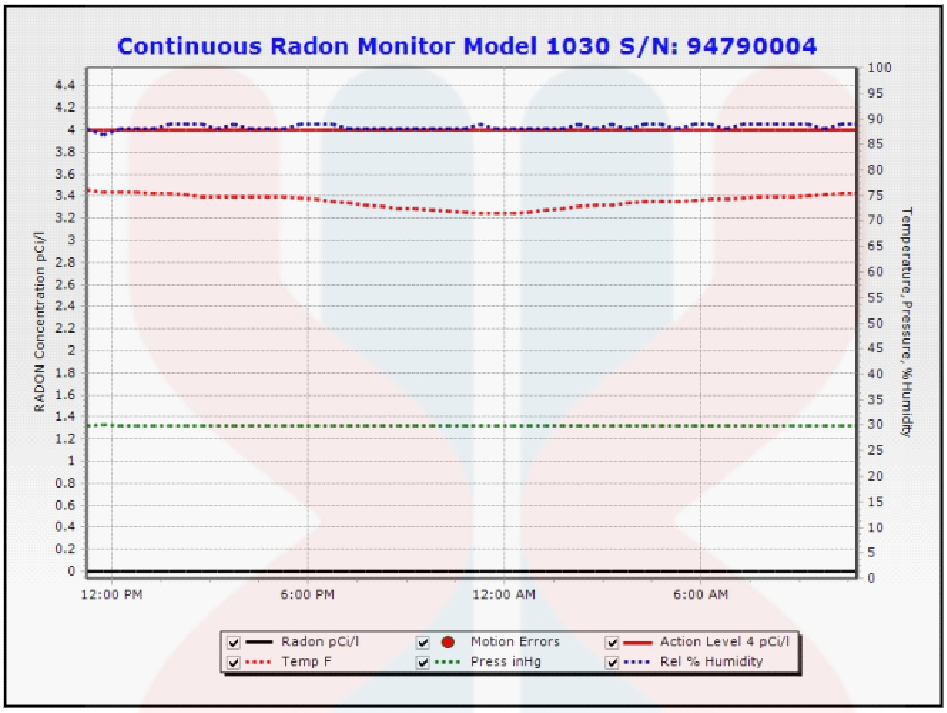


Figure A.8 : Layer 2 Day 4

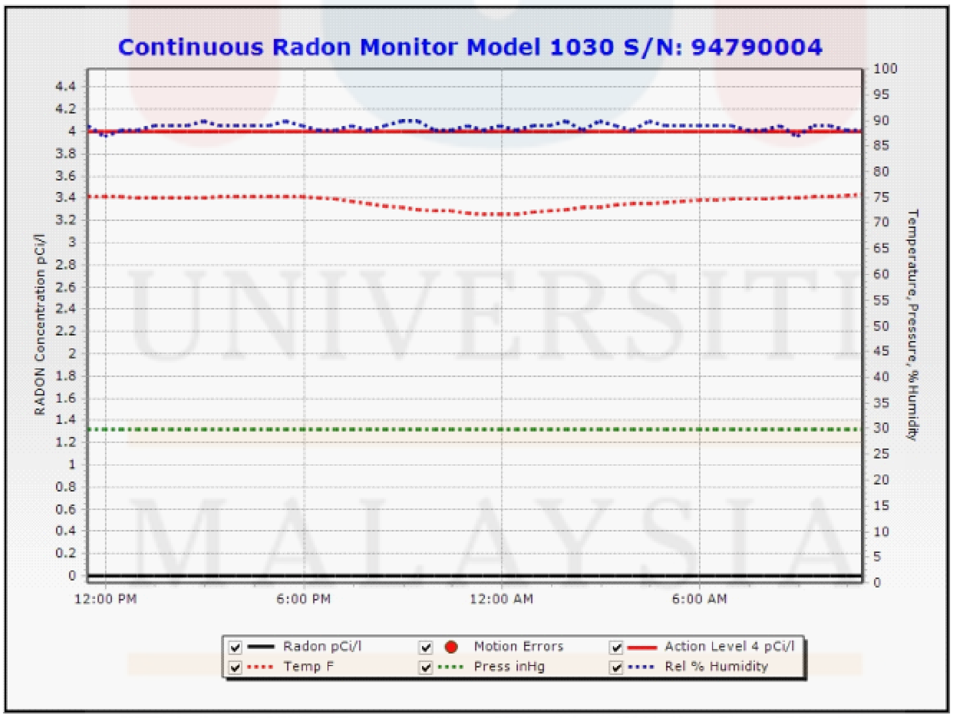


Figure A.9 : Layer 3 Day 1

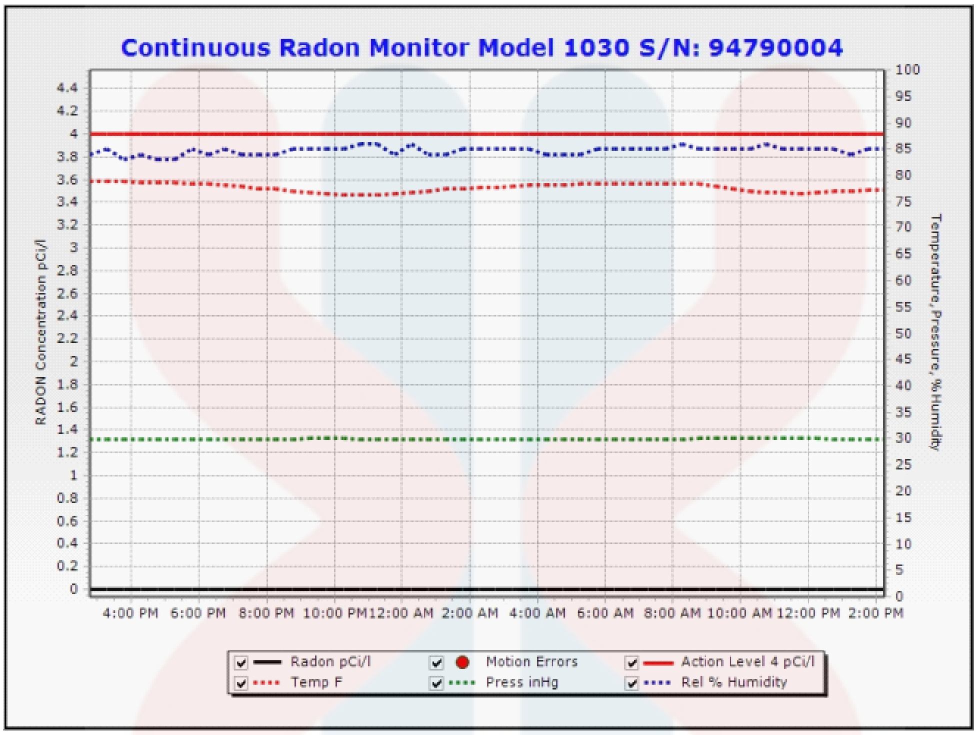


Figure A.10 : Layer 3 Day 2

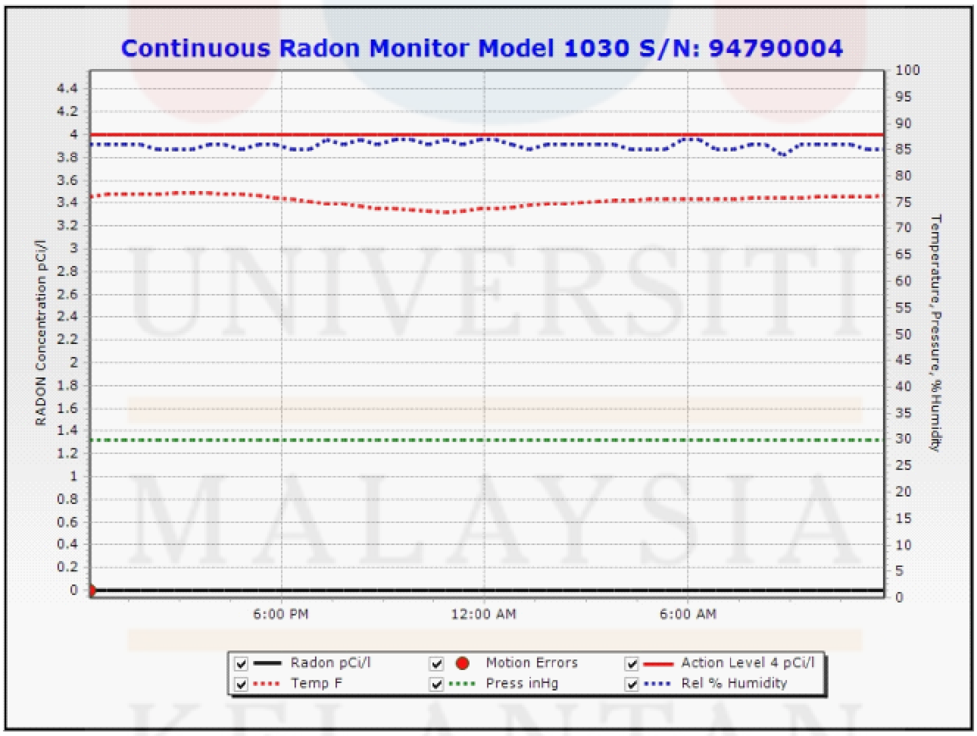


Figure A.11 : Layer 3 Day 3

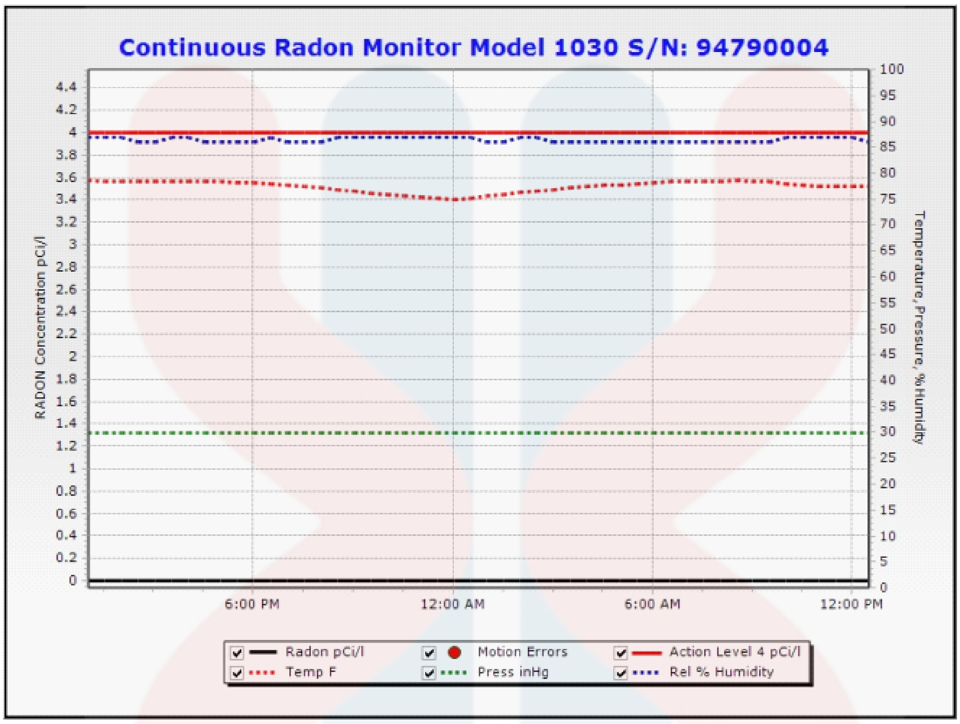
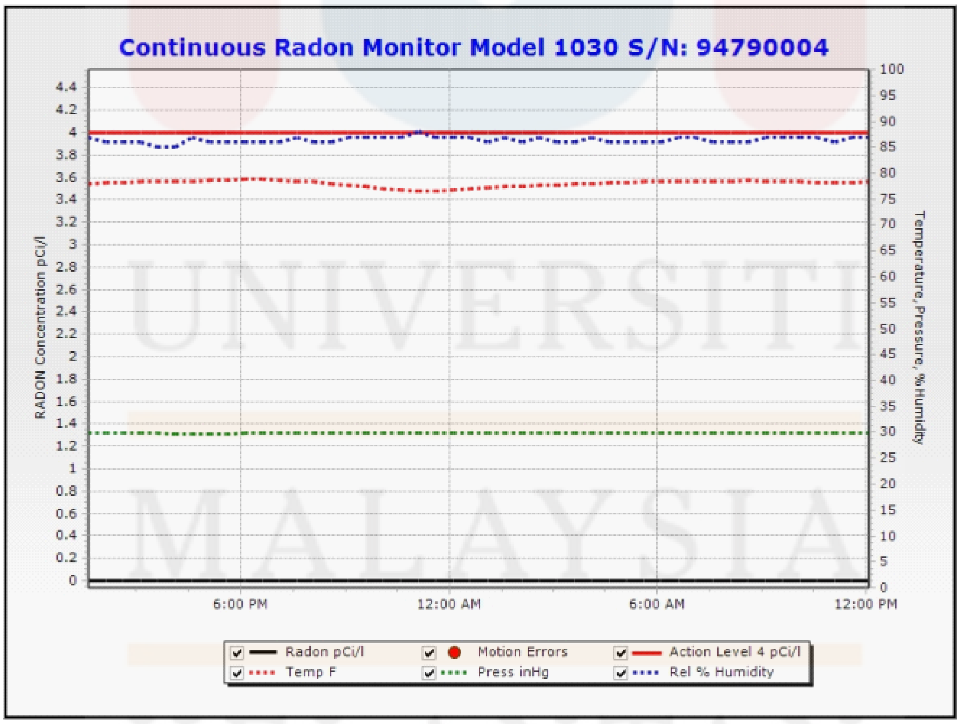


Figure A.12 : Layer 3 Day 4



APPENDIX B

Raw data collected in 24 hours

Table B.1 : Empty Beaker :

Date/Time	pCi/l F	Temp inHg	Pressure	Humidity %	Flags
8/14/2016 9:07 AM	0.100	84.400	29.80	69.00	
8/14/2016 9:37 AM	0.600	84.200	29.80	69.00	0
8/14/2016 10:07 AM	1.000	83.700	29.80	68.00	0
8/14/2016 10:37 AM	0.600	83.300	29.80	69.00	0
8/14/2016 11:07 AM	0.800	83.100	29.80	68.00	0
8/14/2016 11:37 AM	0.500	83.100	29.80	69.00	0
8/14/2016 12:07 PM	0.500	83.100	29.80	68.00	0
8/14/2016 12:37 PM	0.800	83.100	29.80	68.00	0
8/14/2016 1:07 PM	0.600	83.100	29.80	68.00	0
8/14/2016 1:37 PM	0.400	83.300	29.80	68.00	0
8/14/2016 2:07 PM	1.200	83.300	29.80	69.00	0
8/14/2016 2:37 PM	1.100	83.500	29.80	67.00	0
8/14/2016 3:07 PM	0.600	83.500	29.80	68.00	0
8/14/2016 3:37 PM	0.100	83.500	29.80	67.00	0
8/14/2016 4:07 PM	0.700	83.700	29.70	67.00	0
8/14/2016 4:37 PM	0.600	83.700	29.70	68.00	0
8/14/2016 5:07 PM	0.800	83.700	29.70	68.00	0
8/14/2016 5:37 PM	0.400	83.700	29.70	67.00	0
8/14/2016 6:07 PM	0.800	83.800	29.70	68.00	0
8/14/2016 6:37 PM	0.700	84.200	29.70	67.00	0
8/14/2016 7:07 PM	0.800	84.700	29.80	67.00	0
8/14/2016 7:37 PM	0.700	85.300	29.80	67.00	0
8/14/2016 8:07 PM	0.800	85.500	29.80	67.00	0
8/14/2016 8:37 PM	0.600	85.800	29.80	67.00	0
8/14/2016 9:07 PM	0.600	86.000	29.80	67.00	0
8/14/2016 9:37 PM	0.500	86.000	29.80	66.00	0
8/14/2016 10:07 PM	0.400	86.200	29.80	67.00	0
8/14/2016 10:37 PM	0.800	86.200	29.80	67.00	0
8/14/2016 11:07 PM	0.600	86.200	29.80	66.00	0
8/14/2016 11:37 PM	0.500	86.000	29.80	67.00	0
8/15/2016 12:07 AM	0.400	86.000	29.80	67.00	0
8/15/2016 12:37 AM	0.700	85.800	29.80	67.00	0
8/15/2016 1:07 AM	0.400	85.800	29.80	67.00	0
8/15/2016 1:37 AM	0.800	85.600	29.80	67.00	0
8/15/2016 2:07 AM	0.500	85.600	29.80	67.00	0
8/15/2016 2:37 AM	0.500	85.500	29.80	66.00	0
8/15/2016 3:07 AM	0.500	85.300	29.80	66.00	0
8/15/2016 3:37 AM	0.500	85.300	29.80	67.00	0
8/15/2016 4:07 AM	0.600	85.100	29.80	67.00	0
8/15/2016 4:37 AM	0.600	85.100	29.80	67.00	0
8/15/2016 5:07 AM	0.600	84.900	29.80	66.00	0
8/15/2016 5:37 AM	1.400	84.700	29.80	66.00	0
8/15/2016 6:07 AM	0.100	84.600	29.80	67.00	0
8/15/2016 6:37 AM	0.400	84.600	29.80	67.00	0
8/15/2016 7:07 AM	0.600	84.400	29.80	68.00	0
8/15/2016 7:37 AM	0.600	84.200	29.80	67.00	0
8/15/2016 8:07 AM	0.400	84.400	29.80	67.00	0
8/15/2016 8:37 AM	1.200	84.700	29.80	67.00	0

Table B.2 : Beaker and Sand :

Date/Time	pCi/l F	Temp inHg	Pressure	Humidity %	Flags
8/15/2016 9:24 AM	0.600	84.000	29.80	65.00	M
8/15/2016 9:54 AM	0.600	83.700	29.80	66.00	0
8/15/2016 10:24 AM	1.300	83.100	29.80	68.00	0
8/15/2016 10:54 AM	0.700	82.900	29.80	69.00	0
8/15/2016 11:24 AM	0.600	82.900	29.80	70.00	0
8/15/2016 11:54 AM	0.800	82.900	29.80	71.00	0
8/15/2016 12:24 PM	0.600	82.900	29.80	72.00	0
8/15/2016 12:54 PM	0.500	82.900	29.80	72.00	0
8/15/2016 1:24 PM	0.700	82.900	29.80	73.00	0
8/15/2016 1:54 PM	0.400	82.900	29.80	73.00	0
8/15/2016 2:24 PM	1.300	82.900	29.70	73.00	0
8/15/2016 2:54 PM	0.600	83.100	29.70	73.00	0
8/15/2016 3:24 PM	0.600	83.100	29.70	74.00	0
8/15/2016 3:54 PM	0.500	83.100	29.70	74.00	0
8/15/2016 4:24 PM	0.700	83.100	29.70	75.00	0
8/15/2016 4:54 PM	1.200	83.100	29.70	75.00	0
8/15/2016 5:24 PM	1.100	82.900	29.70	75.00	0
8/15/2016 5:54 PM	0.600	83.100	29.70	75.00	0
8/15/2016 6:24 PM	1.200	83.500	29.70	75.00	0
8/15/2016 6:54 PM	0.800	83.800	29.80	75.00	0
8/15/2016 7:24 PM	0.400	84.400	29.80	75.00	0
8/15/2016 7:54 PM	1.100	84.700	29.80	75.00	0
8/15/2016 8:24 PM	0.700	85.100	29.80	76.00	0
8/15/2016 8:54 PM	0.500	85.300	29.80	76.00	0
8/15/2016 9:24 PM	0.800	85.500	29.80	76.00	0
8/15/2016 9:54 PM	0.400	85.500	29.80	76.00	0
8/15/2016 10:24 PM	1.000	85.600	29.80	76.00	0
8/15/2016 10:54 PM	1.000	85.600	29.80	76.00	0
8/15/2016 11:24 PM	0.500	85.500	29.80	76.00	0
8/15/2016 11:54 PM	1.200	85.500	29.80	76.00	0
8/16/2016 12:24 AM	1.200	85.500	29.80	77.00	0
8/16/2016 12:54 AM	1.200	85.300	29.80	77.00	0
8/16/2016 1:24 AM	0.600	85.300	29.80	77.00	0
8/16/2016 1:54 AM	0.700	85.100	29.80	77.00	0
8/16/2016 2:24 AM	0.400	85.100	29.80	77.00	0
8/16/2016 2:54 AM	0.500	84.900	29.80	77.00	0
8/16/2016 3:24 AM	0.500	84.900	29.80	77.00	0
8/16/2016 3:54 AM	0.700	84.700	29.80	78.00	0
8/16/2016 4:24 AM	1.000	84.700	29.80	78.00	0
8/16/2016 4:54 AM	1.100	84.600	29.80	78.00	0
8/16/2016 5:24 AM	0.500	84.600	29.80	78.00	0
8/16/2016 5:54 AM	1.300	84.400	29.80	78.00	0
8/16/2016 6:24 AM	0.700	84.400	29.80	78.00	0
8/16/2016 6:54 AM	0.800	84.200	29.80	78.00	0
8/16/2016 7:24 AM	0.500	84.000	29.80	78.00	0
8/16/2016 7:54 AM	1.100	84.000	29.80	79.00	0
8/16/2016 8:24 AM	0.600	84.000	29.80	79.00	0
8/16/2016 8:54 AM	1.400	83.800	29.80	79.00	0

Table B.3 : Cement :

Date/Time	pCi/l	Temp	Pressure	Humidity	Flags
	F	inHg		%	
8/16/2016 9:43 AM	1.200	82.800	29.80	71.00	M
8/16/2016 10:13 AM	1.200	82.200	29.80	71.00	0
8/16/2016 10:43 AM	1.400	81.900	29.80	71.00	0
8/16/2016 11:13 AM	1.700	81.700	29.80	71.00	0
8/16/2016 11:43 AM	1.200	81.500	29.80	71.00	0
8/16/2016 12:13 PM	1.600	81.500	29.80	71.00	0
8/16/2016 12:43 PM	1.100	81.700	29.80	71.00	0
8/16/2016 1:13 PM	0.800	81.900	29.80	71.00	0
8/16/2016 1:43 PM	1.100	82.000	29.80	71.00	0
8/16/2016 2:13 PM	1.300	82.200	29.80	71.00	0
8/16/2016 2:43 PM	1.200	82.400	29.70	71.00	0
8/16/2016 3:13 PM	1.200	82.600	29.70	71.00	0
8/16/2016 3:43 PM	0.600	82.600	29.70	71.00	0
8/16/2016 4:13 PM	0.500	82.600	29.70	71.00	0
8/16/2016 4:43 PM	0.800	82.800	29.70	71.00	0
8/16/2016 5:13 PM	0.700	82.800	29.70	71.00	0
8/16/2016 5:43 PM	0.700	82.600	29.70	71.00	0
8/16/2016 6:13 PM	0.200	82.900	29.70	71.00	0
8/16/2016 6:43 PM	0.500	83.300	29.80	71.00	0
8/16/2016 7:13 PM	0.800	83.800	29.80	71.00	0
8/16/2016 7:43 PM	0.400	84.200	29.80	71.00	0
8/16/2016 8:13 PM	0.800	84.600	29.80	71.00	0
8/16/2016 8:43 PM	0.600	84.700	29.80	71.00	0
8/16/2016 9:13 PM	0.700	84.900	29.80	71.00	0
8/16/2016 9:43 PM	0.700	85.100	29.80	70.00	0
8/16/2016 10:13 PM	0.600	85.300	29.80	70.00	0
8/16/2016 10:43 PM	0.400	85.300	29.80	70.00	0
8/16/2016 11:13 PM	1.000	85.300	29.80	70.00	0
8/16/2016 11:43 PM	0.800	85.300	29.80	71.00	0
8/17/2016 12:13 AM	0.600	85.100	29.80	71.00	0
8/17/2016 12:43 AM	1.200	85.100	29.90	70.00	0
8/17/2016 1:13 AM	0.800	85.100	29.80	70.00	0
8/17/2016 1:43 AM	1.000	84.900	29.80	70.00	0
8/17/2016 2:13 AM	0.800	84.900	29.80	71.00	0
8/17/2016 2:43 AM	1.300	84.700	29.80	70.00	0
8/17/2016 3:13 AM	1.100	84.600	29.80	70.00	0
8/17/2016 3:43 AM	1.300	84.600	29.80	70.00	0
8/17/2016 4:13 AM	0.600	84.400	29.80	70.00	0
8/17/2016 4:43 AM	0.700	84.400	29.80	71.00	0
8/17/2016 5:13 AM	0.400	84.200	29.80	71.00	0
8/17/2016 5:43 AM	0.700	84.200	29.80	71.00	0
8/17/2016 6:13 AM	0.700	84.000	29.80	71.00	0
8/17/2016 6:43 AM	0.800	84.000	29.80	70.00	0
8/17/2016 7:13 AM	0.900	83.800	29.80	71.00	0
8/17/2016 7:43 AM	1.100	83.800	29.80	70.00	0
8/17/2016 8:13 AM	1.100	83.700	29.80	70.00	0
8/17/2016 8:43 AM	0.700	83.700	29.80	71.00	0
8/17/2016 9:13 AM	0.700	83.100	29.80	70.00	0

Table B.4 : Water :

Date/Time	pCi/l F	Temp inHg	Pressure	Humidity %	Flags
8/21/2016 10:02 AM	0.100	80.800	29.80	72.00	M
8/21/2016 10:32 AM	0.000	80.400	29.80	74.00	0
8/21/2016 11:02 AM	0.000	80.100	29.80	76.00	0
8/21/2016 11:32 AM	0.500	81.000	29.80	76.00	0
8/21/2016 12:02 PM	0.400	81.500	29.80	75.00	0
8/21/2016 12:32 PM	1.000	81.500	29.80	76.00	0
8/21/2016 1:02 PM	0.600	81.700	29.80	77.00	0
8/21/2016 1:32 PM	0.600	81.900	29.80	77.00	0
8/21/2016 2:02 PM	0.400	81.900	29.80	78.00	0
8/21/2016 2:32 PM	0.600	82.000	29.70	77.00	0
8/21/2016 3:02 PM	0.500	82.000	29.70	78.00	0
8/21/2016 3:32 PM	0.100	82.000	29.70	78.00	0
8/21/2016 4:02 PM	0.200	82.200	29.70	78.00	0
8/21/2016 4:32 PM	0.500	82.200	29.70	78.00	0
8/21/2016 5:02 PM	0.400	82.200	29.70	78.00	0
8/21/2016 5:32 PM	0.600	82.200	29.70	78.00	0
8/21/2016 6:02 PM	0.500	82.000	29.70	79.00	0
8/21/2016 6:32 PM	1.000	81.900	29.70	79.00	0
8/21/2016 7:02 PM	0.100	82.200	29.70	78.00	0
8/21/2016 7:32 PM	0.500	82.600	29.70	79.00	0
8/21/2016 8:02 PM	0.200	82.900	29.80	79.00	0
8/21/2016 8:32 PM	0.400	83.300	29.80	78.00	0
8/21/2016 9:02 PM	0.200	83.700	29.80	78.00	0
8/21/2016 9:32 PM	0.400	83.800	29.80	78.00	0
8/21/2016 10:02 PM	0.200	84.000	29.80	78.00	0
8/21/2016 10:32 PM	0.000	84.200	29.80	79.00	0
8/21/2016 11:02 PM	1.000	84.400	29.80	78.00	0
8/21/2016 11:32 PM	0.200	84.400	29.80	78.00	0
8/22/2016 12:02 AM	0.200	84.400	29.80	78.00	0
8/22/2016 12:32 AM	0.000	84.400	29.80	79.00	0
8/22/2016 1:02 AM	0.500	84.200	29.80	79.00	0
8/22/2016 1:32 AM	0.500	84.000	29.80	79.00	0
8/22/2016 2:02 AM	0.200	84.000	29.80	78.00	0
8/22/2016 2:32 AM	1.000	83.800	29.80	79.00	0
8/22/2016 3:02 AM	0.200	83.800	29.80	79.00	0
8/22/2016 3:32 AM	0.100	83.800	29.80	79.00	0
8/22/2016 4:02 AM	0.100	83.700	29.80	81.00	0
8/22/2016 4:32 AM	0.100	83.700	29.80	81.00	0
8/22/2016 5:02 AM	0.500	83.700	29.80	80.00	0
8/22/2016 5:32 AM	0.200	83.500	29.80	81.00	0
8/22/2016 6:02 AM	0.100	83.500	29.80	80.00	0
8/22/2016 6:32 AM	0.400	83.500	29.80	81.00	0
8/22/2016 7:02 AM	0.000	83.500	29.80	81.00	0
8/22/2016 7:32 AM	0.200	83.300	29.80	81.00	0
8/22/2016 8:02 AM	0.200	83.300	29.80	82.00	0
8/22/2016 8:32 AM	0.500	83.300	29.80	81.00	0
8/22/2016 9:02 AM	0.200	82.900	29.80	81.00	0
8/22/2016 9:32 AM	0.000	82.400	29.80	82.00	0

Tabble B.5 : Prototype Room :

Date/Time	pCi/l	Temp	Pressure	Humidity	Flags
	F	inHg		%	
8/8/2016 9:06 AM	0.200	82.200	29.90	67.00	M
8/8/2016 9:36 AM	1.000	81.700	29.90	67.00	0
8/8/2016 10:06 AM	1.200	81.300	29.90	66.00	0
8/8/2016 10:36 AM	1.400	81.100	29.90	67.00	0
8/8/2016 11:06 AM	0.800	81.100	29.90	67.00	0
8/8/2016 11:36 AM	1.100	81.300	29.90	66.00	0
8/8/2016 12:06 PM	0.700	81.500	29.90	65.00	0
8/8/2016 12:36 PM	1.300	81.900	29.80	65.00	0
8/8/2016 1:06 PM	1.100	82.000	29.80	66.00	0
8/8/2016 1:36 PM	0.700	82.200	29.80	67.00	0
8/8/2016 2:06 PM	1.000	82.200	29.80	66.00	0
8/8/2016 2:36 PM	1.100	82.400	29.80	66.00	0
8/8/2016 3:06 PM	1.600	82.600	29.80	66.00	0
8/8/2016 3:36 PM	1.200	82.600	29.80	65.00	0
8/8/2016 4:06 PM	0.700	82.800	29.80	66.00	0
8/8/2016 4:36 PM	0.700	82.800	29.80	65.00	0
8/8/2016 5:06 PM	1.500	82.800	29.80	66.00	0
8/8/2016 5:36 PM	1.600	82.900	29.80	65.00	0
8/8/2016 6:06 PM	0.800	82.900	29.80	65.00	0
8/8/2016 6:36 PM	1.400	83.100	29.80	65.00	0
8/8/2016 7:06 PM	0.800	83.500	29.80	65.00	0
8/8/2016 7:36 PM	1.300	84.000	29.80	65.00	0
8/8/2016 8:06 PM	1.300	84.400	29.80	65.00	0
8/8/2016 8:36 PM	1.200	84.700	29.80	65.00	0
8/8/2016 9:06 PM	0.700	85.100	29.90	65.00	0
8/8/2016 9:36 PM	1.400	85.300	29.90	65.00	0
8/8/2016 10:06 PM	0.700	85.300	29.90	65.00	0
8/8/2016 10:36 PM	0.700	85.300	29.90	65.00	0
8/8/2016 11:06 PM	1.400	85.300	29.90	65.00	0
8/8/2016 11:36 PM	0.500	85.100	29.90	66.00	0
8/9/2016 12:06 AM	1.000	85.100	29.90	65.00	0
8/9/2016 12:36 AM	0.700	84.900	29.90	66.00	0
8/9/2016 1:06 AM	1.100	84.700	29.90	66.00	0
8/9/2016 1:36 AM	0.700	84.600	29.90	65.00	0
8/9/2016 2:06 AM	1.000	84.400	29.90	66.00	0
8/9/2016 2:36 AM	0.800	84.200	29.80	66.00	0
8/9/2016 3:06 AM	0.500	84.200	29.80	66.00	0
8/9/2016 3:36 AM	1.100	84.000	29.80	66.00	0
8/9/2016 4:06 AM	0.200	84.000	29.80	66.00	0
8/9/2016 4:36 AM	1.200	83.800	29.80	66.00	0
8/9/2016 5:06 AM	0.500	83.700	29.90	66.00	0
8/9/2016 5:36 AM	0.400	83.700	29.80	66.00	0
8/9/2016 6:06 AM	0.900	83.700	29.80	66.00	0
8/9/2016 6:36 AM	1.000	83.500	29.90	66.00	0
8/9/2016 7:06 AM	1.200	83.500	29.90	66.00	0
8/9/2016 7:36 AM	1.400	83.300	29.80	66.00	0
8/9/2016 8:06 AM	1.100	83.300	29.90	66.00	0
8/9/2016 8:36 AM	1.000	83.500	29.90	66.00	0

Table B.6 : Interlocking Block :

Date/Time	pCi/l F	Temp inHg	Pressure	Humidity %	Flags
8/9/2016 9:28 AM	1.000	83.300	29.90	66.00	M
8/9/2016 9:58 AM	0.800	82.900	29.90	68.00	0
8/9/2016 10:28 AM	0.800	82.800	29.90	69.00	0
8/9/2016 10:58 AM	1.400	82.600	29.90	70.00	0
8/9/2016 11:28 AM	1.000	82.400	29.90	71.00	0
8/9/2016 11:58 AM	0.800	82.400	29.80	71.00	0
8/9/2016 12:28 PM	1.200	82.400	29.80	72.00	0
8/9/2016 12:58 PM	1.100	82.400	29.80	72.00	0
8/9/2016 1:28 PM	1.600	82.600	29.80	73.00	0
8/9/2016 1:58 PM	1.100	82.600	29.80	73.00	0
8/9/2016 2:28 PM	0.800	82.600	29.80	73.00	0
8/9/2016 2:58 PM	1.100	82.600	29.80	74.00	0
8/9/2016 3:28 PM	0.600	82.600	29.80	74.00	0
8/9/2016 3:58 PM	0.600	82.600	29.70	75.00	0
8/9/2016 4:28 PM	0.800	82.600	29.70	75.00	0
8/9/2016 4:58 PM	0.200	82.600	29.70	75.00	0
8/9/2016 5:28 PM	0.500	82.600	29.70	75.00	0
8/9/2016 5:58 PM	0.600	82.900	29.70	75.00	0
8/9/2016 6:28 PM	0.800	83.300	29.80	75.00	0
8/9/2016 6:58 PM	0.500	83.800	29.80	75.00	0
8/9/2016 7:28 PM	0.700	84.200	29.80	76.00	0
8/9/2016 7:58 PM	1.000	84.700	29.80	76.00	0
8/9/2016 8:28 PM	0.400	84.900	29.80	76.00	0
8/9/2016 8:58 PM	0.200	85.100	29.90	76.00	0
8/9/2016 9:28 PM	0.600	85.100	29.90	76.00	0
8/9/2016 9:58 PM	0.800	84.900	29.90	76.00	0
8/9/2016 10:28 PM	0.600	84.700	29.90	76.00	0
8/9/2016 10:58 PM	1.000	84.400	29.90	77.00	0
8/9/2016 11:28 PM	1.300	84.400	29.90	77.00	0
8/9/2016 11:58 PM	1.100	84.200	29.90	77.00	0
8/10/2016 12:28 AM	0.500	84.000	29.90	77.00	0
8/10/2016 12:58 AM	0.500	83.800	29.90	77.00	0
8/10/2016 1:28 AM	0.400	83.800	29.90	77.00	0
8/10/2016 1:58 AM	1.100	83.700	29.90	77.00	0
8/10/2016 2:28 AM	0.700	83.700	29.90	78.00	0
8/10/2016 2:58 AM	1.100	83.500	29.80	78.00	0
8/10/2016 3:28 AM	1.100	83.500	29.80	78.00	0
8/10/2016 3:58 AM	0.500	83.300	29.80	78.00	0
8/10/2016 4:28 AM	0.600	83.100	29.80	78.00	0
8/10/2016 4:58 AM	0.500	83.100	29.80	78.00	0
8/10/2016 5:28 AM	0.700	82.900	29.80	78.00	0
8/10/2016 5:58 AM	0.600	82.900	29.80	78.00	0
8/10/2016 6:28 AM	0.800	82.800	29.80	79.00	0
8/10/2016 6:58 AM	0.200	82.800	29.80	79.00	0
8/10/2016 7:28 AM	0.600	82.600	29.90	79.00	0
8/10/2016 7:58 AM	0.200	82.600	29.90	79.00	0
8/10/2016 8:28 AM	1.000	82.600	29.90	79.00	0
8/10/2016 8:58 AM	0.400	82.400	29.90	79.00	0