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RESEARCH ARTICLE

RADONSOURCES ININDOORS: A REVIEW PAPER

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ABSTRACT

Radon is a noble gas formed from the natural radioactive decay of uranium (U) and thorium (Th), natural components of the earth"s crust, which decay to radium (Ra) and then to radon (Rn). The primary sources of indoor radon were identified and the immediate solutions are recommended as the way to reduce its health hazards. The sources include soil, building materials and water. Within the frame work of a simple steady-state analysis of the radon concentration in a model of atypical house, the potential contribution to indoor radon levels from each source is determined. The purpose of this paper is to examine the significant sources of indoor radon as well as its primary path ways into the indoor environment. The health effects of radon on humans were traced and it is the second cause for human lung cancer next to smoking. While an exact modeling of indoor radon levels is not possible, the simple analysis presented here may be used to determine the potential contribution of each source to the total average radon concentration in a house building. This information is particularly valuable in assigning logical priorities for the development of radon control measures and devices which will be both practical and effective in houses to minimize the radon concentration and its effect.

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INTRODUCTION

Radon (^{222}Rn) is a direct decay product of ^{226} Ra produced naturally during the radioactive decay of thorium and uranium (Khan, 2014). Radon is inactive gas that is odorless and colorless, and it does not form chemical bonds with other substances, with half-life 3.823 days and it can stay in the air for significant amount of time (Shoeib and Thabayneh, 2014) (Bowie and Bowie, 1991). Radon is 7.5 times higher than that of air, the boiling point of radon is (-61.8^{o} C), freezing point (-71.0 ^{o} C) and density (9.73 Kg.m^{-3}) (Scientific Committee of United Nation, 1982). Radon shares the greater ratio for the mean public exposure to ionizing radiation (Dunn *et al*., 2014). It is often the single largest contributor to an individual's background radiation dose, and is the most variable from location to location (Santawamaitre and Sciences, 2012). Radon gas from natural sources can accumulate in buildings, especially in confined areas such as attics, and basements. It can also be found in some spring waters and hot springs (Abd and Kotb, 2014; IAEA, 2007). In 2000, United Nation Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported that the annual dose average over the world population to be about 2.8 mSv. (UNSCEAR, 2008). Over 85% of this is from natural sources with about half coming from radon decay products in the home (Bonnefoy, 2007).The worldwide average annual effective dose from the decay products of radon is estimated to be about 1.2 mSv (IAEA, 2007). The ICRP and IAEA have recommended the use of action levels in the range 200-600 Bqm-3 above which house holders are advised to reduce radon levels in their homes (N.W.M.O. 2011). Several studies have confirmed 222Rn to be the cause breathing system problems coming from the deposited concentration in the underground water and indoor environment and that it is a major contributor to the ionizing radiation dose received by the general population (WHO, 2009). Radon decays with a 3.82 day half-life in to its short-lived decay products, which typically attach themselves to small particles in the air shortly after they are created. Up on inhalation, these decay products are deposited in the lung so that the lung receives a dose of alpha radiation from subsequent decays. In the outdoors, radon and its decay products rarely reach elevated levels because of continual dispersal and dilution (Kozak, 2010). However, in enclosed buildings, the lack of adequate ventilation may enable radon and its decay products to reach levels more than two orders of magnitude above the average out door levels (Halliday, 2009).

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MATERIALS AND METHODS

An investigation of the available research regarding the sources of radon in indoors was made. The basic concepts were organized from the online literature search using the known data bases in order to show the reality on the ground here in the parts of Ethiopia. Analysis was made to discuss the sources of radon in indoors and suggest possible mechanism to overcome the problem associated to the levels of radon in indoors.

Data analysis

Sources of Radon in Indoors

Soil

The primary and the largest source of indoor radon and its precursors is soil and in global scale, it is estimated that 2,400 million curies of radon are released from soil annually (Santawamaitre, 2012). Geology, soil moisture conditions, and meteorological conditions can affect the amount of radon released from soil (Health and Council, 2005). Because radon is a gas, changes in the atmospheric pressure also affect its emission from the ground and its accumulation in surrounding air (Halliday, 2009). The concrete floor and walls in the basement slow down the movement of radon from the soil into the building. However, cracks in the floor, wall slab joints, and the drainage system allow radon to enter a building (Radon, 2001).

The radon accumulated in indoors of buildings cannot escape easily to outside. Radon levels can be higher in homes that are well insulated, tightly sealed, and/or built on soil rich in the elements uranium, thorium, and radium. Sealing of building is to conserve energy, reduces the intake of outside air and worsens the situation in indoors. Radon levels are generally highest in cellars and basements because these areas are nearest to the source and are usually poorly ventilated (Radon, 2001).The potential for radon entry from the ground depends mainly on the activity concentration of 226Ra in the subsoil and on the permeability of the subsoil for air flow. Examples of surfaces with high radon potential are those made of shales and some granite (having high concentrations of 226Ra) from possible uranium mineralization in carbonations medium.

The nature of the soil on which the building stands and the soil composition in parts of the building affects indoor radon concentration through soil (IAEA, 2007). Climatic conditions and pressure relationships (in particular, the pressure gradient between the subsurface air and the interior of the building) affects radon concentration in a place. Radon concentrations are not constant within a building; the concentration is usually highest in the basement and declines with increasing elevation above the ground (Bonnefoy, 2007; Halliday, 2009). The global emanation from soil is estimated at about 2 billion curies per year and the radon concentration in the soil is a function of (IAEA, 2007):

- The radium concentration,
- The soil moisture content,
- The soil particle size and the rate of exchange of soil-entrapped air pockets with the atmosphere.

Water

Ground water provides a secondary source of radon, with an estimated 500 million curies released globally per year (Admassu, 1954). In different houses, drinking water can also be a significant source of 222Rn in indoors (Brunswick, 2000). The ground water potential is about 500 million curies per year (Pirsaheb *et al*., 2013). 222Rn indoors may be the air released by well water during showering and other house hold activities. Compared to 222 Rn entering the house through soil, 222 Rn entering the house through water will in most cases be a small source of risk (Alexander and Devocelle, 1997; Anastasiou and Tsertos, 2003; Dunn *et al*., 2014). Radon released from water usage indoors can also add significantly to indoor radon when the water source is an underground aquifer in granite or other radium-be a ring rock. In water from underground wells, radon levels as high as 1millionpCi/L have been measured and concentrations above 10,000pCi/L are common (Cooper, 2005). Under typical conditions roughly 50% of the radon in water is released during usage (Radon, 2001; Brunswick, 2000). Assuming that an average house hold uses 1000L/day, the radon contribution to the indoors is roughly 60 pCi/sec for each10, 000 pCi/L of radon in the water. However while radon in water is of great importance in a few regions, typical concentrations nationwide are well below 100 0pCi/L, so that water as a radon source can usually be ignored. Natural gas and propane at the well head frequently contain significant amounts of radon, but the long distribution time to the point of use leads to a many fold reduction in radon concentration. Only in the instance where a house is located close to the well head will natural gas be a potentially significant radon source, and this potential will be realized only if the house burns a great deal of gas without external venting of the combustion products (Jones, 1998).

Building materials

One of the most important indoor pollutants is radon emanating from building materials (Shoeib and Thabayneh,2014; Sabbar, 2016). All construction materials, from rocks and its bi-products, with significant trace amounts of radium are potential contributors of radon in indoors. In studies of different areas in the world, the main source of radon was the building sub-soil and the soil near the house (Quashie *et al*., 2011; Philips, 2016). Indoor radon levels are lower in flats than houses, and in buildings with concrete foundations (IAEA, 2003; Quashie, 2011). Masonry materials such as concrete, stone, and brick are the primary sources of radon among building materials, since they typically contain significant amounts of radium and several tons of such materials are used in a house. Wood and wood products are virtually radium-free and don't contribute to indoor radon (Admassu, 1954; Hilu *et al*., 2002). In houses of no concrete slab, the radon flux from bare soil would introduce radon at a rate of 150pCi/sec (540,000pCi/h) (Andersen, 1992; Quashie *et al*., 2011). However, the on-grade slab will tend to reduce this flux. In a house over a concrete slab, radon from the soil can enter the indoor space either by diffusion through the slab or by direct transport of the soil gas through cracks in the slab (Minkin, 2008). A square meter of average concrete 10cm thick with a bulk density of about 2g/cm3 will contain roughly 2x105pCi of radium (collaborting centre for environmental Health, 2008). If atypical emanation fraction of 0.2 is assumed, the radon flux density from a1pCi/g slab could be no more than about0.08pCi/m2sec. Actual measurements on a variety of concrete and bricks generally have shown a flux density of between 0.001to0.1pCi/m2sec (Bonnefoy, 2007).

Radon Health Effect

Radon is dangerous; it is the second leading cause of lung cancer after smoking, and the primary cause of lung cancer in non-smokers. When smokers are exposed to radon, their risks are magnified (Public and Division, 2011). Radon is present in all air which is found in indoors and out door in various proportions (Collaborting centre for environmental Health, 2008). Inhalation is the principal route of radon exposure of humans (Abd and Kotb, 2014). Atmospheric radon is not an issue of health concern because the radon is rapidly diluted to low levels by circulation throughout outdoor air. There has been a lot of concern about the effects of radon exposure to people all over the world out of which Ethiopia is with no exceptions. Radon poses a major concern with regard to radiation pollution and human health hazard (Quashie *et al*., 2011; Dunn, 2014). Exposure to radon is due mainly to the inhalation of its short-lived decay products (polonium- 214, polonium-218, lead-214, and bismuth-214), which deposit non -homogeneously in the human respiratory tract and irradiate the bronchial epithelium (Mittal *et al*., 2015; Quashie *et al*., 2011).

Table 1. Housing units construction materials of walls, roofs and floor of Jimma Town (CSA, 2007)

Construction materials used for	Number of housing units
WALL	
Wood and mud	26,298
Clay Bricks plastered with cement	1,711
Others	2,007
Total	30,016
FLOOR	
Mud	17,380
Cement screed not applied	8,616
Cement /Brick tiles	3, 028
Others	992
Total	30,016

Two progeny, 214 Po and 218 Po, deliver the most important alpha-radiation dose to the lung that can interact with biological tissue in the lungs leading to DNA damage (Pirsaheb *et al*., 2013). The described health effect end point of high exposure to indoor radon is radiation-induced lung cancer (Santawamaitre, 2012). Therefore; it is unlikely that there is a threshold concentration below which radon does not have the potential to cause lung cancer. Health effects of radon, most notably lung cancer, have been investigated for several decades. Recently, efforts to directly investigate the association between indoor radon and lung cancer have provided convincing evidence of increased lung cancer risk causally associated with radon, even at levels commonly found in buildings (Blok, 2007). Radon is now recognized as the second most important cause of lung cancer next to smoking in the general population (Halliday, 2009).

Assessment of radon concentration in buildings of Jimma town

Jimma town is the most historic town in south west of Ethiopia located at a distance about 345km from the capital Addis Ababa. It's geographical coordinates are approximately 7o41'N latitude and 36o50'E longitude. The town is found in an area of average altitude, of about 5400ft (1780 m) above sea level. It lies in the climatic zone locally known as Woyna Daga which is considered ideal for agriculture as well as human settlement. As reported by Ethiopian census of 2007, there are large numbers of buildings used for residence, business center, offices, recreational centers, etc. The house buildings in the town is about 30, 016 in which almost all of them are from materials which are considered as the basic source of radon more than 95% of the walls and floor of the houses were made from the materials such as; soil, stone, cement, and concrete of higher potential for radon emanation to indoors. Most houses are traditional in design having ground well for water sources and the internal structure is with no or little opening for easy flow of air across the inner surfaces. Almost all the houses have no proper ventilation in indoors except the natural ventilation with improper size and number of windows and doors.

Conclusion and Recommendation

Radon is internationally recognized as the second cause of lung cancer next to smoking and many developed countries conducted a series of research to mitigate the problems coming its basic sources with respect to their spatial nature. In Ethiopia little is known for about the effect from NORM in general Radon specifically. The house buildings in Ethiopia were constructed with improper design that will not allow good ventilation that reduces the concentration of radon in indoors which is maximized by the soil and its products in walls and floor. The use of ground water for personal consumption in large number of the housing units in town, persisted in current time for many reasons, is considered as the maximization of radon concentration in indoors of the area in addition factors. Most of the traditional and some modern house buildings are with the inner area with no path for the easy flow of fresh air to indoor which aggravate the concentration level of radon. The problem becomes series for the fact that almost all the house buildings doesn't contain well designed ventilation system to regulate the radon concentration. Though there is no well-defined action level for radon in indoor for the whole location of the country Ethiopia, most of the problems which are expected from the above listed radon sources at indoors can be maintained with possible means that are recommended below:

- the public and the engineers in general needs to be aware of the sources radon in indoors as they can work for the ways to minimize the radon concentration in indoors to control its effect simultaneously.
- the use of ground water and all other water sources for personal consumption should be treated by aeration or other methods (such as filtration with activated charcoal) to reduce the radon levels prior to use.
- If the ground floor is in contact with soil, an effective migratory measure is to ventilate the space beneath the floor by increasing natural ventilation or by installing a fan that removes the radon laden air from under the floor and replaces it with outdoor air. This is a means reduces the amount of radon entering the structure by reducing the concentration of radon in the air beneath the floor.
- Sealing cracks and other openings through which radon enter the inner structure, though it is difficult to seal all entry routes adequately and because seals tend to deteriorate over time.
- Radon in indoor air may be diluted by increased ventilation of the indoor spaces with outdoor air economically. Since this method represents a major undertaking, it is only used in exceptional circumstances. The society should work on the way to ventilate the indoor environment properly for the already built indoors and the designer and engineers should work jointly to include the complete ventilation system for newly constructed house buildings.

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