Investigation of the Efficacy of Damp-Proof Montmorillonite Nanoclay for Radon Reduction Strategies in Radon Prone Areas of Ramsar

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ABSTRACT

Background: Ramsar, a northern city in Iran, lies on the coast of the Caspian Sea. This city has areas with some of the highest levels of natural radiation measured to date. The radon concentration in some areas of Ramsar is up to 3700 Bq m^{-3}. On the other hand, due to high level of humidity, damp-proof barriers should be used in construction of new buildings in radon prone areas of this city. Montmorillonite clays can be used as both moisture-proof and radon-proof agents. This study was an attempt to investigate the radon-proof properties of montmorillonite nanoclay in construction of new buildings in radon prone areas.

Methods and Results: Although soaked nanoclay samples could not reduce the radon level, when wet nano-montmorillonite was used, mean radon level inside the house was 1082.4 ± 5.9 Bq/m^3 (ranged 826.3 – 11.40.5 Bq/m^3) while removing nano-montmorillonite sheet increased the radon level to 1146.5 ± 6.2 Bq/m^3. The high moisture in the soil of these areas, makes the nano-montmorillonite wet and converts it to a good radon-proof sheet.

Conclusion: It is worth mentioning that the nano-montmorillonite clay used in this study is not supposed to replace radon-barrier (membrane) sheets but when used with proper membranes can enhance the efficiency of radon mitigation systems.

Keywords:
Radon reduction, Mitigation, Nanoclay

Introduction

In developing countries, nanotechnology has provided new solutions for the millions of people who have no access to essential services such as safe water, reliable energy, health care and education. However, there are concerns regarding to what extent this emerging technology will benefit or cause risks for humans. Nanoclays as nanoparticles of layered mineral silicates are categorized into several types including montmorillonite, bentonite, kaolinite, hectorite, and halloysite. The most commonly used nanoclay in materials applications are plate-like montmorillonite. Although cigarette smoking is the leading cause of lung cancer, radon exposure is reported to be an important contributor to the total burden of lung cancer [1]. World Health Organization (WHO) reports that the main health hazard from high radon exposure is an increased risk of lung cancer [2]. It has been reported that the vast majority of radon induced lung cancers are caused by exposure to low and moderate radon concentrations [3]. The U.S. Environmental Protection Agency (EPA) believes that radon causes about 20,000 cases of lung cancer annually [4] but there is currently no data on radon inhalation caused deaths. WHO recommends that countries perform national programs to reduce the population's radon risk, as well as reducing the risk for individuals exposed to higher than population-average levels of indoor radon. In this light, special codes for construction of building should be implemented to reduce radon levels in homes. WHO recommends a national reference level of 100 Bq/m^3. WHO believes that if this level cannot be reached under the prevailing country-specific conditions, the reference level should not exceed 300 Bq/m3 [2]. In this light, most countries have adopted a radon concentration of 200–400 Bq m^{-3} for indoor air as an action or reference level.

Recent studies show that radon inhalation even at low concentrations poses a risk of developing lung cancer [5]. Furthermore, there are published reports indicating that environmental radon exposure may be a risk factor for squamous cell carcinoma [6], or chronic obstructive pulmonary disease (COPD) mortality [7]. Radon-222 and radon-220 (thoron) are the most common isotopes of radon. It has been reported that the radon health risk is proportional to its concentration, down to the Environmental Protection Agency's action level of 148 Bq m^{-3}. Although naturally occurring isotopes of radon in indoor air are identified as the second leading cause of lung cancer after tobacco smoking [8], there is no large scale data on the incidence of radon-related lung cancers in Iran. Ramsar, a northern coastal city in Iran, has areas with some of the highest levels of natural radiation measured to date. The high level of radioactivity is thought to be due to the local geology. Underground water dissolves radium in uraniferous igneous rocks and carries it to the surface through several hot springs [9]. The radon concentration in some areas of Ramsar is up to 3700 Bq m^{-3} [10].

Montmorillonite clay has significant waterproofing properties because of its high coefficient of moisture absorption. Montmorillonite which occurs mainly in bentonite, has a capacity to absorb large amounts of water. In this light, this clay can be used as an absorbent waterproof membrane on foundation walls made of brick and concrete [11]. It is widely accepted that sealed barriers (membranes) with very low radon gas permeability which are commonly placed over the entire footprint of new buildings at the time of construction, is an effective method of reducing indoor radon levels. In Ramsar, due to very high levels of humidity, damp-proof barriers are also needed. In this light, this study aimed at investigating the radon-proof properties of montmorillonite nanoclay in construction of new buildings in radon prone areas.

Materials and Methods

House Model

Two wooden model houses were designed in this study. Ramsar soil samples were used for simulating a typical house in radon-prone areas with radon levels over the EPA's action level (148 Bq/m^3 or 4 pCi/l). These cube house models had a volume of 8000 cubic centimeters (dimesions 20 cm × 20 cm × 20 cm).

Environmental Monitoring and Soil Sampling

Before soil sampling, environmental monitoring in Talesh Mahalleh (a well-known district in HBRAs of Ramsar) was performed using a RDS -110 (RADOS. Inc., Finland) multi purpose survey meter. Absorbed dose rates in air were measured at one meter above the ground level. Soil was sampled in 4 areas with different dose rates, and sent to the National Radiation Protection Department (NRPD) of the Iranian Nuclear Regulatory Authority for gamma spectroscopy. Ra-226, Th-232 K-40 concentrations in each soil sample was measured. Soil sampling locations were recorded by a Global Positioning System (GPS).

Radon Measurements

In each experiment 350 g Ramsar HBRAs' soil was used. Radon level measurement was performed by using a PRASSI portable radon gas survey meter that was provided by Radiation Research Center of Shiraz University.

Nano-montmorillonite

In each experiment 35 g nano-montmorillonite was used. Nano-montmorillonite (Cloisite® 20A) was obtained from Southern Clay Products Inc (Gonzalez, TX).

Results

The mean radon concentration in a house model in which nano-montmorillonite was used as the radon-proof barrier is summarized in Table 1. As indicated in the table, when a thin sheet of dry nano-montmorillonite was placed over the floor of the house (above the Ramsar HBRAs' soil layer, the mean (±SD) radon level inside the house was 588.2 ± 6.5 Bq/m3 (ranged 418.2 – 632.8 Bq/m^3). When there was no nano-montmorillonite sheet over the floor, mean radon level was 588.2 ± 7.6 Bq/m3 (ranged 384.4 – 639.4 Bq/m^3). When dry nano-montmorillonite was replaced with a soaked sheet of this nanoclay, mean radon level inside the house was 1114.0 ± 2.8 Bq/m3 (ranged 1011.8 – 1166.0 Bq/m^3). When there was no nano-montmorillonite sheet over the floor, mean radon level was 949.3 ± 4.6 Bq/m3 (ranged 796.8 – 996.1 Bq/m^3).

On the other hand when a sheet of thoroughly wet nano-montmorillonite was placed over the floor, mean radon level inside the house was 878.4 ± 6.3 Bq/m^3 (ranged 643.0 – 928.8 Bq/m3). When there was no nano-montmorillonite sheet over the floor, mean radon level was 1005.5 ± 6.8 Bq/m^3 (ranged (724.1 – 1064.1) Bq/m^3). And finally in an attempt for reducing the water content of the nanoclay, when thoroughly wet nano-montmorillonite was replaced with a wet sheet of this nanoclay, mean

Table 1: Different interventions using nano-montmorillonite in dry. Soaked, thoroughly wet and wet conditions for reducing the radon concentration in the house model.

Sample	Date	No. of Measurements	Mean±SD Radon Concentration (Bq / m^3) HBRAs' Soil Alone (Range)	Mean±SD Radon Concentration (Bq / m^3) HBRAs' Soil + Nanoclay (Range)	Significance (P-Value)
Dry Nano-montmorillonite	22/5/1391	36	588.2 ± 7.6 (384.4 – 639.4)	588.2 ± 6.5 (418.2 – 632.8)	NS
Soaked Nano-montmorillonite	28/6/1391	24	949.3 ± 4.6 (796.8 – 996.1)	1114.0 ± 2.8 (1011.8 – 1166.0)	Increase < 0.0001
Thoroughly wet Nano-montmorillonite	24/7/1391	24	878.4 ± 6.3 (643.0 – 928.8)	1005.5 ± 6.8 (724.1 – 1064.1)	Increase < 0.0001
Wet Nano-montmorillonite	13/9/1391	24	1146.5 ± 6.2 (858.7 – 1207.4)	1082.4 ± 5.9 (826.3 – 11.40.5)	Decrease < 0.0001

radon level inside the house was 1082.4 ± 5.9 Bq/m3 (ranged 826.3 – 11.40.5 Bq/m3). When there was no nano-montmorillonite sheet over the floor, mean radon level was 1146.5 ± 6.2 Bq/m3 (ranged 858.7 – 1207.4 Bq/m3).

Discussion

Although soaked nanoclay samples could not reduce the radon level, when wet nano-montmorillonite was used, mean radon level inside the house was 1082.4 ± 5.9 Bq/m3 (ranged 826.3 – 11.40.5 Bq/m3) while removing nano-montmorillonite sheet increased the radon level to 1146.5 ± 6.2 Bq/m3. These results clearly show that the water content of nano-montmorillonite strongly affect its radon-proof properties. As Ramsar lies on the coast of the Caspian Sea, mean level of humidity is about 83%. In this light, damp-proof barriers should be used in construction of new buildings in radon prone areas of Ramsar. A membrane of 300 µm polyethylene sheet can be used as a common radon-proof agent. However, montmorillonite clays can be used as effective moisture-proof agents. Based on the findings of this study, wet nano-montmorillonite not only is damp-proof but also serves as an efficient radon-proof barrier. The high moisture in the soil of these areas, makes the nano-montmorillonite wet and converts it to a good radon-proof sheet.

At the present time in IR Iran there are no national radon mitigation strategies for radon prone areas. However, National Radiation Protection Department of the Iranian Nuclear Regulatory Authority has started preliminary studies for developing a national radon mitigation system. Radon proof sheets are a major part of any design considerations for reducing indoor radon concentration. It is worth mentioning that the nano-montmorillonite clay used in this study is not supposed to replace radon-barrier (membrane) sheets but when used with proper membranes can enhance the efficiency of radon mitigation systems.

Conclusion

In this study wet nano-montmorillonite significantly reduced the radon level. This finding can lead us to this conclusion that the high moisture in the soil of HBRAs of Ramsar, naturally makes the nano-montmorillonite wet and can convert it to a good radon-proof sheet. As discussed before, the nano-montmorillonite clay used in this study is not supposed to replace radon-barrier (membrane) sheets but when used with proper membranes can enhance the efficiency of radon mitigation systems.

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