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UDC 6

Environmental Radiation Hazards of Building Materials

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Abstract. In the last few decades, the importance of studying the environmental impact of building material properties grew. The main focus was to study physical, mechanical and chemical characteristics of building materials. Buildings are the environment that a human spend about 80% of his life. Human exposure to radiation doses emerging from natural and manufactured building materials caused serious diseases. The hazard of radiation doses on human body, especially Radon, was discovered. Radon is produced of the radioactive decay of Uranium and Thorium series. It is a colorless, odorless and tasteless gas. It inters human body by breathing and produces harmful radioactive elements. It has become a goal to know the limits of safety for building materials and to establish green buildings. Health and environmental risks have to take first command in the construction field to take proper precautions to ward off risks. Radon emission was investigated. The radioactive concentration of indoor air may be decreased under the permissible doses by the building geometry variation and other ways as reviewed in this investigation.

Keywords: Environmental Hazards; Radiation; Radon Emission.

1. Introduction. During the last two decades, changes in building design devised to improve energy efficiency. Nowadays, modern homes and offices are frequently airtight. These improvements led to more comfortable buildings with low running costs and produced contaminants. Indoor pollutants can emanate from a range of sources. Radon, the radioactive gas presents a serious health risk when found indoor. Radon and its decay products are recognized as risky indoor pollutants. Sick Building Syndrome becomes a known phenomenon of certain affected buildings occupants. Occupants repeatedly describe a complex range of vague and often subjective health complaints [1].

2. Radon. Typically exposure to radon and its progeny accounts for half of an individual's radiation exposure. Radon is the heaviest noble gas. It can easily penetrate common materials like paper, Leather, mortar... etc. Radon is a radioactive, colorless, odorless, tasteless gas. Its most stable isotope, 222Rn, has a half-life of 3.8 days [2].

2.1. Radon Hazard. According to the United States Environmental Protection Agency, Radon is the second most frequent cause of lung cancer. Radon gas decays into radioactive particles that can get trapped in lungs with breathing. As they break down further, these particles release small bursts of energy. This can damage lung tissue and lead to lung cancer over the course of lifetime [2].

2.2. Radon Sources. Terrestrial Naturally Occurring Radioactive Material (NORM) consists of radioactive material that comes out of the Earth's crust and mantle. Thorium and Uranium series are the most important chains providing nuclides of significance in NORM. The variation of indoor radon concentrations is explained by the mapped bedrock and superficial geology [3].

The radon in water supplies poses an inhalation risk and an ingestion risk. Water risk comes from radon released into indoor air when water is used for showering and other household purposes. In some regions, natural gas used for cooking and heating contains elevated concentrations of radon which is released on combustion [4].

Geological materials usually contaminated with naturally occurring radioactive materials (NORM) used in the building material manufacture. These NORM under certain conditions can reach hazardous contamination levels. The activity concentrations of the natural radionuclides in the measured samples were calculated. Over 210 building material used in 42 countries all over the world were investigated. It was found that most of the investigated building materials are within the safe limit. Building materials that overcome the safe limit were by-product Phosphogypsum, marble and granite (Egypt), Granite (uranium & thorium rich) (Pakistan), Phosphogypsum (industrial by product) (Israel), Portland cement type II using fly ash as an additive (Greece), and Ceiling asbestos and red clay (Malaysia) [5].

3. Indoor Radon Concentration

3.1. Soil. The underlying bedrock type is the main factor influencing indoor radon levels. High values of indoor radon concentrations on the ground floor confirm the role of underlying soil as the primary source of radon entry. Radon concentration is high in rooms without a cellar underneath. High soil permeability was found to be responsible for the main radon entry. Radon easily moves through the ground and further into buildings. Slab-on-grade with foundation walls made of porous light-weight concrete blocks increased the soil-air leakage into dwellings [6].

3.2. Building Defects. Basic concrete slab damage of the house was found to be the main radon entry. Radon enters a room through imperfectly constructed concrete slab. So, high quality concrete slab reduces indoor radon concentrations. Cracks and decorative holes in concrete are potential outlets of radon. Their presence in buildings may aggravate high radon indoors concentrations [7].

3.3. Building Material. An extensive theoretical study was performed for Rn emission. This study is a theoretical approach to calculate the indoor radon concentration. An ordinary domestic room was virtualized. Measuring the radioactivity of building materials of the virtual room was used to determine radon emission. The values of mass exhalation rate of the materials investigated were calculated as illustrated in table (1).

The mass balance equation was used for indoor radon concentration. Form of the mass balance equation is:

$$\text{Accumulation} = \text{Input} - \text{Output} - \text{Reaction} \qquad \text{eq.(1)}$$

Table 1). Mass Exhalation Rate of the Material Used and the Building Materials

No.	Floor			Wall			Ceiling		
	Material	A_u	Exh.*	Material	A_u	Exh.*	Material	A_u	Exh.*
1	Mosaic Tile	85	16.57	Cement plaster	53	10.33	Cement plaster	53	10.33
2	Ceramic	77.3	15.07	Ceramic	81.6	15.91	Mortar	24	4.68
3	Granite	18.7	36.45	Granite	187	36.45	Plaster	53	10.33
				Plaster	53	10.33			
4	Marble	32	6.24	Marble	32	6.24	Plaster	53	10.33
				glass	8	1.559			
5	Concret	30	5.85	Sand	15.1	2.943	Asbestos	448	87.33

e	brick

* Exhalation Rate x10-4(Bq/m3)

The time dependency of the gas concentration $C_i(t)$ inside a single room is given by the differential equation [8]:

$$\frac{dC_i(t)}{dt} = J\frac{S}{V} + C_o\lambda_v - C_i(\lambda + \lambda_v) \qquad \text{eq. (2)}$$

where: $C_i(t)$: radon concentration (Bq/m^3) in room at time t, J: radon exhalation rate of concrete (Bq/m^2/s), S: exhalation surface area (m^2), V :volume of room (m^3), C_o: radon level (Bq/m^3) of outside air, λ_v :ventilation rate(s^{-1}), λ:Decay constant of radon (2.1*10^{-6} s^{-1}).

From Eq.(2), indoor radon levels depend on the source of radon such as emission from building materials and outdoor radon levels, radon flux (area radon exhalation rate, J), ventilation rate (λ_v) and surface to volume ratio of room besides other removal processes. The differential equation was solved by Matlab program. The ventilation value was taken 0.5h^{-1}. Radon decay constant is 2.1x10^{-6}s^{-1}. Radon emission was studied versus different cases using the parameters of material variation, dimensions of rooms and ventilations.

3.4. Building Design. Virtual rooms were studied representing indoor area with bad ventilation λ_υ=0.5h^{-1}, plan dimensions 3.0*3.0 m and height was selected from 2.75m to 4m. The maximum height is 4m. The relation between height and radon concentration is shown in figure (1). It results unsafe dose for rooms 1,2,3 and 5 at height 2.75m. Raising height reduces the radon concentration for room (3) at height 4.0m to 84%. It reduces the radon concentration for room (5) at height 4.0m to 75%. The radon concentration of room (4) is within the safe limit.

Virtual room dimensions were taken 2*3*2.7m. The length varied from 2 to 5.0m with an interval 0.25m and λ_υ =0.5h^{-1}. The relation between room length and radon concentration is shown in figure (2). Increasing length reduces the radon concentration for room (3) at length 5.0m to 91%. It reduces the radon concentration for room (5) at length 5.0m to 98%.Changing the dimension of plan is very difficult either in existing building or planned to be constructed. Increasing of dimensions does not affect the dose seriously.

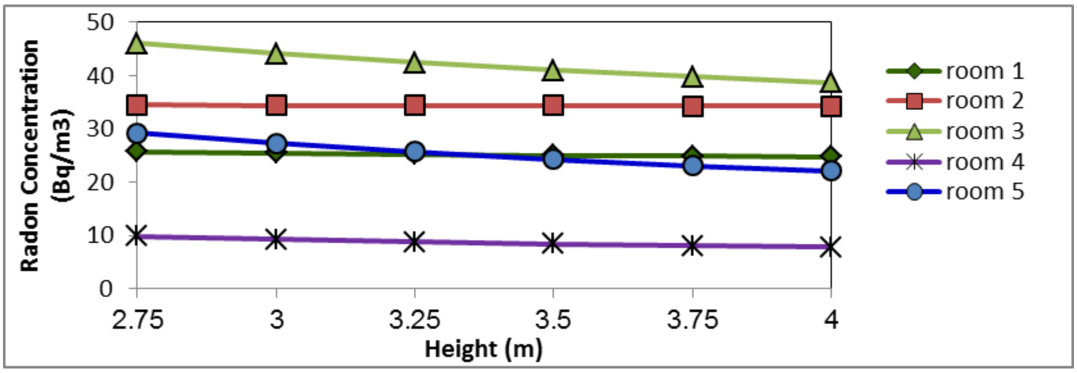

Figure .1 Relation between Room Height and Radon Concentration

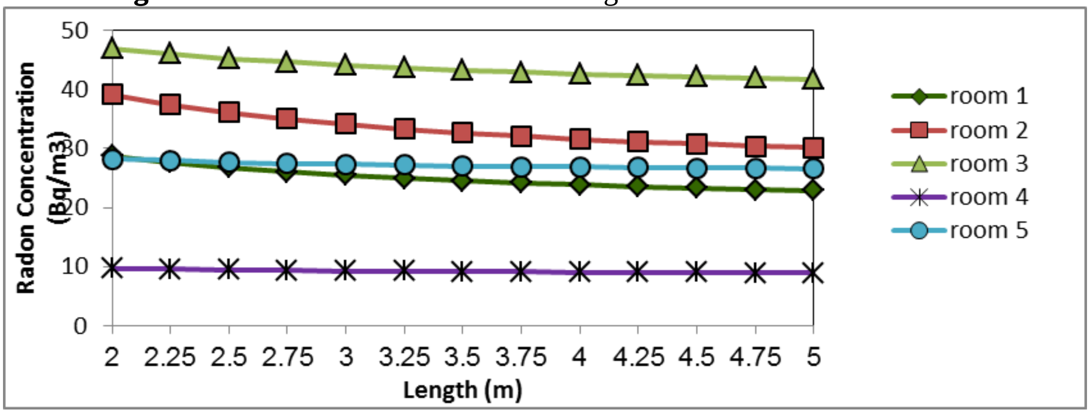

Figure 2. Relation between Room Height and Radon Concentration

3.5. Ventilation. Since the ventilation is the most important factor affecting Radon emissions in buildings, it was taken as a critical parameter to be studied. Bad ventilation was taken as the first case, in which the λ_υ ventilation rate equals $0.5h^{-1}$.Good ventilation was assumed $3h^{-1}$. Intermediate cases in between were calculated. The illustrated rooms in table (1) are studied. The room dimensions were 3*3*2.75m. The relation between ventilation and radon concentration is illustrated in figure (3). Room (4) was the only safe case. Other rooms have high radon concentration beyond the safe limit of radon concentration at $\lambda_\upsilon=0.5h^{-1}$. The ventilation reduces the radon concentration effectively. All unsafe radon concentrations become safe at $\lambda_\upsilon=2h^{-1}$. Increasing the ventilation is very effective on reducing radon concentration.

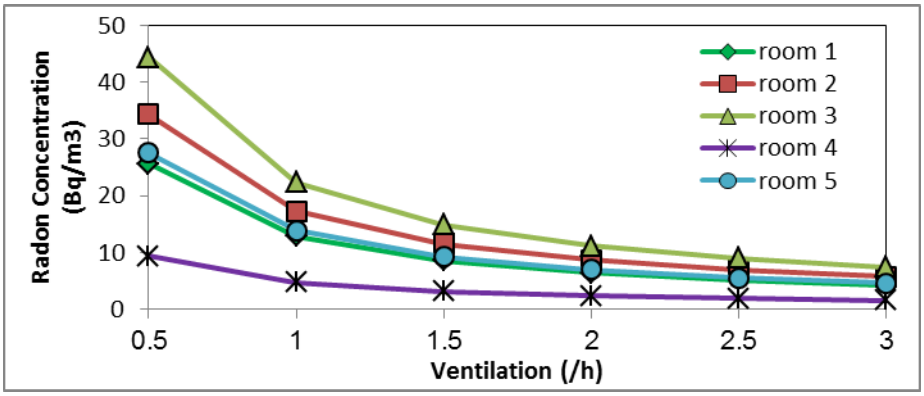

Figure 3. Relation between Ventilation and Radon Concentration

4. Radon Mitigating

4.1. Soil. A high quality concrete slab should be constructed for high radon level kindergartens to reduce indoor radon concentrations. Sealing cracks and ventilating the under-floor channel are sufficiently effective to reduce radon concentrations to an acceptable level. Installation of aluminized bitumen felt and use of elastic sealants prevent flow of radon-bearing air from the soil into the house Installation of perforated piping in floor slab subsoil decreases the radon concentration 32% lower than the median reference values. In houses with a sub-slab piping connected to an operating fan, radon concentration was safe. In houses with piping but no fan, the corresponding fraction was only 45%. Sub-slab piping without a fan had no remarkable effect on radon concentration [7, 9].

4.2. Building Material. Customary building materials except for polymer concrete are normally not radon-tight. Thin paints, plasters and wallpapers are generally radon-permeable. Plastic coatings with a thickness of more than 2 mm, show good sealing results against radon gas. Plastic foils are radon-tight. An anti-radon coating was developed and experimented in a new constructed building in China. It was 99% efficient experimentally. It decreases the indoor radon background concentration down to a safe level in 72hours. The coating has remained in a good condition and anti-radon efficient for three years after the application [10]. All kinds of plaster composed of polymer cement are able to reduce the diffusion of radon gas up to 50–100% in the laboratory environment. Adding radioactive shielding agents, mortar can successfully mitigate radon concentration levels over 90% in the laboratory tests. In the field tests, an average reduction of 85% in radon levels was recorded that confirms the radon shielding effect of the mortar [11].

4.3. Ventilation. Concentration of radon and its progeny were measured. They were found to be high in winter and low in summer. Radon concentration in moderate weather is minimal, because it has maximum ventilation. Inhabitants tend to ventilate small volume rooms with many people. The existence of many openings encourages the inhabitants to ventilate their rooms. The rooms located in upper floors are ventilated more than those of ground floor. Inhabitants tend to ventilate small area rooms than those of big areas. They tend to ventilate rooms with big number of people sleeping in the bedroom as well as shared bedrooms [12]. Natural ventilation is the most efficient way to lower ^{222}Rn levels, while air conditioning is the next most efficient method. Dehumidification provides only a marginal reduction of ^{222}Rn levels. A higher air exchange rate introduces more outdoor air with low ^{222}Rn concentration inside the building and thus lowers the indoor ^{222}Rn concentrations [13]. Depressurization techniques in underground sumps reduce indoor radon concentrations. Sump effectiveness; underneath the basement and outside the exterior walls of the building, were analyzed. The systems proved to be highly efficient, lowering radon levels by 91-99%. However, passive ventilation across an outside sump lowered radon levels by 95% due to a Venturi effect induced drop in pressure [14].

Ionizers are proven to be effective in reducing the activity concentration of radon decay products in poorly ventilated environments. Removal of the coarse fraction of the decay products is responsible for lowering the activity concentrations [15]. Filtration techniques were tested for their potential to reduce the indoor exposure in terms of the total effective dose for mixed radon and Thoron indoor atmospheres. Filtration removes attached radon and Thoron decay products effectively and indoor aerosol as well. A permanent filtration is recommended because of the slow decrease of the Thoron decay product concentrations [16].

5. Conclusion

- There is a clear link between breathing high concentrations of radon and incidence of lung cancer.
- The presence of cracks and holes in concrete may aggravate the high radon indoors concentrations.
- Foundations sealing work as well as high quality slabs are important to prevent radon entry.
- Ventilating the under-floor channel reduces radon concentrations to an acceptable level for high prone radon areas.
- Most of the investigated building materials are within the safe limit according to UNSCEAR limits.
- Although some of building materials have safe effective doses, room material collection causes unsafe radon concentration.
- Raising height reduces the radon concentration better than that of plan dimensions.
- Increasing the ventilation is very effective on reducing radon concentration.

6. Recommendation

- The construction of new dwellings should employ techniques that minimize radon entry and facilitate post-construction radon removal.
- Developing building codes for radon regulation in new buildings is essential.
- A primary data base of radionuclides content in typical building materials and their available components should be created to develop building materials radioactivity standards.

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УДК 6

Радиационная опасность строительных материалов

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Аннотация. В последние несколько десятилетий важность изучения влияния строительных материалов на окружающую среду выросла. Основной акцент делается на изучение физических, механических и химических свойств строительных материалов. Люди проводят примерно 80 % жизни в зданиях. Подверженность людей радиации, излучаемой натуральными и промышленными строительными материалами, явилась причиной серьезных заболеваний. Вредное влияние радиационного излучения, особенно радона на организм человека был доказан. Радон – это результат распада урана и тория. Газ не имеет цвета, запаха и вкуса. Он попадает в организм человека по воздуху и является источником вредных радиоактивных элементов. Целью работы является определение границ безопасности строительных материалов, и организация экологического строительство. Экологические риски и риски для здоровья должны стать основными в области строительства, чтобы своевременно принять меры предосторожности для предотвращения рисков. В работе исследуются излучения радона. Радиоактивная концентрация воздуха, находящегося в помещении, может быть уменьшена до допустимой дозы с помощью изменения геометрии сооружения и другими способами, проанализированными в данном исследовании.

Ключевые слова: вредные факторы окружающей среды; радиация; радоновые излучения.