Investigation of Seasonal Variation of Indoor Radon-222 Concentration

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Research Article

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Abstract

Inhalation and ingestion are the two main routes upon which human beings are exposed to radon and its decay products. Due to the electrostatics nature, radon can attach to solid particles and aerosols in the surrounding air. During the inhalation of these radioactive aerosols deposition will be takes place in different regions of the human respiratory tract. The deposited aerosols carrying radon and its progeny undergo a continuous radioactive transformation and exposing the lung to the ionizing alpha radiation which can destroy sensitive cells in the lung causing a mutation that turns to cancerous. Radon which is colorless, odorless and tasteless radioactive noble gas is the major health concern which is the second leading cause of lung cancer. In this concern, indoor radon survey has been conducted in many countries in the world. The result of these surveys shows that indoor radon concentration has a seasonal variation. This is due to the fluctuation of environmental parameters and geological nature of the building. Its concentration was found maximum in cool (winter) season and minimum concentration was recorded in warm (summer) season of the year.

Introduction

Since the existence of life in the universe living things such as humans, animals and plants have been exposed to natural radiation [1]**.** Our world is full of radioactivity and hence there are over 60 radionuclides can be found in nature [2]. These radionuclides are the sources of radioactivity and emit nuclear radiations which have become a part of our daily lives. Radiation is present everywhere and human being is directly or indirectly being continuously exposed to radiations. Radiation in which human beings are exposed comes from different natural and human made sources. The ionizing radiation are originated from soils, water, building materials, air, water, mining areas, cosmic origin, etc[2]. Every day, we ingest/inhale nuclides in the air we breathe, in the food we eat and the water we drink. Therefore we have to investigate the natural radioactive level of the environment where human beings live is suitable or not for healthy living.

Human population in the community can be exposed to manmade and natural radiation sources. The natural radiations surrounding the life on earth can either be terrestrial or extraterrestrial (cosmic) origin. Terrestrial radiation includes the ionizing radiation arising from radionuclides in the earth's environment originated from soil, rocks, construction materials, water, air, mining areas and the cosmic rays are high energy radiations which enters to the earth's atmosphere from the outer space [3].The radioactive elements such as ^{238}U, ^{232}Th and their daughter products, ^{226}Ra, ^{222}Rn and ^{235}U and also ^{40}K are major sources of radiation of natural origin [4]. The ionizing radiations such as α, β, and γ radiations are emitted out from different terrestrial materials from which soil is a major source for natural radioactivity, and it is the main source for migration and transfer of radionuclides into the surrounding environment [5]. In worldwide different studies have being performed to determine the activity concentration of these radioactive elements which are the main sources natural radiation in soil upon which human beings are undergo a direct contamination [6]. The magnitude of these natural exposures depends on geographical location and on some human activities [7].

Human beings can also be exposed to man made radiation sources in addition to natural radiation sources. Radiation has different application to various sectors such as medicine, biology, industry, agriculture, and electric power generation. During their applications, humans can be exposed to the radiation emitting from different radioactive sources and exposed to different radiation induced diseases [8]. Man made sources are the artificial radionuclides, which include Medical radiation sources (x- rays and radioactive isotopes that are used in medicine for diagnosis and therapy), Consumer products: (Such as static eliminators (containing polonium-210), smoke detectors (containing americium-241), cardiac pacemakers (containing plutonium-238), fertilizers (containing isotopes potassium, from uranium and thorium decay series), and tobacco products (containing polonium-210 and lead-210)), and Atmospheric testing of nuclear weapons (radiations released during testing of nuclear weapons and nuclear power generations**).** More than 80% of human exposure comes from the natural radioactivity from different sources [9] the rest is contributed from manmade radiation sources.

Radon (Rn), which is a radioactive decay product of one of the members of uranium decay series called radium (Ra), is a radioactive, colorless, odorless, and tasteless noble gas. This is what makes radon difficult to detect without a special equipment. There are three known radon isotopes; Radon (^{222}Rn) which has half-life of 3.82 days, Thoron (^{220}Rn) which has half-life of 55.8 second, and Actinon (^{219}Rn) which has half-life of 3.98 second. ^{222}Rn, ^{220}Rn, and ^{219}Rn are found from the decay chain of the three uranium isotopes of ^{238}U, ^{236}U and ^{235}U respectively [9, 10, 11]. Uranium can be found in soil, rock, building materials, ground water and mining areas [12]. Even though soil is the major sources of radon, different building materials such as cement, rock, concrete, marble, paints, and gypsum always contain uranium and radium [13]. Radon is the leading source of ionizing radiation which is received by humans. It contributes around 55% of the environmental background radiation dose which is identified as a health hazard for mankind [13, 14], and it is found in variable concentration from location to location depending on the geological nature of that particular place [11].

Radon is radioactive nuclei means it is unstable and hence it undergoes a continuous radioactive transformation and it forms a number of short-lived radioactive decay products called radon progenies. Polonium (^{218}Po), lead (^{214}Pb), bismuth (^{214}Bi) and polonium (^{214}Po) are the successive radon decay products. Under each radioactive transformation alpha radiation, beta radiation or sometimes gamma radiation are emitted out [11]. Over 90% radiation dose from radon is contributed by the two alpha radiation emit decay products called polonium (^{218}Po) and lead (^{214}Pb) [15].

Indoor Radon and Its Health Effect

The earth’s atmosphere is full of gas with liquid and solid particles. Those particles in air are known as aerosols which have various size, shape and chemical composition. Mostly radius and diameter of aerosols can be used to define their size. Due to their size and shape difference, they have different settling velocity and diffusion coefficient.

When radon is exhaled into the earth's environment from different sources such as soil, rock, building materials, ground water and mining areas through diffusion and emanation, it become attached to the mono-dispersed and poly-dispersed aerosols due to its electrostatics characteristics [16]. Depending on the amount of aerosol concentration of the surrounding environment and humidity of the surrounding environment around 80% of the radon decay progenies will be attached to the aerosols in the air that we take in.

Inhalation and ingestion are the two main route in which the human being is exposed to radon and its decay products. After inhalation and ingestion of aerosols carrying radon is taking place, it releases energetic alpha radiation with some associated gamma radiation that can damage the sensitive cells of the lung and stomach and can induce cancer. Radon is a noble gas, it is non-reactive and it exhaled after being breathed in, but its decay products combine with other particles in air such as dusts or aerosols will be deposited on the surface of different regions of the respiratory system. Two of its decay products Polonium (^{218}Po) and lead (^{214}Pb) are significantly hazardous. The deposited radioactive aerosols continued to undergo a successive radioactive spontaneous transformation. Under each decay energetic alpha radiation is bombarded with the vital molecules in the lung cells causing a DNA structure break which cause mutations that will be turned to lung cancer [17].

Based on several investigations in Europe, North America and China there is a direct relation between indoor radon concentration and inducing lung cancer. Based on these studies, radon was identified as the second leading cause of lung cancer after cigarettes [9]. Different countries and organizations put their action level to reduce radon health risk. The occupant needs to take action when radon concentration exceeds the recommended safe limits. The World Health Organization (WHO) and Environmental Protection Agency (EPA) suggest that home owners take action when radon levels exceed 100 Bq/m^3 and 148Bq/m^3 respectively [11, 15].

Major Factors Affecting Indoor Radon Concentration

The exposure to radon and its progeny is not limited to the underground miners only, humans in the indoor environment is also exposed to radon and its decay products. Uranium is widely distributed constituent of the earth's crust, typically in 2–4 parts per million and in consequence is found in most materials commonly used by the building industry. In confined places of the buildings and houses which do not allow air exchange can be accumulated by radon gas which diffused from building materials and soils so that the people living in the house can easily inhaled radon and its decay products [18]. In the indoor environment it can be accumulated upto a harmful level. Different housing and environmental factors such as the types of construction materials of the building, the soil composition around the house, design of the house, construction, and level of ventilation of the house are the major factors which determine the amount of indoor radon (^{222}Rn) concentration [19].

It is known fact that the probability of inducing lung cancer of the room occupant is increased when the indoor radon concentration is high. And hence different studies are conducting in concerning with radon and it decay products. In order to understand the distribution of radon concentration in dwellings, different indoor radon surveys have been conducted in different countries of the world. The results of these surveys indicate that the amount of indoor radon concentration shows a strong variation with time. In general, one can study this in terms of two types of variations: daily and seasonal variation. On the diurnal context, the amount indoor radon concentration is found maximum during the night and early morning, while the minimum concentration is recorded during the day [9]. In order to manage the health hazards from radon and radon progeny one needs to study the seasonal variation of indoor radon concentration.

The results of different papers show that the concentration of radon and its decay products in dwellings varies from season to season. Meteorological parameters, geology, building materials, building construction type and the degree of ventilation of closed environments are among the important factors affecting the radon in indoor air [20]. The fluctuation of weather or environmental parameters such as temperature, pressure, humidity, ventilation condition, wind speed and direction, and soon plays a role in a seasonal variation of indoor radon concentration [21].

The variation in concentration of radon of the given dwelling is related to the seasonal change. This is because a climate change can cause different effects on the dwellings environment or to the indoor air [21]. The windows and doors of buildings during the winter months tend to be closed for longer period of time due to rain, snow or ice, this will results a lower ventilation rate of the room and hence the accumulation of the indoor radon tends to rise and may be build up to the harmful levels. But in Contrast during the summer months the people open the door and windows which increases the ventilation of the house [22]. In fact ventilation rate and radon concentration has inverse relation. Ventilation rate is a key to reduce indoor radon concentration [21]. Improvements in ventilation systems normally change radon concentration by less than 50 percent [23]. Furthermore, the temperature is low in winter and autumn seasons, windows and doors are closed to save energy meaning there is restricted ventilation and hence causing the level of radon concentration to increase in the room. Therefore the indoor radon concentration in winter is found higher as compared to the other seasons of the year.

Geological nature of the building is also another factor for the variation of the concentration. Different building materials such as cement, rock, concrete, marble, paints, and gypsum always contain uranium and radium [24]. Buildings are made from rocks of different ages, origin, mineral and chemical composition. Heavy construction materials such as concrete and stone generally increases the thermal mass of the building meaning increases the internal air temperature which keeps the building warmer in summer [25]. For this purpose the home owners can apply different ventilation methods such as installing a radon pump system, opening of windows, doors and vents of the house (called natural ventilation), and house pressurization uses a fan. This makes the radon concentration is seasonal that is low in warm (summer) and higher in cool (winter) seasons [16, 26].

Different article suggest that there is a relationship between the variation of indoor radon concentration and the construction style of the house. Some houses are constructed with a basement and the other are constructed without basement. The basement is an important construction element of a building. Radon concentrations in buildings with and without basements are different [27]. Houses with a basement have greatly increased levels of radon concentration than without basement. Since radon enters homes from the ground, the presence of a basement is expected to be a determinant of high concentrations [28]. Soil is most frequently the main source of radon in building air. Soil permeability of the basement is the primary responsible for the migration of radon into the basements which allows the gas to build up to the harmful levels. In confined spaces such as basements of the house and buildings where air exchange is not allowed, radon can accumulate to harmful levels. It is recommended that basements must not to be used for residential purposes if radon concentration is high enough.

The construction of the house plays the role for the cause of the variation of indoor radon concentration. The construction of houses in urban and rural area is different. Due to economic, social, and environmental terms, which have been reflected by the type of buildings in urban and rural area. In rural areas including villages and hamlets most of the houses are constructed from mud and local stones. These houses are poor ventilated constructed with and without windows. The building materials of these houses such as stone and soil allow more radon to diffuse into the room due to the porosity of the materials used contributed to the high concentration of radon [24]. In fact the buildings in the rural area are smaller and older. The indoor radon concentrations in these mud houses are relatively higher than that in the normal buildings [29].

Moreover, the wind speed and direction are the other factor for the variation of indoor radon concentration. It has its own effect on the pressurization of the room it can create a pressure difference between the inside air and atmospheric air [27]. In addition, the life style or habits of the home owners of shutting and opening of doors and windows is also another factor that influence the level of indoor radon concentration [21].

The age of a house determines construction features of the house, technologies and materials. Cracks and lack of continuity appear together with age in construction material and increase radon inflow [27]. Older homes are going to have higher concentrations of radon because they typically have more cracks in flooring and the foundation and thus have higher risk of contamination [21].

As it has been observed from the data of different published papers radon concentration is not constant with time. Its concentration shows day to day, even season to season variation. So as to manage its adverse health effect one needs to detect its seasonal concentration.

Measurement Technique and Methodology

In order to measure the indoor radon concentration different instruments can be apply from active to passive detectors. Passive integrated CR-39 alpha tract detector can be used to measure long term radon-222 concentration. The measurement should be performed four times a year corresponding to the four seasons of a year so as to observe the seasonal dependence of the indoor radon concentration. This could be performed by placing the detector in one part of the house such as bedroom, sitting room, kitchen, etc which most frequently used parts of the house where the room occupants spent most of their time.

The detectors can be exposed during the four consecutive seasons of a year by placing in different houses made from different building materials in different designs so as to observe the effect of the types of the building materials used at a height of 1m from the floor and 0.5m from the walls of the building [30, 31]. Parallel to the measurement process the house owners were given a questionnaire so as to gather information about building materials used, age and shape or design of the house, etc.

After the exposure time, the detector is needed to be etched using NaoH solution to enlarge the alpha tracks to get ready for optical microscope observation for appropriate time and temperature. Then the etched tracks can be converted into radon concentration by using a conversion factor as follow [32].

$$C_{Rn} = C_f \times \frac{\rho_{Tracks}}{46.8} \times \frac{1000}{T}$$

Where C_{Rn} is radon concentration in $Bq.m^{-3}$, C_f is calibration factor, r_{Tracks} is track density (number of tracks per cm^2), T is the exposure time in hours.

Result And Discussion

In order to obtain homogeneous and interrelated results as well as to study the effects of climate change on radon concentration, radon concentration measurements were selected over different seasons of the year [33]. The measurements period extended for a year and was divided into four periods to represent the four Seasons: Winter (December - February), spring (March - April), summer (June- August) and autumn (September–November); to ensure that it covers all seasons of the year [34].

Season variation of indoor radon concentrations were measured in buildings under similar designs, resided on the same geology in Azarqa town, Jordan [22]. An indoor radon survey has been conducted in 50 dwellings situated in Sri Ganganagar district of Rajasthan using a time-integrated passive technique containing LR-115 type II solid state nuclear track detectors exposed for four seasons [28]. In similarly the seasonal variation of indoor radon concentration has been conducted in southern Haryana and Western Utter [26]. The minimum, maximum and average value of radon concentration in the four seasons in those study areas are given from Table 1–3.

Table 1
Statistical summary of radon concentration with seasons inside shops of Alzarqa Town

No.	Season	Min. Con. (Bq/m^3)	Max. Con. (Bq/m^3)	Mean Con. (Bq/m^3)	SD. Con. (Bq/m^3)
1	Winter	34.8	63.7	45.04	4.21
2	Spring	17	27.1	22.04	3.92
3	Summer	10.2	38.7	16.63	3.94
4	Autumn	16.7	113.2	42.57	9.67

Table 2
Annual indoor radon levels in Karanpur village in Sri Ganganagar district of Rajasthan

No.	Season	Min. Con. (Bq/m^3)	Max. Con. (Bq/m^3)	Mean Con. (Bq/m^3)	SD. Con. (Bq/m^3)
1	Winter	114	249	197	48
2	Spring	99	224	153	43
3	Summer	96	163	141	24
4	Autumn	92	185	159	34

Table 3
Seasonal variation of indoor radon in southern Haryana and Western Utter

No.	Season	Min. Con. (Bq/m^3)	Max. Con. (Bq/m^3)	Mean. Con. (Bq/m^3)
1	Winter	40.7	80.6	65.2
2	Spring	19.8	29.7	23.5
3	Summer	31.2	54.2	40.2
4	Autumn	22.3	46.8	32.6

* Min. Con.=minimum concentration, max. Con. = Maximum concentration, Mean Con = mean concentration, and SD Con.=standard deviation concentration.

As it has been observed in the three tables interestingly radon concentration shows a seasonal variation. What a common the three tables show is, maximum radon concentration is recorded during a winter season in contrast the minimum concentration is found during a summer season. This is due to the fluctuation of environmental factors and the geological characteristics of the building.

Conclusions

Radiation is always around us as we are surrounded by natural and manmade radiation sources. A long time exposure to the radiation can cause adverse health hazards on humans. Radon, which is the sixth daughter of uranium, contributes almost half of the natural radiation in which human beings are exposed. And hence International Agency for Research on Cancer classified radon as human carcinogen. Due to its health hazards different researches have been conducted to determine its concentration in a place where human beings are live in. The indoor radon concentration has a seasonal variation. Its concentration was found maximum in cool (winter) season and minimum concentration was recorded in warm (summer) season. The seasonal concentration of indoor radon concentration in homes, offices, schools, hospitals, shops, and industrial buildings is needed to be study.

Declarations

Conflict of Interest

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