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# **MEASUREMENT OF RADON AT NMBU- CONCENTRATION, SEASONAL VARIATION, AND DOSE ESTIMATION**

**KHUMANAND SHARMA DHUNGANA**  
Master's of Science in Radioecology

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NMBU Ås

## ABSTRACT/SUMMARY

Radon-222 is radioactive noble gas which is formed by the decay of Radium-226, which is the decay product of the Uranium-238. Radon-222 and its decay products have the negative effect on health, hence it becomes a major concern when the radon is presence in higher concentration in buildings with poor ventilation or with strong source. Increasing amount of indoor radon concentration is huge problems in Norway in comparison to other countries. It is estimated that more than 300 deaths from lung cancer occurs in each year due to indoor radon in Norway. Life expectancy can be increases by 14 to 18 years on avoiding of lung cancer. Norway, Sweden and Finland are the countries having the highest level of radon in the world, perhaps due to the geological condition and cool climatic condition. But at the same time the radon problem can be eliminated in cost effective ways. This research work is performed at NMBU (Norwegian University of life Sciences) Ås Norway. As the NMBU is an academic institution where the large number of students, employees, and researchers are conducting their own work. Therefore, this study investigated the radon concentration, seasonal variation, annual occupational dose in the study area which can be helpful to reduce the existing radon concentration level if it exceeds beyond the action level.

The objective was to measures the radon concentration in different three building in terms of their ages. As well the measurements were done in two different season viz summer and winter season. The annual dose was also calculated for the professional, and employees who spend their times at NMBU.

The portable radon monitor (PMR145) was used for radon measurement. The samples were taken and measure in June, July and August which is supposed to be the pick summer season and November, December, and January which is supposed to the pick winter season. At the same time, Background samples were also taken and measured in summer and winter season to calibrate with indoor radiation. In selected three buildings, measurements were done in underground, first, second and third floor. In each floor one room was randomly selected either. In each floor and room five samples were taken to find the more variability. All the collected data were calculated and analysed in Ms-Excel, Mini-Tab 17 and R studio. For investigating the radon concentration on different buildings and different season, significant test  $< 0.005$  were done statistically significant. For calculating the annual dose equilibrium

factor 0.4, dose conversion factor 9 and occupancy level supposed (44 weeks X 37.5h) = 1650 h for full time working employees were taken.

The study shows that indoor radon concentration varies in summer and winter season specifically in underground floor of tower building. The highest average radon concentration with standard deviation  $147 \pm 59$  Bq/m<sup>3</sup> and minimum to maximum range of radon concentration (44-197) Bq/m<sup>3</sup> was detected in underground floor of tower building in summer season while highest average radon concentration with standard deviation  $56 \pm 27$  Bq/m<sup>3</sup> and minimum to maximum range of radon concentration (17-79) Bq/m<sup>3</sup> was detected in winter season in tower building.

Anova Tukey test was performed to investigate the significant difference in mean levels of radon concentration in between floors in different buildings, and it was found that there is significant difference ( $P < 0.005$ , 95% confidence level) in between underground to first, second and third floor. Similarly, one way ANOVA was performed to find the seasonal variation in buildings and floors and the results reveals that radon concentration is significantly difference ( $P < 0.005$ , 95%) in summer and winter. Furthermore, annual occupational dose were calculated, considering the dose conversion factor 9 nSv/Bq/h/m<sup>3</sup>, equilibrium factor 0.4, and occupancy used in the study (44 weeks X 37.5h) and it was found that maximum annual dose was found to 1.0 mSv/y in underground floor of tower Building in summer season.

On the basis of this research work following facts can be concluded.

In all the three building the radon concentration was found to be less then action level 100 Bq/m<sup>3</sup> accept Underground floors. The action level is recommended by Norwegian regulation protection authority.

The seasonal variation in radon concentration indicates that higher radon concentration was in summer and minimum in winter.

The highest radon concentration and annual dose was found at underground floors in summer season which indicates that there is need to take some action to reducing it.

*Keywords:* Indoor radon concentration, season variation, annual dose, portable radon monitor.



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## Introduction

Radon is chemically inert gas produced by the decaying of uranium and radium. These elements are majorly occurs in earth's crust. These are considered as the source of natural radioactivity (Catelinois et al., 2006). Natural radiation exposure occurs in two ways; first by gamma radiation and radon exhalation. Gamma radiation rises from the  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  and consequently whole body exposure to that radiation while radon leads to internal dose exposure (UNSCEAR, 1988). Righi & Bruzzi, (2006) stated that "Half of the total annual effective dose equivalent received by the population is originated by radon and its decay product due to inhalation".

There are several factors which contributes the indoor radon; these factors are building ground, interior or exterior building material, soil properties, water supply, ambient air, environmental parameters (temperature, barometric pressure, wind rainfall) age of buildings, height and seasonal variation (Barros-Dios, Ruano-Ravina, Gastelu-Iturri, & Figueiras, 2007; Sundal, Henriksen, Soldal, & Strand, 2004; Xie, Liao, & Kearfott, 2015). Diffusion and advection are important phenomena by which radon enters into indoor condition from building materials (Durrani & Ilic, 1997). In fact, it will not be appropriate to correlate radon concentration in a building only to the basis of radium content of the ground and building materials. The releasing of radon gas from building materials depends on many factors; such as the texture, size and permeability of the grain, temperature and pressure of environment and the presence of radium concentration in ground (Durrani & Ilic, 1997). While Sundal et al. (2004) mentioned in his paper that building ground are chief cause of indoor radon because the indoor radon concentration is dependent on the building capability to produce and transport of radon (Sundal et al., 2004). By products used in building material such as fly ash from coal- fired power plants, alum shale and phospho-gypsum from phosphate fertilizer industry also helpful to increases the natural radioactivity (Stoulos, Manolopoulou, & Papastefanou, 2003). Righi & Bruzzi (2006) also reported that higher radiation arises when the decorative materials such as granite tiles are used in buildings, as these decorative materials may contain higher concentration of natural radionuclides. Hence it can be said that higher dose rate in indoor may be due to the high activities of natural radionuclide by buildings material or that buildings traps radon gas from the ground or by several other factors which are the contributors of radon.

Seasonal variation of indoor radon concentration is most often observed phenomena. In dwellings, higher indoor radon concentration was reported in winter season while the lower radon concentration was investigated in summer season (Faheem & Matiullah, 2008; Gillmore, Phillips, & Denman, 2005; Groves-Kirkby, Crockett, Denman, & Phillips, 2015; Kapdan & Altinsoy, 2012; Xie et al., 2015). Even though the opposite result are found in few of the studies; higher radon concentration in summer and lower in winter (Wilson, D. L.; Gammage, R. B.; Dudney, C. S.; Saultz, 1991).

The European commission published two recommendation recitation to indoor radon exposure and natural radiation; the first one is radon level in residential dwellings and second states principles regarding radiological protection and natural radioactivity in building material (NRPA, 2010).

It is quite fundamentals matter that people spend their significant times in indoor condition, both at work and at home. Increasing amount of indoor radon concentration is huge problems in Norway in comparison to other countries. It is estimated that more than 300 deaths from lung cancer occurs in each year due to indoor radon in Norway (NRPA, 2010). Life expectancy can be increases by 14 to 18 years on avoiding of lung cancer. Norway, Sweden and Finland are the countries having the highest level of radon in the world, perhaps due to the geological condition and cold climatic condition. But the radon problem can be eliminated in cost effective ways (Darby et al., 2005). Therefore the Norwegian radiation protection Authority has set up the maximum radon concentration 100 Bq/m<sup>3</sup> as the action level which is applied for kindergartens, schools, new residences and rented housing (NRPA, 2010)

The Norway is supposed to be highest radon existing country in the world and it was estimated that about 9% housing stock has an annual indoor radon concentration which is higher than the current action level of 200 Bq/m (Jelle, et al., 2010). So, it is a great importance of matter to find the indoor radon concentration at NMBU, as The NMBU is an academic institution holding many students and employees and researchers.

## **Objective**

Norwegian university of life sciences (NMBU) is an academic institution where the large number of students, researchers, professionals and employees are carrying out their own respective job. Hence, they spend their significant times at universities in different buildings. Therefore, the specific objectives of this study were to investigate the radon concentration as well to investigate whether radon exist beyond action level or below the action level.

The following study will be carried out to meet the objectives.

- 1) To measure the radon concentration in different building build at different time at NMBU premises.
- 2) To find out the concentration, seasonal variation and occupational dose estimation in different building at NMBU campus.
- 3) To estimate the annual occupational dose due to radon concentration.

## **Research question**

The present research work will be based on following question.

- are there major problem areas due to radon exposure?
- are the people of NMBU are at the risk of indoor radon exposure?
- Is there any area where radon exist above the action level?

## **Rationale of the study**

There are several studies conducted by different investigators which shows that Norway, Sweden, and Finland has the highest radon containing countries in the world. Among these countries increasing level of radon is the major problem in Norway. It was find from the literature investigation that nearly 300 deaths cause from the lungs cancer in Norway. It was estimated that 14 to 18 years of life expectancy can be increases if present level of radon is reduced. Hence this study will help to investigate the radon exposure levels to human beings in an academic institution and will contribute to reducing radon at NMBU.

### **Limitation of the study**

In present research radon concentration was measured in three different buildings of different age as well as in different floors. The present study could not include the several other factors such as geology of the study area, soil types and different attributes of soil, and climatic factors which largely influences the radon concentration and influences in seasonal variation.

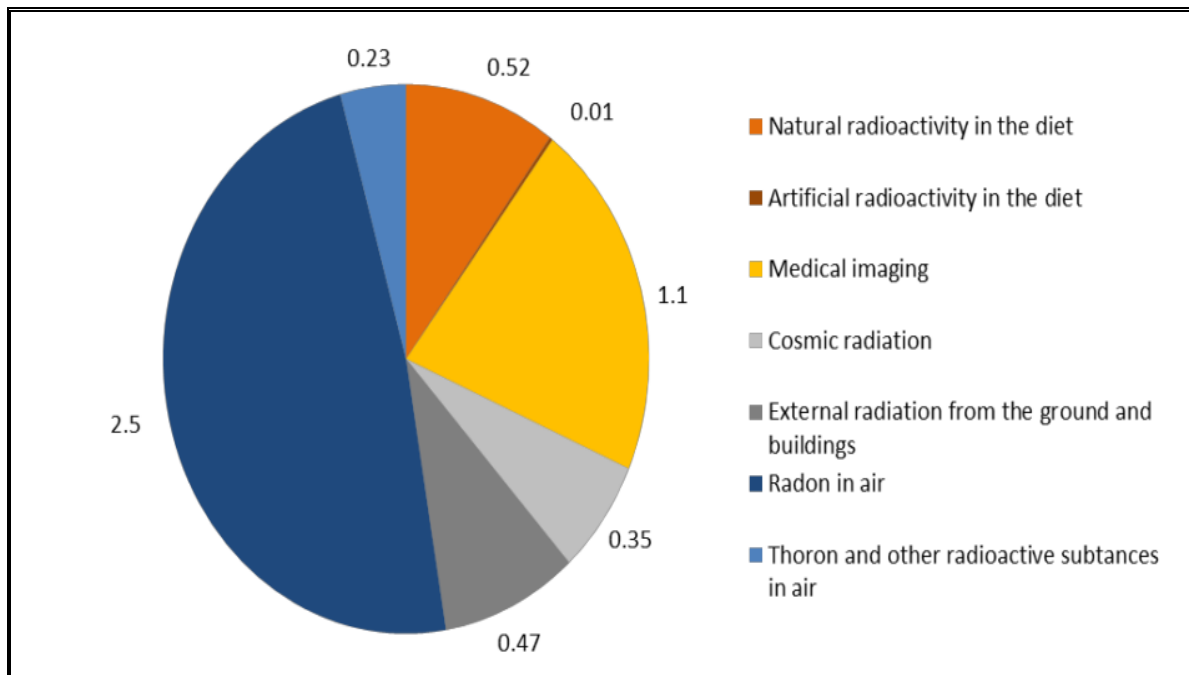
# Theory

## Radiation and its sources

Radiation is energy which is transport either in the form of particles or electromagnetic waves. Basically, radiation can be categorised in two types; the first one is ionizing radiation which possess high energy to carry electrons from atoms and molecules in the cell (Organization, W.H. 2000) . The harmful consequence due to ionizing radiations are biological damages in DNA or other parts of body. Even in low dose of radiation, there is the higher risk of developing cancer. Radiation from radioactive elements or radionuclide and X rays are also the sources of ionizing radiation (Komperød & Nrpa, 2015).

Atoms are unstable and changes into atoms of another element by the process of ionizing radiation and this process is known as radioactivity and change is called radioactive decay. The decay or rate of changing of atom is determined by its half- life (Scheib, Appleton, & Miles, 2013). Alpha beta and gamma are the most common radiation that are emitted or the radionuclides commonly emits the alpha beta and gamma rays. The major sources of radiation are the gamma sources which chiefly originate from uranium minerals in the ground (NRPA, 2010). Even though in terrestrial condition gamma rays derived from the radioactive decaying process of natural potassium, uranium, and thorium and these minerals are commonly distributed in rocks, soil, and building material which are the products of earth crust (J. Appleton, 2013).

Radon is a radioactive noble gas that continuously originates from rock and soils which emits alpha radiation from itself and decay products (Colgan & Gutiérrez, 1997). However, indoor radon concentration is higher than outdoor and causes higher radiation dose. Several studies show that in Norway, indoor radon concentration is highest in the world (Colgan & Gutiérrez, 1997). Similarly, it can be seen from (figure 1) Norwegian population receives radiation doses dose from different kind of radioactive sources and it was estimated that Norwegian population receives total average dose 5.2 mSv/year through ionizing radiation (Komperød & Nrpa, 2015). Komperød & Nrpa, (2015) mentioned that; the world population receiving average radiation doses of approximately 3.0 mSv/year while only radon contributing a major proportion of radiation dose (2.5mSv) in Norway (Figure 1).



**Figure 1. Figure shows the average radiation dose received by Norwegian population from different radioactive sources (Komperød & Nrpa, 2015)**

Hence, the radon and its progeny are the major radiation dose contributors for Norwegian population. According to Jelle, Noreng, Erichsen, & Strand, (2011) “9% of house holding have the annual mean indoor radon concentration which is higher value than the current action level of 200 Bq/m<sup>3</sup>”. In the winter season, radon level can be increased if there is no proper ventilation to balance the indoor radon, if the precaution is taken in order to save energy avoiding from the moisture and cold measure (Jelle et al., 2011). The geology of Norway is the main basis of indoor radiation as radium is prominently found in soil and bedrock and on the other hand, material used in the ground part of houses is the important source of radon in Norwegian dwellings (NRPA, 2010). The total amount of radon present in dwellings is basically dependent on the amount of radium present in the ground. The other important factor is that most of the family have the house which possess living area which is partly below the ground level and clay is broadly used in the construction of foundation of building in Norway (NRPA, 2010). Hence, the access of radon through the building ground is the significant source of indoor radon in Norwegian houses. It is the great importance of

matter to build the airtight ground structure as much as possible to prevent the passing of radon gas from soil and these air tightness can be done in joint occurs during building construction (Strand, Lunder Jensen, Ånestad, Ruden, & Beate Ramberg, 2005). Apart from the Transfer of radon via pore spaces in the ground up to a building is through convection or diffusion depending on factors such as water content and permeability of the ground (Nazaroff, 1992). In another study carried out in Norwegian dwellings are made up of from wooden materials, while in these dwellings the radium level was very low in concrete and brick manufactured industry. Therefore, building materials is not the significant source of indoor radon in Norway (Jensen, Strand, Ramberg, Ruden, & Ånestad, 2004).

### **NORM (Naturally Occurring Radioactive materials)**

All naturally occurring elements found in earth's crust are present in different concentration; these elements are O, Si Al, Fe, Ca, Na, Mg, and K make up approximately 98.5% (Grice, 1991) . The term NORM refers to Naturally Occurring Radioactive Material (NORM) is defined as, "Materials which may contain any of the primordial radionuclides or radioactive elements as they occur in nature, such as potassium, uranium, and thorium potassium, that are undisturbed because of human activities" (Vearrier, Curtis, & Greenberg, 2009). These are also known as the background radiation as they occur in almost everywhere at all times (Vearrier et al., 2009). Radionuclides, which are originated naturally are present in all kind of environment. There is possibility of formation of petroleum from organic matter if there is continuous emission of alpha energy from the natural radionuclides (El Afifi, Hilal, Khalifa, & Aly, 2006). In recent years, due to the increasing levels of development and innovative technologies, by products and waste are producing which are also called as technologically enhanced naturally occurring radioactive materials (TENORM). Hence, human activity is increasing the radiation exposure to whole population, community, and local people (El Afifi et al., 2006).

### **Radon and its properties:**

Radon is odourless and colourless radioactive Nobel gas that causes indoor pollution and found in all over the world. The radon is dependent on the soil, building material, ground water, geology of the surface which possess the radium as natural radioactive substances (Minireview & Yamada, 2003). Hence, when radon gas is found in Uranium mines, it has most adverse effect on health. Radon is produced from the decay activity of Radium. It comprises of two isotopes, Rn-222 and Rn- 220 (Thoron). The isotopes of radon are found in



substantial amount in indoor condition. Radon- 222 is the decay product of Uranium and its half is  $4.5 \times 10^9$  years. The other isotope radon-220 has  $1.4 \times 10^{10}$  years of half-life (Organization, 2009). The radon-220 (Thoron) has very short half-life (about 55 seconds) and it is found in low concentration in indoor condition, but in certain condition it has significant effect in human health (Steinhäusler, Hofmann, & Lettner, 1994). The quit important aspect of the radon decay products are the alpha emitters. The short lived daughter products such as Po-218, Pb-214, Bi-214 and Po-214 can be deposited in lungs via respiration process and receives the high dose from alpha particles radiation (Jelle et al., 2011; Minireview & Yamada, 2003). When radon decays, its progeny are detached but a significant portion is immediately attached to particles in the air or to the other surfaces (CRE, 1992).

Similarly, in SI system and in most of the countries, radon concentration is measured in Becquerel per cubic meter ( $\text{Bq/m}^3$ ). Likewise, the maximum limit of radon concentration for kindergartens, schools, new buildings and rented houses is  $200 \text{ Bq/m}^3$ , with  $100 \text{ Bq/m}^3$  as the action level (Jensen et al., 2004). In United states, Radon concentration is measured in picocuries per liter of air ( $\text{pCi/liter}$ ) either it is present in the form of indoor or outdoor and the recommended radon level in United States is  $4 \text{ pCi}$  per liter ( $148 \text{ Bq}$  per cubic meter (J. Appleton, 2013).

### **Decay scheme of Uranium and the Production of Radon:**

As radon has many isotopes but Rn-222 (Radon) and Rn-220 (Thoron) are its important isotopes which causes health effect in human environment. U-238 and Th- 232 are the novel radionuclides that produced the Rn-222 (Radon) and Rn-220 (Thoron) by decay activity. The decay activity of U-238 and Th- 232 are illustrated from the (figure 3) which clearly indicates that Rn-222 is the decay product of U-238 and Th-232 as well Pb and Po are the chief dose contributor when Rn-222 undergoes further disintegration.

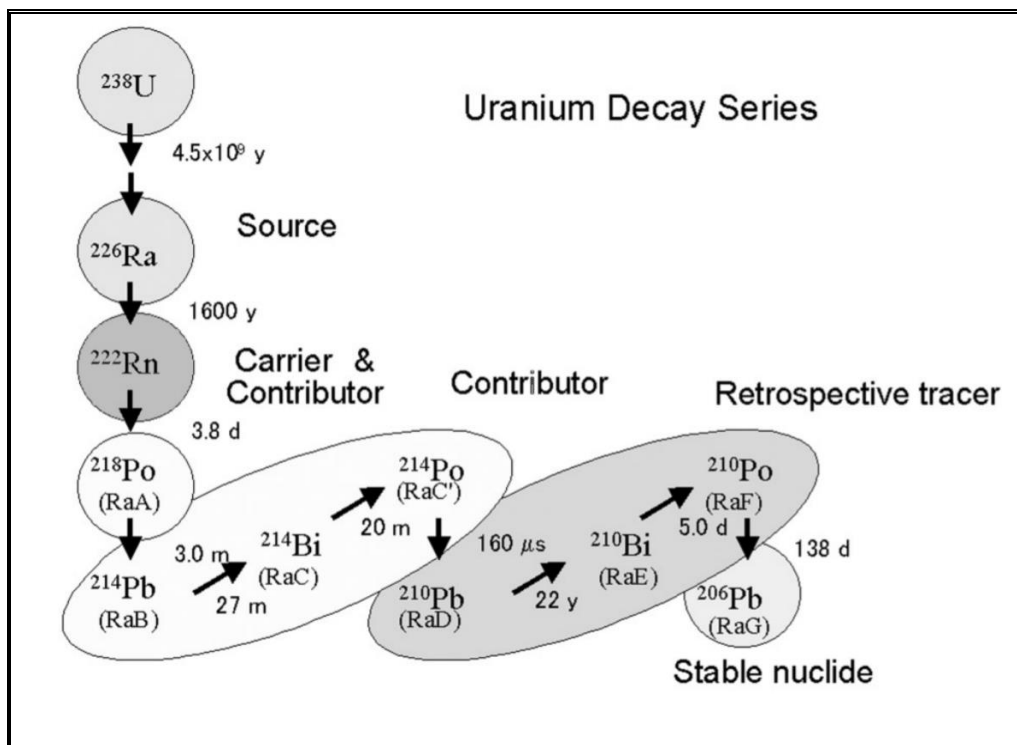


Figure 2. Decay series of  $\text{U}^{238}$  and production of Radon  $\text{Ra}^{222}$  (Minireview & Yamada, 2003)

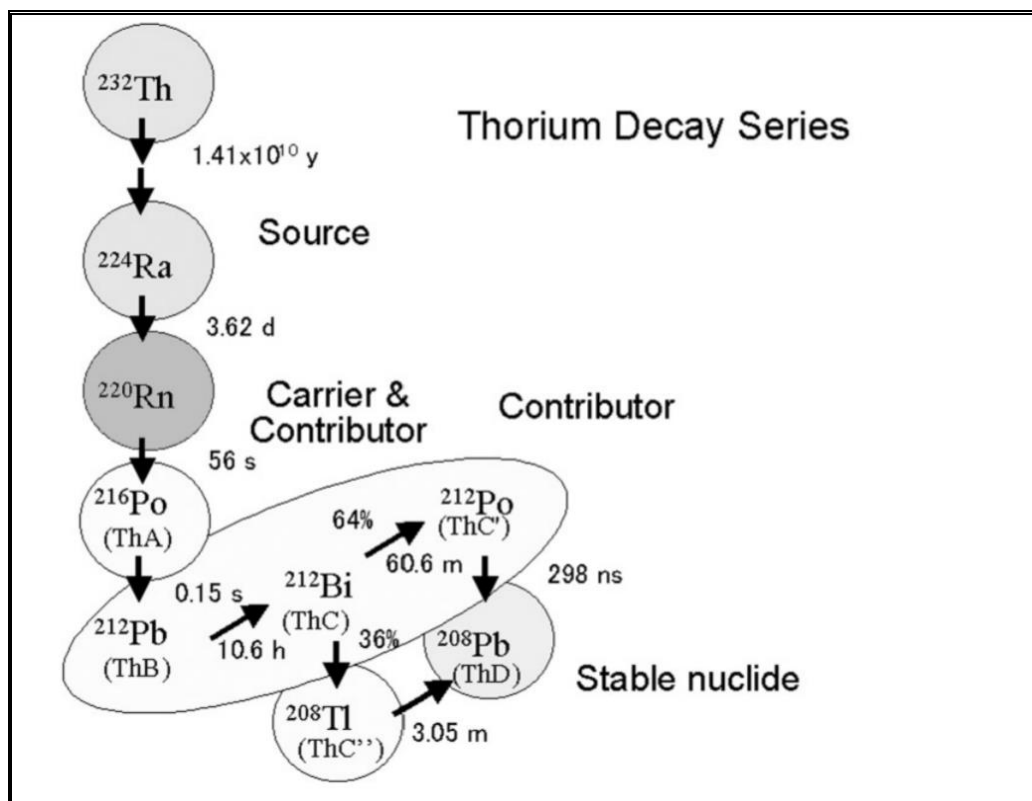
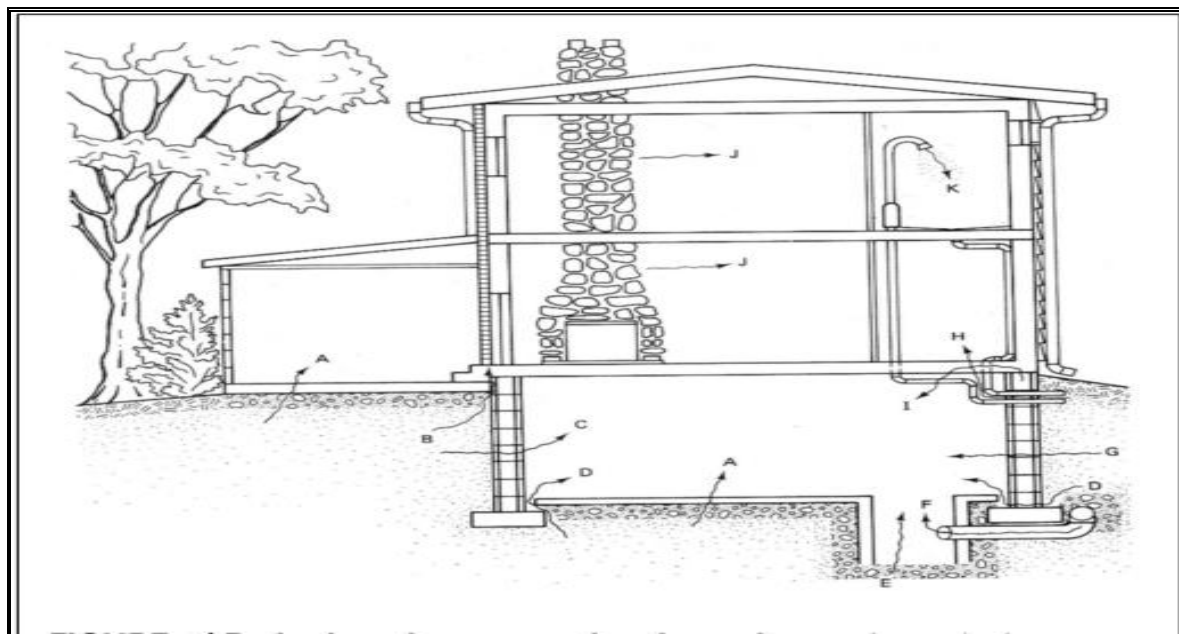


Figure 3. Decay scheme of  $\text{Th}^{232}$  and production of  $\text{Rn}^{222}$  (Minireview & Yamada, 2003)

## Sources and pathways of indoor Radon:

Basically, Uranium is present in earth's crust and radon is the daughter product of Uranium. Radon occurs in buildings, ground waters and natural gases as uranium decays into its daughter product into Rn-222 and enters into dwellings and buildings through different pathway. Occasionally the kind of ground, having moderate amount of uranium or radium may be great source of indoor radon concentration (L.M. Hubbard, Hagberg, & Enflo, 1992). The following figures illustrates the radon enters into houses through different pathways.



**Figure 4: Different entering pathways of radon to enter into a house- A. radon enters through cracks in concrete slabs; B. space behind brick veneer walls that rest on hollow; C, pores and cracks in concrete blocks; D pores and cracks in concrete blocks; D, floor wall joints; E, exposed soil as in sump; F, weeping drain tile, G, mortar joints; J, building materials such as some rocks; K water from some wells (Komperød & Nrpa, 2015; Vogianis, Nikolopoulos, & Efsthathiou, 2015)**

## Building materials as a source of indoor radon

The presence of radon is also depending on the nature of building construction. Because building material made from soil or rock always contain uranium and radium. Even though the quantity of radiation sources usually low but some materials may have higher concentration (Salonen, 1994). Usually the radon concentration in outdoor air is higher in large area than over the sea level. When temperature inversed the concentration, level may

reach hundreds of Bq/m<sup>3</sup> in specific regions having concentration of uranium and radium in the ground (Robe, Rannou, & Le Bronec, 1992). Basically, radon concentration largely depends on house construction and building material. Additionally, concentration and variation of radon level is also affected with climatic factor and human habitat. Moreover, the concentration of radon also differs in hour, day, season and year. It also varies building to building in same place, rooms, and within rooms (Salonen, 1994). In case of present study area, all the selected buildings have the similar pattern of building construction as well all they are build up from same construction material. However, in present study area, few parts of the buildings are constructed with concrete while the walls are made up with wood or light weight walls.

## **Water as a source of indoor Radon**

Rocks and soil are the chief sources of radionuclides as fundamentally they are produced by decay series of U<sup>238</sup> and Th<sup>232</sup>. Hence geology and geochemistry are the important aspects in presence and dispersal of radionuclide in ground water system also. The most common radionuclides are U<sup>238</sup>, U<sup>234</sup>, Rn<sup>222</sup>, Ra<sup>226</sup> and U<sup>234</sup> is decay product of U<sup>238</sup> and Ra<sup>228</sup> is the decay product of Th<sup>232</sup> while other radionuclides are not present in significant amount in ground water due to their immobile and short half- life nature. In ground water, parent and daughter radionuclides are not present in similar amounts nor they decay in similar rates and they do not produce the same level of radioactivity as every decay product has its own chemical properties then its parent radionuclides (Maged, 2009).

Water is used in the household, and working place in significant quantity and radon in water has a possible health effect especially people who use the well water contains higher radon concentration as well the increase concentration of radon in air is also inhaled by the people increase the potential health hazard (Erlandsson, Jakobsson, & Jönsson, 2001) stated in his paper that in Sweden high concentration of radon is restricted in small areas where the ground geology possesses high concentration of Radon. At the same time Wu et al., (2014) concluded in his paper that “Ingestion of waterborne radon but inhalation of radon escaping from water is substantial part of radiological hazard”. According to Komperød & Nrpa, (2015) Norwegian people are also receiving radiation (dose 0.53mSv/year) from the drinking water and food from natural and artificial sources. Wu et al., (2014), also stated that natural

gas is the potential source of indoor radon in Egypt when the natural gas and underground water is supplied in kitchen and other parts of buildings.

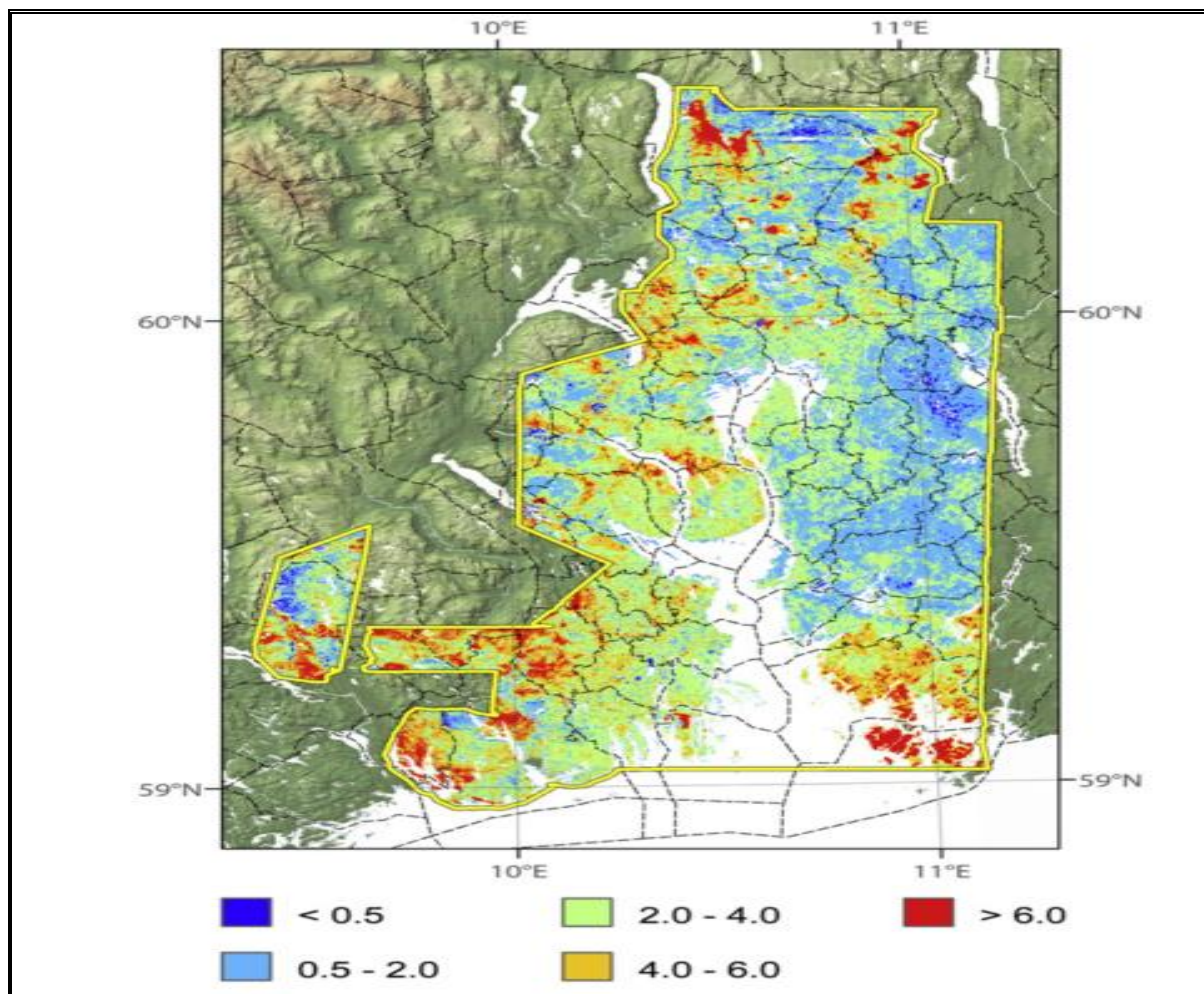
## **Geology as a major source of Radon**

According to World Health Organization (2000), presence and concentration of radon differ between countries because of different geological structure, and climate J. Appleton, (2007) mentioned the association of different types of rocks and radon emission in different country; in Czech republica higher radon concentration emits from Variscan granites, granodiorites, syenites, and phonolites of the Bohemian massif. Volcanic and Palaeozoic metamorphic rocks possess high radon concentration. Similarly, highest radon concentration is found In Germany in Palaeozoic basement rocks and granite. Likewise, main radon concentration is found in Cambrian to lower Devonian bedrocks in Belgium. In these rocks, Uranium is concentrated with ferric oxyhydroxides in fractures and joints and these joints and fracture are supposed to be the chief source of radon (J. Appleton, 2007). In contrast of France, metagranitoids or peraluminous leucogranites rocks are well known for highest level of radon concentration and these rocks are originated from uraniferous granitoid. In case of Norway, Sweden, and Finland highest level of radon is concentrated in alum shale and granite (J. Appleton, 2007). High radon is associated with granite and alum shale in Sweden, Norway, and Belgium (Smethurst et al., 2008). In case of Korea higher radon is strongly correlated with blended gneiss and granite gneiss, however In India, radon emits due to uranium mineralization and lithology (Singh, Mehra, & Singh, 2005), whereas in Korea, high soil-gas radon is associated with granite gneiss and banded gneiss, and low concentrations occur in soils over shale, limestone, and phyllite schist (J. Appleton, 2007). The study conducted by Smethurst et al., (2008) in Norway and they investigated that houses are build up in different rocks and according the rock type, based on their permeability and thickness properties and indoor radon concentration exist more than 200 Bq/m<sup>3</sup> in that area.

## **Radon abundance in Norway**

Norway is supposed to be one of the most Radon affected area in the world (Smethurst et al., 2008). According to Strand et al., (2005), the mean radon concentration value in household is estimated about 89B Bq/m<sup>3</sup> and 9% dwellings have an annual average beyond the recommended action level 200 Bq/m<sup>3</sup>. Even very high radon concentration was recorded in

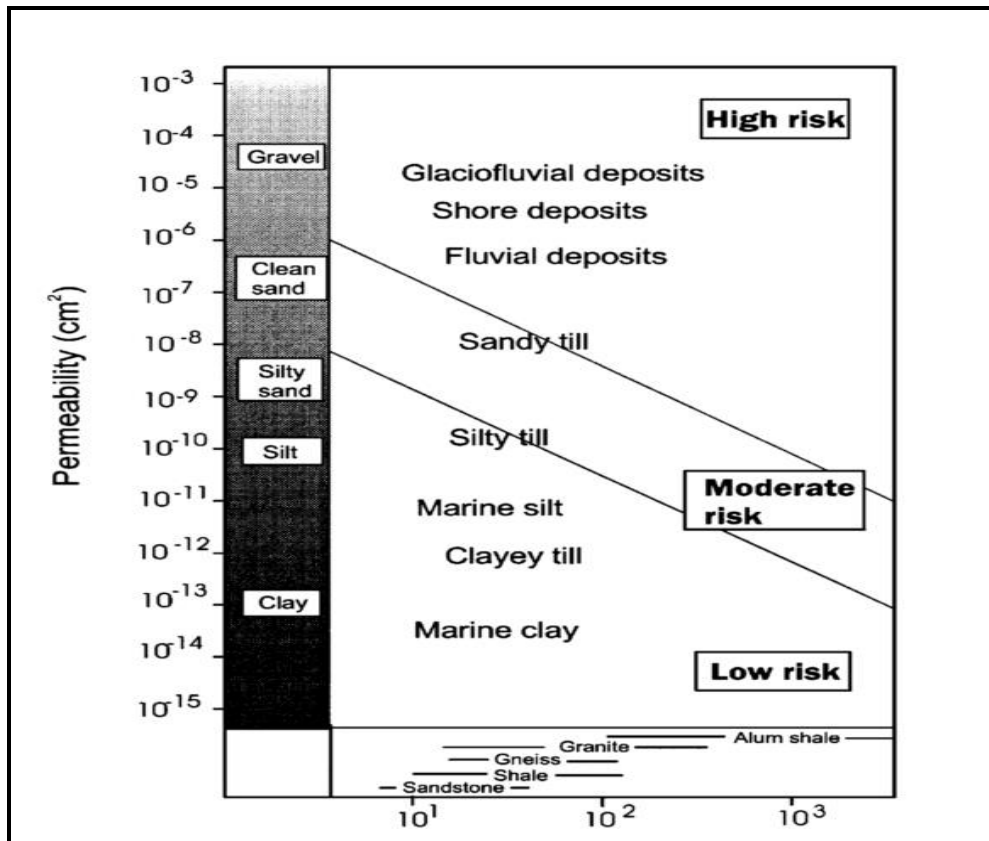
some areas where the dwellings are located near to highly permeable sediments, and in some of the area 75% dwelling have the beyond the action level of radon (Strand et al., 2005). There is strong relation between geological structure and radon concentration. Hence Geological data can be important tool for identifying the risk of higher radon in background and buildings grounds in Norway (Sundal et al., 2004). At the same time, Salonen, (1994) stated that only geological information is not enough tool to identify radon susceptible areas. The following map (figure 6) shows higher uranium concentration region and bedrock geology in Oslo region.



**Figure 5. Uranium concentration in oslo region (Smethurst et al., 2008)**

Hence, Smethurst et al., (2008) mentioned that indoor radon concentration and geology are important aspect in Norway as radon is mainly concentrated in those areas where the uranium concentration occurs more. Similarly, permeability is another key factor for indoor radon which varies according to different soil structure. The following (figures 6) also clarifies the

variation of radon concentration on different strata of soil; it can be seen from (figure 7) that higher radon risk level is increasing from clay soil to Glaciofluvial soil (Sundal et al., 2004).



**Figure 6. Different strata of soils and risk of radiation from radon (Sundal et al., 2004)**

### Seasonal variation in indoor radon:

According to Pinel, Fearn, Darby, & Miles, (1995), Radon concentration in home is not equal throughout the year. The greatest concentration was found during the winter season in indoor while the outdoor concentration was found during summer. Arvela, (1995) stated that it cannot be perfect accuracy on radon concentration measurement in different season if the different sources are not detected Ramola, Negi, & Choubey, (2005) also reported that radon concentrations were found to be highest in winter and lowest in summer season. In winter radon concentration was measured between 30 and 40 Bq/m³ while in summer found in between 10 and 20 Bq/m³. However, no regular seasonal difference was detected for thoron concentrations. Hence it was found to be consistently distributed in different seasons.

It was found that radon concentration is also dependent on seasonal variation and type of building and it was significantly different in winter and summer season. It was found that radon concentration was double in winter season in blocks of flats in the same season

(Muntean, Cosma, Cucos, Dicu, & Moldovan, n.d.). Singh et al., (2005) also studied the radon concentration in different season, with 105 dwelling to 21 villages in Mukhtasar and Ferozepur districts, and they found that radon value varies from 76.25 Bq/m<sup>3</sup> to 145.50 Bq/m<sup>3</sup>. They also reported indoor radon was higher in winter than summer and the winter/summer ratio ranges from 0.84 Bq/m<sup>3</sup> to 1.89 Bq/m<sup>3</sup> with an average of 1.46. According to Singh et al., (2005) the difference in indoor radon may be due to the type of building materials used during construction, nature of ventilation and differences in radioactivity level in the soil under the buildings. Radon concentration was found higher in non-ventilated house than in poor ventilated (J. D. Appleton & Miles, 2010).

According to one of the studies, the total radon concentration in worldwide is 40Bq/m<sup>3</sup> but in few of the European countries such as Finland, Sweden, Austria, Switzerland, and Czech Republic the radon level is higher by several orders of magnitude. In these countries, the percentage of radon concentration is 300 Bq/m<sup>3</sup> which is very high (Muntean et al., n.d.). Regarding to indoor radon level, World health organization (WHO) advised that indoor radon concentration should not be higher than 100Bq/m<sup>3</sup> in indoor condition but in some exceptional cases it should not be higher than 300Bq/m<sup>3</sup> (Zeeb & Shannoun, n.d.). Higher level of radon can be found if the buildings are older, made up of from blocks, stones, muddy walls, and having concrete roofs (Rafique, Rahman, & Rahman, 2011).

## **Radon and its effect on health**

On inhalation of radon, alpha particles are released through the short-lived decay products of radon (Po-218 and Po-214) and these alpha particles interact with lungs tissues and can cause the DNA damage. It is supposed that cancer can occur even mutation in one cells which can acts as a pool of developing cancer cells by damaging the DNA. Hence, a single alpha particles can cause the DNA damage at any level of exposure (Organization, 2009). Radon is inhaled and ingested when human being is exposed to it and due to the harmful effects of radon on human, its monitoring is going to increase worldwide (Duggal, Rani, & Mehra, 2014). During the regular activities, such as flushing toilets, washing clothes, radon is released, which increases the concentration of indoor radon by mixing. The radon released from water also contributes to inhalation risk of radon with indoor air. Therefore, natural sources play the significant role for increasing the radiation that human receives (Duggal et al., 2014). The study done in Europe shows that if the radon concentration level exists 200



Bq/m<sup>3</sup> to human exposure then there is higher chance of being the lung cancer and this study also further suggests that in low concentration and long term of radon exposure is risk to health (Butkus, Morkūnas, & Pilkyte, 2005). Different studies show that effect of radon exposure on women is different than man, that may be due to differences in lung dosimetry or other factors correlated to gender. This study shows that women have exhibited lower rate of lung cancer occurrence than males (Butkus et al., 2005). Similarly, Children are more vulnerable to radon exposure than adults as children have different lung structure and breathing patterns, which causes large dose of radiation to the respiratory tract. The risk from domestic radon exposure is also higher for children because they spend more time (approximate 70%) at home (Keller, Folkerts, & Muth, 1982). The risk of lung cancer is also associated with smoking habit.

Even though many studies carried out in many European countries (Table 1) to correlate with radon and risk of lung cancer, these studies were not enough to evaluate reasonable risk reliably. They also stratified several factors for study such as smoking habits, dwelling location, age and sex and they found that risk of lung cancer increased by 8.4% per 100 Bq/m<sup>3</sup>. They also concluded that from residential radon there is hazardous for smokers and ex-smokers which is responsible for 2% death from cancer in Europe (Vogiannis et al., 2015).

**Table 1: A control case study of residential radon and lung cancer in 13 European country** (Darby et al., 2005)

Study	Mean year of diagnosis	Mean measure radon concentration (Bq/m <sup>3</sup> )	
		Lung Cancer	Control
Austria	1983	267	130
Czech Republic	1981	528	493
Finland (Nationwide)	1989	104	103
Finland (South)	1982	221	212
France	1995	138	131
Germany (Eastern)	1994	78	74
Germany (Western)	1993	49	51
Italy	1995	113	102
Spain	1993	123	137
Sweden(Nationwide)	1982	99	94
Sweden (never smokers)	1990	79	72
Sweden (Stockholm)	1985	131	136
United Kingdom	1991	57	54
All studies	1990	104	97

## **Materials and Method:**

### **Study area**

The present work is carried out at NMBU campus Ås to measure the indoor radon. Three different buildings build up in different time, were selected to measure the indoor radon concentration. The red circle areas in the following map indicates three different building located in various places at NMBU premises and these were selected for indoor radon concentration measurement.

Three different buildings of different ages were selected to measure the indoor radon concentration. These three different buildings were Tower, Noragric, and IMV. Among these three buildings and Noragric is the oldest buildings while Tower building is the second oldest and IMV is comparatively new one. The reason of selecting these buildings are based on the fact that indoor radon concentration is basically dependent on the building ages and the building construction material and types of ventilation. Initially background samples were taken and measured to find out the calibrate between the indoor radon concentration and outdoor radon concentration. Initially, background samples were taken and measured in summer season (June July and August) and repeated in winter season (November, December, and January).



**Figure 7: The red circle area 28 indicates Noragric building, circle 31 indicates the Tower building while 35 circle indicates IMV building (“UMB - Campus Map,” 2017).**

**Tower Building:** It was built in 1924 and supposed to be the second oldest building at study area NMBU. During its construction, Masonry and concrete elements were used, and later on lightweight walls were set up using the wood and plaster. According to information received from university administration, part of the building has been ventilated for last 10 years. As the building has its three floors with Basement the study was conducted in all parts of the building. In the buildings, different rooms were randomly selected.

### Noragric Building

This building was built up in 1859. Hence it is the oldest one but it was completely renovated in 1901. Building materials Masonry was used in load-bearing walls. Kappevelv (steel and stone) was used for covering the basement. Wood or stub loft rent in other covers and roof structure. Lightweight walls were built up in recent times using wood and plaster. Ventilation systems are since last 10 years. As tower building, this building has its three

floors with Basement and study was conducted in all parts of the building. In the buildings, different rooms were randomly selected.

### IMV or Saga Building

Even though this building is not own property of NMBU but still it is in hiring. The building was build up in 1985, during its construction, concrete in load-bearing structures and partition walls in steel, wood, or plaster were used. The ventilation system is unknown. As Tower and noragric building, this building also has its three floors with Basement and study was conducted in all parts of the building. In the buildings, different rooms were randomly selected.

## **Sampling**

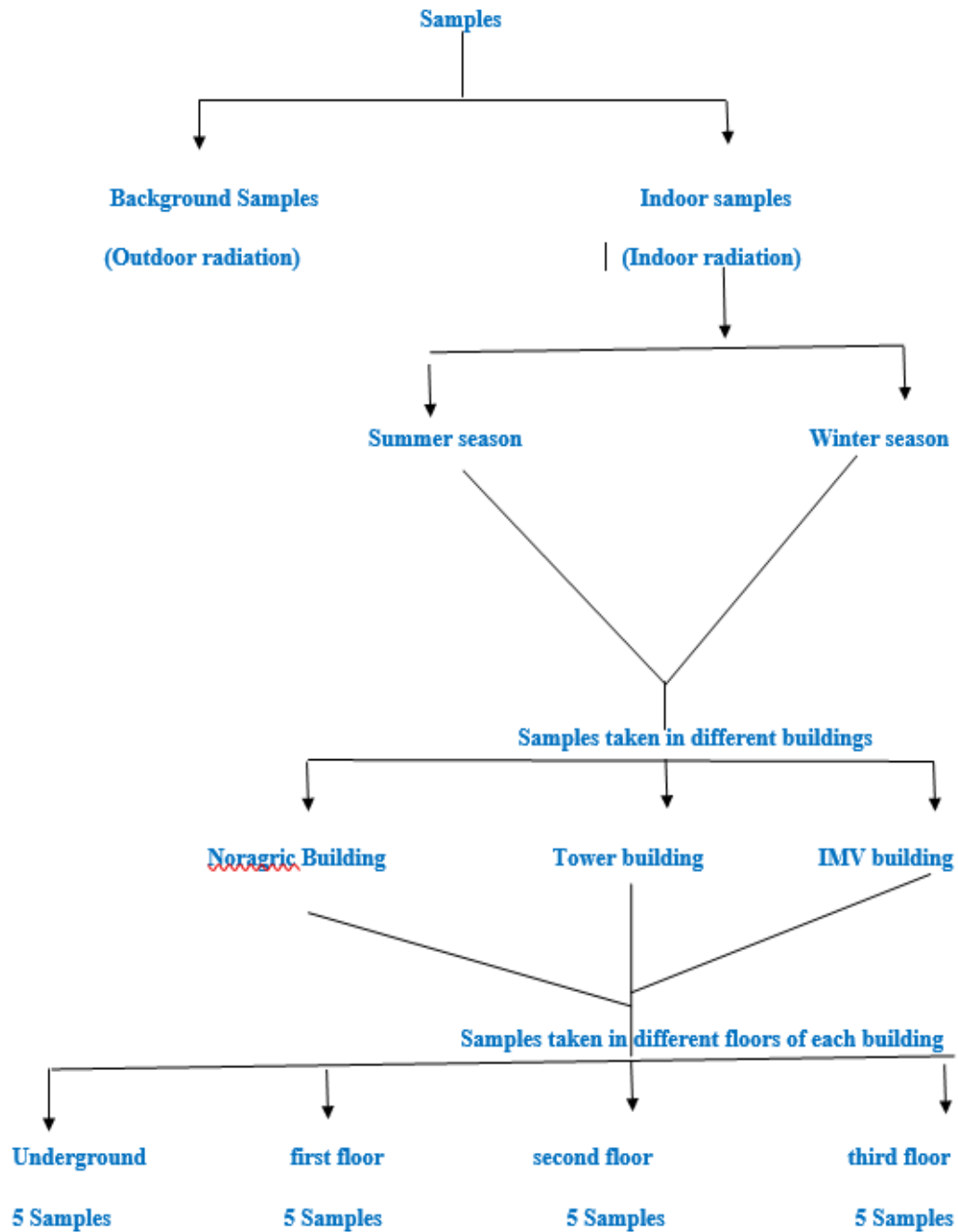
Samples were taken at NMBU premises in different buildings in different floors. Indoor radon activity is measured by capturing the air presence in indoor. In this method, radon is pumped or diffused to a detector with known amount of volume. When the air passes through filter, it captures all the progenies of radon and displays the radon concentration in Bq/m<sup>3</sup> (Ames 2008).

## **Sampling methods or Procedure**

Altogether twenty-one background samples were taken in seven scintillation cells repeating three times with each scintillation cell. Before measuring the samples, each time the basement of scintillation cells was cleaned in order to pass the lights clearly in scintillation cells. After taking the outdoor and indoor samples, these samples were left for three hours to measure the whole activity of Rn-222 and its short-lived decay products such as Po 218 and Po214. These samples were measured until three hours in Portable Radon monitor in Isotope laboratory at NMBU. For indoor radon measurement, different office rooms, lecture rooms and common rooms were randomly selected. At NMBU, these selected building (Tower, Noragric, and IMV building), have the same physical structure, therefore in each building sample were taken from the underground, first floor, second floor and third floor. In each floor, one room was randomly selected, either office room, lecture room, or library or common room. In each room, five samples were collected at five different points and this method was repeated in each floor and in each building. These samples were measured for two hours with PMR in isotope laboratory. During measurement of sample, impulse rate, and radioactivity was recorded. Similarly, the samples were taken and measured in similar procedure and method in winter season to find out the seasonal variation in winter and summer season.

## Graphical representation of Methods

In the field, the samples were taken according to the following graphical patterns and samples were measured with PMR in Isotope laboratory.



## **Description of instrument:**

The radon concentration was measured with the help of portable radon monitor V 1.7-1 (PMR 145). Basically, the instrument has two parts with its carrying case. The first part is known as the impulse detector, which contains the photomultiplier, its power supply, impulse amplifier and scintillation container. Furthermore, the instrument also has the battery, power supply, a keyboard, a control light for container cover and display (Ames 2008).

When the radon is measured, the instrument is plugged with electricity with the help of cable wire or power can be supplied from its own battery. If both the switch is turn on battery can be charged simultaneously. Normally battery is used when the instrument is used in the field works when there is absence of electricity. The instrument is also possessing keyboard having the 10 numeric keys from 0-9. Additionally, there are other keys like Enter, clear and light to perform different functions during measurement. During measuring the samples the instrument is set up manually, such as setting the scintillation cell number, sample taken time and date and duration of measurement. At the end of measurement, the instrument gives a sound and radon concentration is displayed in Bq/m<sup>3</sup>.

**Scintillation cells:** The most important part of the instrument is alpha scintillation cells. These cells are differ in their shape, size and the material but all the scintillation cells are covered with zinc sulphide which is activated by silver and here it acts as optic link with photomultiplier tube. Alpha particles are released during the decay of radon or decay products of radon it interacts with zinc sulphate. At the same time, light is released which has wavelength of 600 nm. Now the photomultiplier tube converts the light signals to electric signals and these electric signals are counted. In this way radon concentration is measured.

## **Data Analysis**

The statistical analyses were done by using the Windows (MS Excel 10) and the statistical programs MINITAB 17 as well R. Descriptive data analysis was performed to explain the average radon concentration, standard deviation and their minimum to maximum level. The Analysis of variance (ANOVA) was performed to study the significant difference in radon concentration in different floor and building in summer and winter season. In addition, a



post-hoc analysis with Tukey test was performed to see the difference in the level of these factors.

## **Dose calculation**

Even though there are large uncertainties in assessing the dosimetry and epidemiological aspect for converting an exposure to radon to a radon dose. It is nevertheless essential to be able to estimate the radon dose from the radon concentration because of its harmful effects on the human body. The equilibrium level, time spent in indoors and the dose conversion factor are the major factors which determine the level of radon dose. In the present study, the following methods are applied for calculating the inhaled annual dose by using the different factors associated with it (“radon doses estimation.pdf,” n.d.)

$$D = \sum (C \times F \times O \times DCF)$$

Where,

D= dose Rn/Th

C= Concentration (Bq/m<sup>3</sup>) of Rn -222 and Rn-220

F= Equilibrium factor, of UNSCEAR for indoor environment

For radon = 0.4 (EERC), or Thoron= 0.1 EETC

O= occupancy used in the study (44 weeks X 37.5h) = 1650 h

DCF: Dose Conversion Factor, of UNSCEAR 2000

Radon DP: 9 nSv/Bq/h/m<sup>3</sup>

## Result and Discussion

### Existence of radon concentration in different building

The Radon concentration was measured at NMBU in three different buildings using the Portable radon monitor (PRM 145). The measurements were done in two season (summer and winter) to investigate the seasonal variation. The range (minimum - maximum) and average radon concentration with standard deviation (uncertainty) are presented in (Table 1 and Table 2) for summer and winter season respectively. The highest average radon concentration with Uncertainty was obtained in underground with  $147 \pm 59$  Bq/m<sup>3</sup>, while radon concentration varies (Minimum - maximum) between 44 Bq/m<sup>3</sup> to 197 Bq/m<sup>3</sup> at underground floor in tower building (Table 1 and Figure 8), similarly the second higher average radon concentration with Uncertainty was found to be  $47 \pm 17$  Bq/m<sup>3</sup>, while the radon concentration varies from (minimum - maximum) 32 Bq/m<sup>3</sup> to 74 Bq/m<sup>3</sup> at underground floor in Noragric building, (Table 1 and Figure 8), likewise the lowest average radon concentration (Uncertainty) was found  $14 \pm 4$  Bq/m<sup>3</sup> while the radon concentration varies from (minimum -maximum) 8 Bq/m<sup>3</sup> to 17 Bq/m<sup>3</sup> in IMV building (Table 1 and Figure 9) for summer season.

Similarly, in winter season, the highest average radon concentration with Uncertainty was found to be  $56 \pm 27$  Bq/m<sup>3</sup>, while the radon concentration (minimum-maximum) varies from 17 Bq/m<sup>3</sup> to 79 Bq/m<sup>3</sup>, in underground at tower building, similarly the average radon concentration (uncertainty)  $19 \pm 11$  Bq/m<sup>3</sup> in Noragric building whereas the lowest average radon concentration (uncertainty)  $13 \pm 6$  Bq/m<sup>3</sup> in winter season (Table 2, Figure 9). While the action level for households or dwellings are prescribed by different authorities such as; Norwegian Radiation Protection Authority (100 Bq/m<sup>3</sup>), Environmental Protection Authority ( i.e., 148 Bq/m<sup>3</sup>), World Health Organisation ( i.e., 100 Bq/ m<sup>3</sup>), International Commission on Radiological Protection ( 200-600 Bq/ m<sup>3</sup>) (Komperød & Nrpa, 2015; NRPA, 2010).

**Table 2 Average Radon concentration in summer season, standard deviation, and their range from minimum-maximum values for different buildings.**

Buildings		Floors			
		Underground	First	Second	Third
		N=5	N=5	N=5	N=5
Tower	Av. Radon	147	11	3.67	2.67
	S.D	59	4	0.1	0.5
	Range	44-197	3-12	3-4	2-4
Noragric	Av.Radon	47	25	17	10
	S.D	17	13	2	3
	Range	32-74	15-46	15-20	8-15
IMV	Av.Radon	14	5	4	4
	S.D	4	1	1	1
	Range	8-17	4-9	3-6	3-4

Av. Radon = Average Radon Concentration (Bq/m<sup>3</sup>)

S.D = Standard deviation (Bq/m<sup>3</sup>)

Range = Radon Concentration Range(Min-Max)

In present study, higher average radon concentration ( $147 \pm 59$  Bq/m<sup>3</sup>) and ( $56 \pm 27$  Bq/m<sup>3</sup>) was detected in underground floor, in summer and winter season respectively (Table1, & Table 2 and Figure 8 and figure 9). Several authors (Khokhar, Kher, Rathore, Pandey, & Ramachandran, 2008; Sundal et al., 2004) have mentioned that building ground is the main source of radon seeping in dwellings or buildings, therefore underground floors can accumulate higher radon concentration then rest floors of the buildings.

The study carried out by Strand, Lunder Jensen, Ånestad, Ruden, & Beate Ramberg, (2005) in Norway; found that in few of the municipalities, due to variation in geological structure with highly permeable soil characterstic, where the mean radon concentration was 89 Bq/m<sup>3</sup>, while 9 % and 3% houses have the more then 200 Bq/m<sup>3</sup> and 400 Bq/m<sup>3</sup> radon concentration respectively. Our findings reveled the highest average radon concentration in Tower building was highest ( $147 \pm 59$  Bq/m<sup>3</sup>) then Noragric ( $47 \pm 17$  Bq/m<sup>3</sup>) and IMV ( $14 \pm 4$  Bq/m<sup>3</sup>) in underground parts of the other buildings. This showed that Tower building has radon

concentration level which is above the action level but below the recommendation level in Norway (Strand et al., 2005). At the same time (Barros-Dios et al., 2007) found that there is no significant difference in radon concentration in the households which are constructed with the basement or without basement but he also mentioned that underground floors or basement may have the higher radon concentration as basement or undergrounds floors acts the entry points for the radon gas. Barros-Dios et al., (2007) also found that in Spain Galicia is a high radon-emission area, with average radon concentration of  $69.5\text{Bq/m}^3$ , 21.3% of homes above  $148\text{Bq/m}^3$ , and 12% above  $200\text{ Bq/ m}^3$ . Which is higher than the present study area. Even though in present study, all three buildings have the same kind of buildings materials were used during construction; like Steel and stone in floor wood and plaster in walls. But several other studies (Abd-Elzaher, 2013; Barros-Dios et al., 2007) shows that radon concentration varies within the same building in different floors due to uses of different material inside the building. They found that mean radon concentration varies within the living room, bedroom, and kitchen, as concrete and cement was used in kitchen while the decorating and finishing materials were used in other rooms. According to (Kenawy, M.A.; Morsy, A.A., Abdel Ghany, 2002) reported that ceramic may be the possible cause of radon emit which is the decay product of uranium and thorium which already presents in entire decorating materials (Abd-Elzaher, 2013).

The undergrounds parts of Tower and Noragric buildings are allocated for the purpose of storing books and other stationary, while underground part of the IMV building is allocated for the classrooms. Among all these three buildings, undergrounds of IMV buildings has the better ventilation system than other two buildings. Hence it can be Seen from (Table 1, and Table 2 and Figure 8 and Figure 9) that underground floor has lower radon concentration than other two buildings. As well the underground part of the Tower and Noragric buildings remains closed almost all the times as they are not used frequently. Therefore due to these reasons higher radon concentration may be found in Tower and Noragric buildings. Radon concentrations are generally highest in basements and ground floor that are in contact with the soil or bedrock (J. Appleton, 2013). According to Administrator, (2004), soil was the main contributor of radon in Lithuania and there was higher Radon concentration radon reported in lithological region where the soil contains the high concentration of radium. It was also observed in present research work that the underground parts of Tower and Noragric buildings were not used frequently as other rooms or floors were used, hence ventilation system may not be in proper use which could be the significant factor for indoor air

exchange. Kapdan & Altinsoy, (2012) also did the comparative study between dwellings and school in the same region of Turkey and they found that indoor radon concentration is mainly reliant on ventilation of indoor air and they also investigated the higher radon concentration was in dwelling than schools because in the school's indoor air changes in break time in each hour.

Result from other studies also showed that the oldest houses are build up from stones, and differ in architecture and building material, have smaller or fewer window which might cause for the presence of the highest radon concentration. Barros-Dios, Ruano-Ravina, Gastelu-Iturri, & Figueiras, (2007) also reported that basement or underground part of the dwelling may acts as entry point for the radon gas. Though fairly considered, the air released by well water during showering and other household activities may contribute in adding radon concentration in small amount (J. Appleton, 2013).

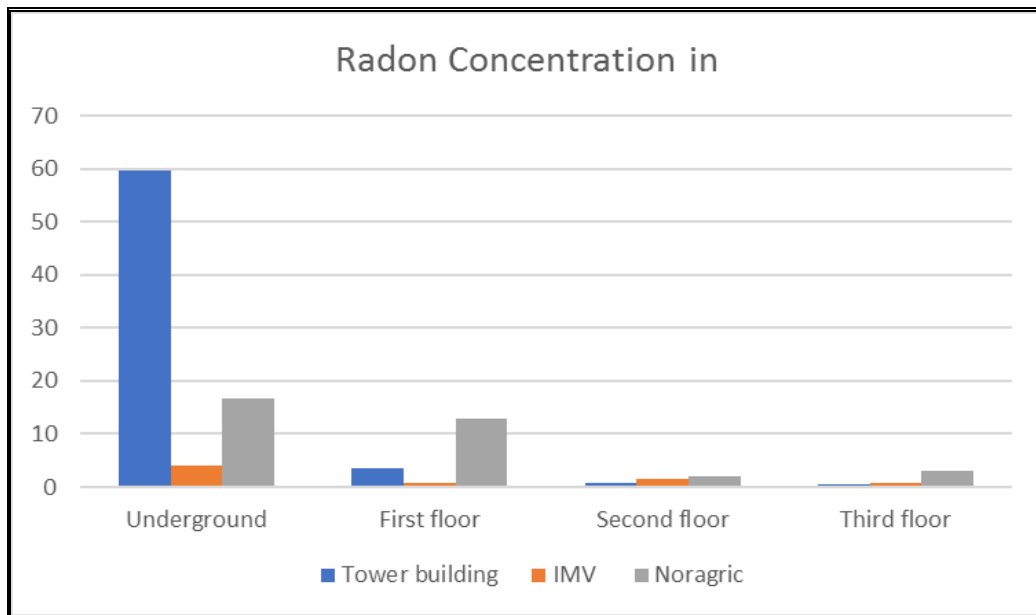
**Table 3 Indoor radon concentration (Bq/m<sup>3</sup>) in winter season with standard deviation and Range of concentration for different buildings.**

Buildings	Parameters	Floors			
		Underground N=5	First N=5	Second N=5	Third N=5
Tower	Av.Radon	56	12	3	3
	S.D	27	7	1	1
	Range	17-79	6-26	3-4	3-4
Noragric	Av.Radon	19	13	6	3
	S.D	11	3	2	1
	Range	9-34	9-18	4-9	1-4
IMV	Av.Radon	13	8	4	3
	S.D	6	3	2	1
	Range	4-20	6-13	3-9	2-3

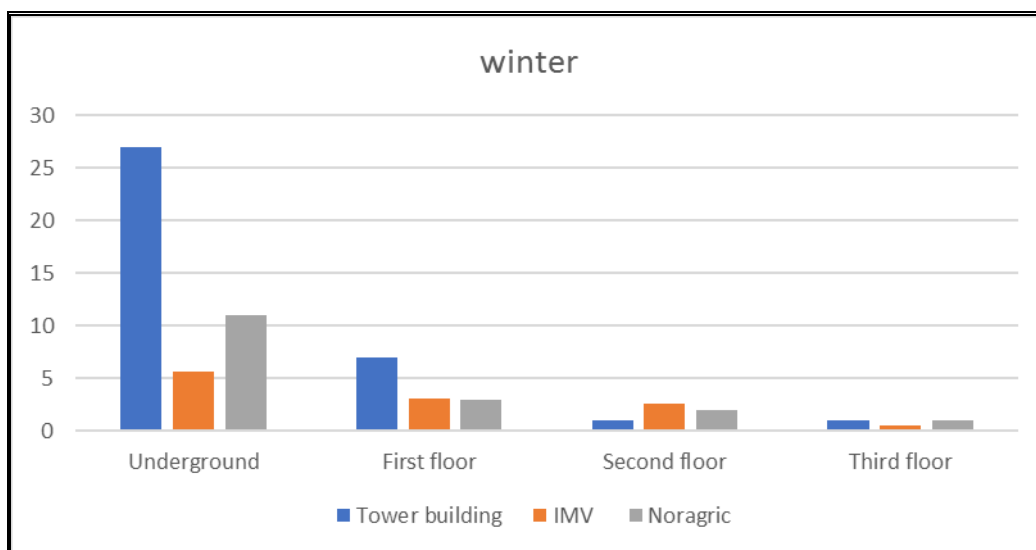
Av. Radon = Average Radon Concentration (Bq/m<sup>3</sup>)

S.D = Standard deviation (Bq/m<sup>3</sup>)

Range = Radon Concentration Range (Min-Max)



**Figure 8:** Difference of radon concentration (Bq/m<sup>3</sup>) in three different buildings in Summer season shows Maximum radon concentration in Tower, Noragric and IMV building.



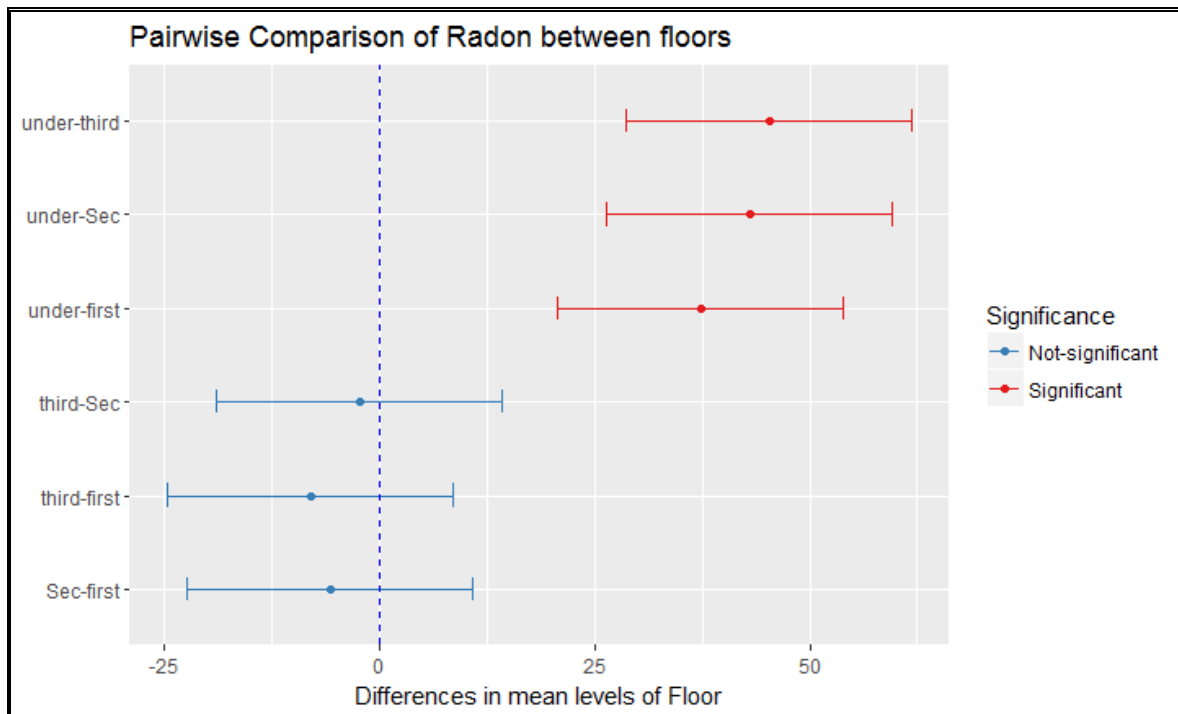
**Figure 9:** Difference of radon concentration (Bq/m<sup>3</sup>) in three different buildings in Winter season shows Maximum radon concentration in Tower, Noragric and IMV building.

## **Relationship of radon concentration among buildings within floors**

ANOVA (Tukey) test was performed to test whether radon concentration is dependent factor of different buildings and floors. From present study, it was investigated that there was a significant difference in radon concentration between underground to first, second and third floor  $P < 0.005$ , 95% confidence level, (Table 2, Table 3 and Figure 10), whereas there was no significant difference of radon concentration between other floors.

From the result, it can be seen that Radon concentration varies according to floor/strata of the building (Table 3, Figure 8). It was found that radon concentration decreased as the height of floor was increasing for each building. (Barros-Dios et al., 2007) also reported the similar kind of result in their study; they also reported that radon levels are quite low at upper storey of the buildings than the lower storey. In present study, in each building first, second and third floors have well ventilated system and almost all the rooms are allocated either for classrooms, office or common rooms, where student, people and other employees use these rooms frequently and open ventilation for air exchange which may be one of the significant cause to possessing lower radon concentration.

Papaefthymiou, Mavroudis, & Kritidis, (2003) also did the similar kind of study in Greece and they also find that radon concentration is linearly decreased from underground floor (86 Bq/m<sup>3</sup>) to second floor (19 Bq/m<sup>3</sup>) as similar to our present findings. Similar type of trend is observed in several other studies (Giagias, Burghel, & Cosma, n.d.; Kritidis, Kamenopoulou, & Kallithrakas-Kontos, 1994). The another factors may be the indoor temperature which could be increased due radiating heater which may not be turned off during summer season and increased level of temperature can increase the indoor radon activity (Xie et al., 2015).



**Figure 10:** Pairwise comparison of Radon concentration between different floors

### Seasonal variation of Radon concentration

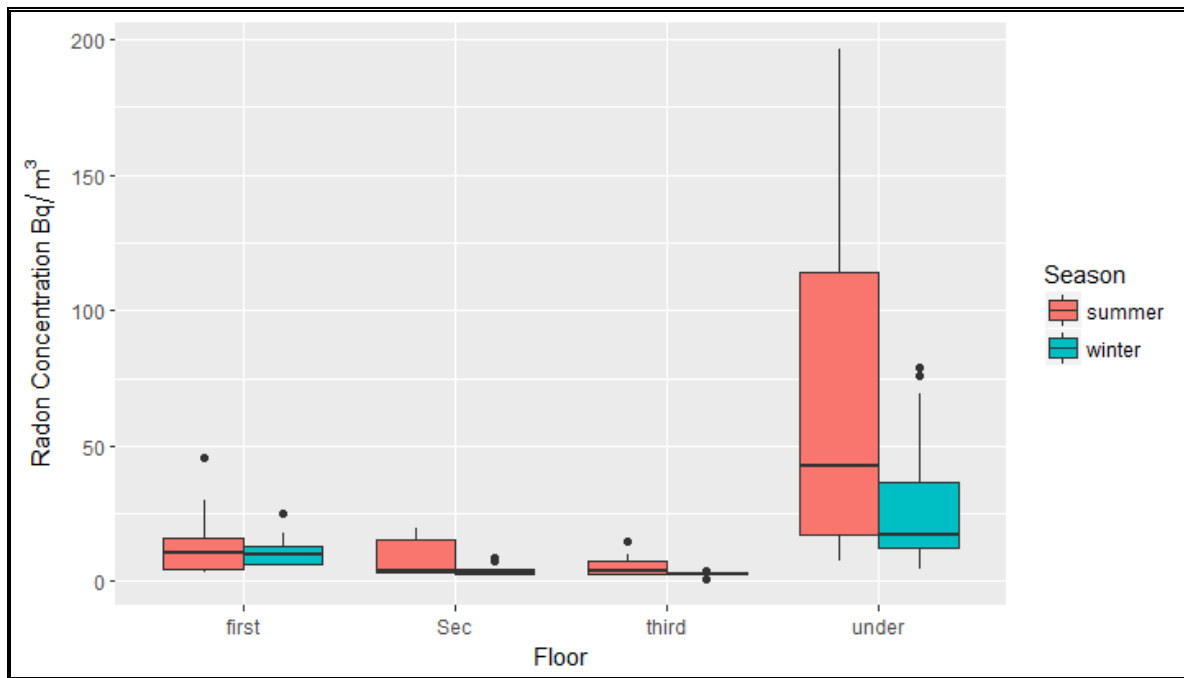
We found that the highest average radon concentration was found nearly ( $147 \pm 59$  Bq/m<sup>3</sup>) in summer and ( $56 \pm 27$  Bq/m<sup>3</sup>) in winter in tower buildings while next higher average radon concentrations was found in Noragric building ( $47 \pm 17$  Bq/m<sup>3</sup>) and ( $19 \pm 11$  Bq/m<sup>3</sup>) in summer and winter season respectively whereas the radon concentration was found least in IMV ( $14 \pm 4$  Bq/m<sup>3</sup>) and ( $13 \pm 6$  Bq/m<sup>3</sup>) in summer and winter season respectively ( $P < 0.001$ , Table 4, Figure 11 and figure 12). Similar kind of result was mentioned by (Xie et al., 2015) where the highest radon level at summer while low at winter in Alabama homes. But the findings of this research work contrast with the characteristics features of Radon which should be higher in winter and lower in summer. The another study carried out by (Denman et al., 2007; Papaefthymiou et al., 2003; "Thoron contribution to the natural irradiation of the Romanian population and problems related," 2013) found that that higher indoor radon (Rn-220 and Rn-222) concentration was in winter season and low concentration at summer season. Similarly, Ramola, Negi, & Choubey, (2005) also reported that radon concentrations were found to be highest in winter and lowest in summer season. In winter radon concentration was measured between 30 and 40 Bq/m<sup>3</sup> while in summer found in between 10 and 20 Bq/m<sup>3</sup>. Furthermore, Singh et al., (2005) also investigated indoor radon was higher in winter than summer and the winter/summer ratio ranges from 0.84 Bq/m<sup>3</sup> to 1.89 Bq/m<sup>3</sup> with an average of 1.46. Similar



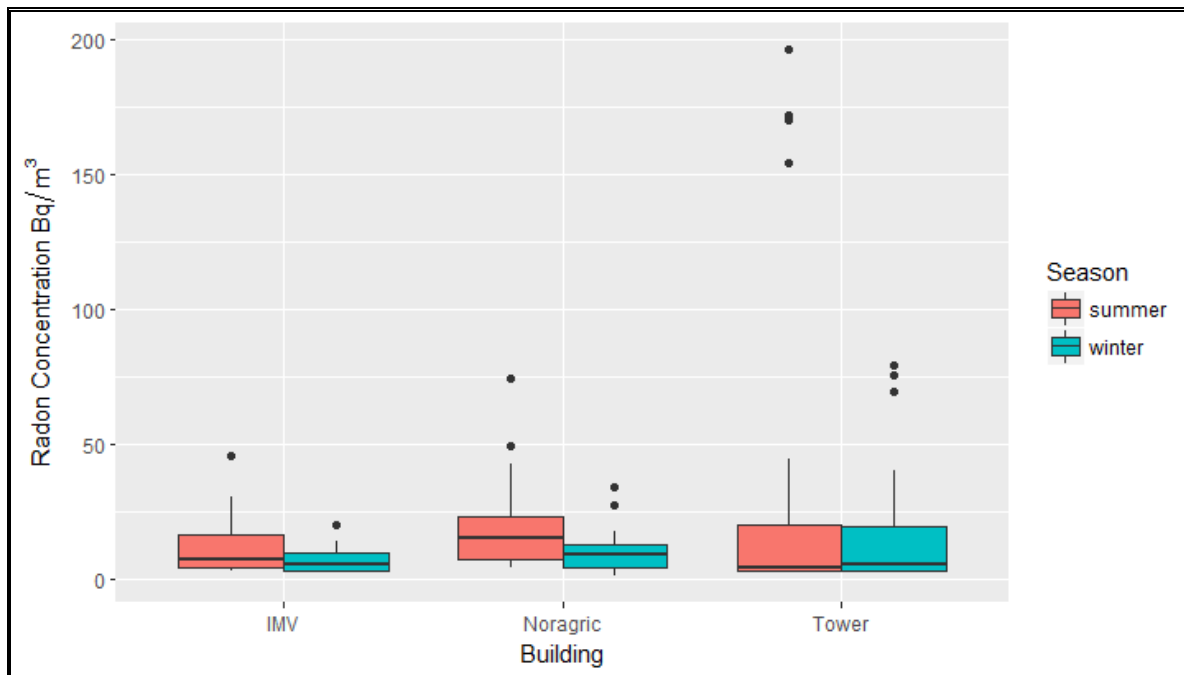
kind of observation was reported by several others investigators in several other countries (Arvela, 1995; Mrdakovic Popic, Bhatt, Salbu, & Skipperud, 2012; Muntean et al., 2010).

Even though in present research work climatic parameters such as temperature, pressure, humidity and wind are not taken into consideration but other studies (Marley, 2001; Xie et al., 2015) revealed that seasonal variation of radon concentration depends on climatic parameters. Marley (2001) and Nazaroff (1992) mentioned that indoor radon concentration increases with increasing indoor and outdoor temperature. At the same time (Lynn Marie Hubbard, Mellander, & Swedjemark, 1996) mentioned the negative effect of temperature in indoor radon. Simultaneously Denman et al., (2007) mentioned that radon activity concentration tends to be increase with increasing of temperature. Therefore, in present study area, radiation heater may not be turned off and increased temperature may increase the higher level of radon concentration in summer season.

There are several other factors which are interrelated with building features and habitat of peoples which also determines radon concentration. There is statistically significant association between aeration system, floor level of room and radon concentration (Denman et al., 2007). Singh, Mehra, & Singh, (2005) and Sundal, Henriksen, Soldal, & Strand, (2004) also reported that seasonal variation in radon concentration largely depends upon physical condition the indoor atmosphere such as temperature, pressure, ventilation system wind speed and building materials etc. and living habitat of the people. Singh et al., (2005) also observed the seasonal variation of indoor radon levels of the Punjab region that may be due to the poor ventilation system as well as the building characteristics.



**Figure 11:** A box plot of seasonal variation of radon concentration in different floors.



**Figure 12:** A box plot of seasonal variation of radon concentration in different buildings.

**Table 4 Analysis of variance shows the significant difference of radon concentration in floor, buildings, and season.**

	<b>Df</b>	<b>Sum Sq</b>	<b>Mean Sq</b>	<b>F Value</b>	<b>P value</b>
Season	1	4455	4455.4	7.3411	0.0078190**
Floor	3	40462	13487.2	22.2224	2.531e-11***
Building	2	8994	4497.1	7.4098	0.0009573***
Season Floor	3	7768	2589.4	4.2665	0.0068470**

### **Annual occupational Dose in study area**

Our results indicate that highest annual dose is 1.0 mSv/y, which was for underground floor of Tower building and lower in the other Floors and buildings (Table 5). But if the indoor radon concentration exceeds beyond the action level (100 Bq/m<sup>3</sup>) then due to adverse effect on health, the effort should be made to reduce the radon concentration level. Because, radon and its progeny emits alpha energy in significant amount in indoor condition and alpha energy is absorbed in lungs through the inhalation process which is causal factor for lungs cancer. Bhatta, C.R., (2011) mentioned in his research work that population who receives <5mSv is supposed to be Normal level natural radiation, 5mSv but < 20 mSv medium level natural radiation dose and 20 to 50 mSv and very high level natural radiation dose is supposed more than >50 mSv.

**Table 5 Annual occupational Radon Dose (mSv/y) in Study Area:**

	<b>Under ground</b>		<b>First floor</b>		<b>Second Floor</b>		<b>Third Floor</b>	
	<b>S</b>	<b>W</b>	<b>S</b>	<b>W</b>	<b>S</b>	<b>W</b>	<b>S</b>	<b>W</b>
Tower	1.0	0.4	0.07	0.08	0.03	0.01	0.02	0.02
Noragric	0.3	0.1	0.2	0.08	0.1	0.09	0.06	0.04
IMV	0.01	0.08	0.03	0.05	0.07	0.07	0.07	0.02

**S= Summer, W=Winter**

According to Environmental protection Agency (EPA) that “if a person exposed to an indoor level of 4 pico curies per litre (4 p Ci/l) or 148 Bq/m<sup>3</sup>, the probability of developing lung cancer is 13-15 persons per 1000. Furthermore, exposure to a radon level of (20 pCi/l ) or (740 Bq/m<sup>3</sup>) is as hazardous as smoking a pack of cigarettes a day” (Henschel & Scott, 1986). But at the same time WHO suggest that when the when the radon concentration increase more than (100 Bq/m<sup>3</sup>) then house owner should take remedial action for reducing radon level in houses.

According to present findings, radon concentration level exceeds more than action level (100 Bq/m<sup>3</sup>) and annual dose 1.0 (mSv/y) exist in undergrounds parts but at the same time people stay for very short time duration in the undergrounds floor. Hence the risk from the annual dose from the radon become very less for employees, professional, and students. Furthermore, from the present findings it can be seen that radon concentration is too lower then action level (100Bq/m<sup>3</sup>) in first, second and third floors than undergrounds floors. On the other hand those students spend few time (like 3-4 hours/day) in first second and third floors of the building so they receives even very less dose due to presence of less indoor radon concentration which may not have significant effect on health, even though the employees who spend their 7-8 hours in their office, they also received the lower radon annual dose due to their occupancy factor and the present of radon concentration.

## **Conclusion:**

In all the three building the radon concentration was found to be less then action level 100 Bq/m<sup>3</sup> accept Underground floors. The action level is recommended by Norwegian regulation protection authority. Even though, these results are of minor importance due to the fact that people don't spend much time in these areas.

- The seasonal variation in radon concentration indicates that higher radon concentration was in summer and minimum in winter due to continuous turned on heating system or poor exchange of indoor air in underground floors.
- The highest radon concentration and annual dose was found at underground floors in summer season which indicates that there is need to take some action to reducing concentration level.
- Ventilation system can be used properly all year around to reduce the radon concentration on those areas where it is supposed to be increased level.
- Hence the appropriate ventilation system is should be set up in the buildings or households reducing the radon level.

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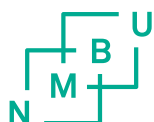
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Norges miljø- og biovitenskapelig universitet  
Noregs miljø- og biovitenskapelige universitet  
Norwegian University of Life Sciences

Postboks 5003  
NO-1432 Ås  
Norway