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ANALYSIS OF THE CAUSES AND CONSEQUENCES OF ANTHROPOGENIC PRESSURE ON THE ENVIRONMENT OF PRODUCTION OF CONSTRUCTION PRODUCTS

Anatolii Marfutin[1], Oleg Nahursky[1]✉, Halyna Krylova[1], Oksana Orobchuk[1], Michał Charlak[2]

[1] Lviv Polytechnic National University,
12, S. Bandery Str., Lviv, 79013, Ukraine,
[2] Politechnika Lubelska,
38, Nadbystrzycka Str., Lublin, 20-501, Poland
oleg.a.nahursky@lpnu.ua

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Abstract. The article is devoted to the study of the causes and consequences of the anthropogenic impact of the construction industry on the environment, with a special emphasis on the use of radon-containing materials in the production of construction products. The key factors that cause environmental pressure, such as raw material extraction, technological processes, insufficient waste disposal technologies, and weak regulatory control, are analyzed. Risks to human health, including exposure to radon, a radioactive gas emitted from natural building materials such as granite and basalt, are discussed. It is shown that radon inhalation is an important factor in the development of lung cancer and other diseases. The article also describes the impact of radon on the environment, including its accumulation in the atmosphere, soil, and water resources, which threatens ecosystems. The authors emphasize the importance of monitoring radon levels in building materials, improving ventilation systems, waste management, and monitoring radioactivity at all stages of production. The authors propose a number of measures to minimize the negative impact of the construction industry, including the introduction of environmental standards, the use of innovative technologies, the use of alternative materials, and raising awareness among consumers and producers. Prospects for further research aimed at creating effective technologies to reduce radon emissions, as well as improving waste disposal methods and assessing their impact on ecosystems are outlined.

Keywords: radon, building materials, environmental safety, anthropogenic impact.

1. Introduction

In recent years, the environmental impact of building material production has become a major concern due to the significant role the construction industry plays in environmental degradation. This sector is one of the largest consumers of both renewable and non-renewable natural resources (Spence et al., 1995; Curwell et al., 1998). It heavily depends on the natural environment to extract raw materials such as wood, sand, and aggregates for construction.

According to the Worldwatch Institute (Worldwatch Institute, 2003), the construction industry consumes 40 % of the world's raw stone, gravel, and sand, as well as 25 % of virgin timber annually. Additionally, it uses 40 % of the total energy and 16 % of global water supplies. Dust and emissions generated in the production, transportation, and onsite application of materials contain toxic substances, including nitrogen and sulfur oxides and radioactive gases. These pollutants pose serious threats to the natural environment (Spence et al., 1995; Ofori et al., 1998; Rohracher, 2001).

The extraction of natural resources alters the environment not only in terms of ecology and aesthetics but also leads to the accumulation of pollutants in the

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atmosphere (Curwell et al., 1998; Ofori et al., 1998; Bernard, 2002). According to Levin, H., construction activities account for 40 % of air emissions, 20 % of wastewater, and 13 % of other emissions. The growth of this sector involves the intensive use of raw materials that contain naturally occurring radionuclides, such as radon. Radon is a colorless, odorless radioactive gas that forms from the decay of uranium, thorium, and radium found in soil, rock, and building materials. Elevated environmental radon levels pose a health risk, increasing the likelihood of respiratory diseases and cancers. Since radon enters the body primarily through inhalation, it is critical to monitor its presence in building materials.

The generally recommended maximum indoor exposure limit for radon is 100 Bq/m³ (Shoeib et al., 2014). Natural construction materials and their derivatives contain three key radionuclides: uranium-238 (238 U), thorium-232 (232 Th), and potassium-40 (40 K) (Oloruntobi et al., 2023). Because high concentrations of these radionuclides can lead to significant indoor radiation exposure, it is necessary to implement radon control measures for construction materials and consider other contributing sources (Abdallah et al., 2012). Ventilation plays a significant role in radon concentration levels–poor ventilation contributes to higher radon exhalation rates and elevated indoor levels. Special attention should be given to the radioactivity of brick components in building structures (Pro skhvalennia Natsionalnoi stratehii upravlinnia vidkhodamy v Ukraini; Malanca et al., 1993; Hewamann et al., 2001).

Overall, the radon content in construction materials is not consistently taken into account. As a result, recent literature has increasingly focused on environmental radon monitoring (Khan, 1991; Ahmed, 1994; Jonsson, 1995; ICRP 65; O'Rirdan, 1996). Bernard L. Cohen (Bernard, 2002) emphasized that the most significant environmental impact of construction is the radiation exposure to the public caused by radon in both residential and occupational settings.Research and analysis of building materials provide the necessary information to develop and implement effective strategies for monitoring and controlling radon levels. Further research into this issue is critical to ensuring the safety and health of our communities in the future.

2. Theoretical part

The construction products industry imposes substantial negative anthropogenic pressure on the environment, stemming from both objective and subjective factors related to technology and legislation. These factors include the nature of raw materials used, the production processes, insufficient waste disposal technologies, and the inadequate development of legal regulations.

The use of raw materials that naturally contain radon is a widespread practice in the building materials industry due to the presence of natural radionuclides in certain minerals. Materials like granite, basalt, clay-based substances, and specific sandstones frequently contain trace amounts of uranium, thorium, or radium that decay and release radon gas. These materials are chosen because of their desirable physical and mechanical characteristics–such as durability, strength, and thermal insulation–which make them suitable for construction. Many rocks with radon content, like granite, offer excellent strength and abrasion resistance, making them suitable for wall components, façade panels, paving tiles, and other structural applications. Moreover, some radon-containing materials offer superior thermal insulation, aiding energy efficiency–particularly valuable in colder climates. These raw materials are often abundantly available and less expensive to extract and process, especially when sourced locally, which also helps reduce transport costs and enhances overall cost-efficiency.

However, using natural materials with radioactive elements increases radiation exposure risks during extraction, transportation, and processing. Rocks like granite are notable contributors to contamination risks (Table 1).

Table 1

Main Sources of Radon in Building Materials

Material	Radionuclides	Potential Radon Level	Usage Frequency
Granite	238 U, 232 Th	High	High
Basalt	238 U	Medium	Medium
Phosphogypsum	Natural & Artificial	High	Low
Coal ash	226 Ra	Medium	Increasing

Additionally, the construction sector incorporates substantial amounts of industrial waste. Recently, there has been a growing trend of incorporating new materials with either naturally elevated or artificially increased levels of radioactivity–examples include phosphogypsum, coal ash, oil shale ash, and rare minerals (Azlina et al., 2023; Kovler et al., 2002; Hanfi et al., 2022; Lope, 2011; Maxwell, 2018; Ravisankar et al., 2014; Rostamani et al., 2021; Sabbarese et al., 2021; Shoeib et al., 2014). Consequently, most building materials contain some amount of naturally radioactive elements, mainly potassium-40 (^{40}K), as well as isotopes from the uranium (^{226}Ra) and thorium (^{232}Th) decay series. Fig. 1 visualizes radon content in various building materials.

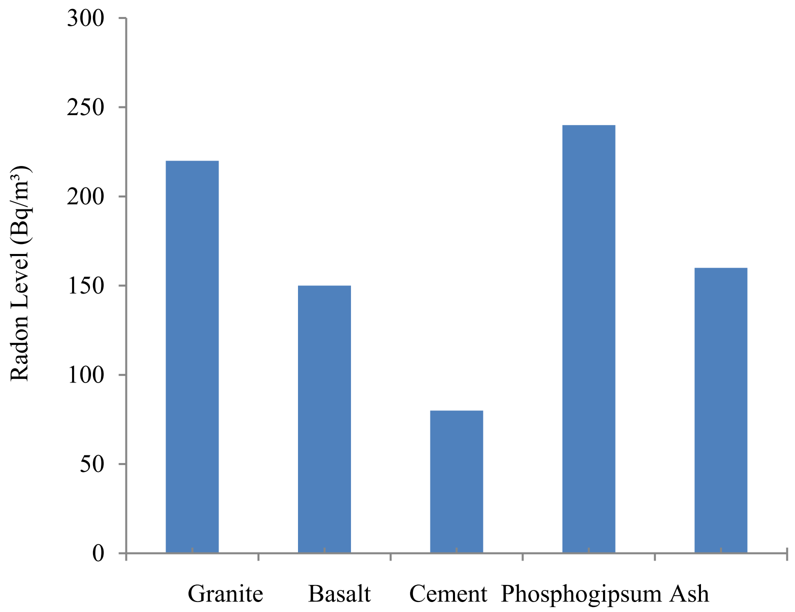

Fig. 1. Radon Content in Various Materials (Bq/m³)

During the manufacturing of construction materials like concrete, bricks, and ceramics, radon may be emitted as the materials are processed or fired–causing localized air contamination both at production sites and in the general atmosphere. Radon release can begin at the raw material extraction phase, when resources such as stone, sand, clay, and industrial byproducts (e.g., ash, slag) are mined. These substances often contain uranium and thorium, the primary sources of radon. As these materials are mined and processed, radon gas is released. For instance, when granite or basalt–naturally rich in uranium–is crushed, more of its surface comes in contact with air, intensifying radon release. Additionally, crushing processes can generate dust particles infused with radon, which then become airborne. In enclosed processing environments, radon concentrations may become dangerously high, posing health risks to workers.

Subsequently, high-temperature processing stages such as drying or firing enhance radon emissions, particularly from materials like clay or cement. Heat accelerates radon release from uranium-bearing minerals. Even after products are manufactured, radon continues to emanate from materials such as concrete, ceramics, granite, marble, and other natural stones. Poorly ventilated storage areas may facilitate radon accumulation. Construction site storage and transportation of such materials can also contribute to elevated radon levels in the air.

During installation–whether of concrete blocks, tiles, or stone structures–radon release persists, especially in enclosed spaces like basements or poorly ventilated areas. Such spaces require vigilant monitoring, as radon accumulation presents serious risks for both workers and future occupants.

The absence of efficient technologies for recycling construction waste exacerbates environmental pollution, particularly where radon emissions are not managed.

Waste management in the construction materials industry is a pressing concern for both environmental protection and economic sustainability. If improperly handled, waste generated during the production of concrete, bricks, ceramics, and cement can pose significant environmental hazards. These wastes include dust, fragments, unused raw materials, slag, and ash–many of which may contain hazardous substances.

One key issue is the lack of effective recycling technologies. Although concrete waste can be processed into crushed stone, this requires specialized and often costly equipment. Furthermore, many types of construction waste are still not recycled due to technical and financial constraints, leading to reliance on landfilling–a practice detrimental to environmental conditions (Oloruntobi et al., 2023).

Toxic substances such as heavy metals, found in ash and slag, may leach into soil and water, further endangering ecosystems. Waste disposal processes must therefore be carefully regulated. Uncontrolled disposal poses a major threat to ecological integrity.

Compounding the problem is the low level of environmental awareness and weak governmental regulation regarding construction waste management. In many countries, including Ukraine, existing regulations for recycling building materials are insufficient, and construction companies often treat waste disposal as a low priority. This leads to uncontrolled waste accumulation or environmental discharge (Pro skhvalennia Natsionalnoi stratehii upravlinnia vidkhodamy v Ukraini).

Nonetheless, some positive developments are emerging. Certain companies are adopting innovative recycling techniques, thereby reducing environmental impact and lowering raw material costs. Using secondary raw materials–like recycled concrete or bricks–to produce new construction components is one promising approach. Ash and slag recycling for cement production or concrete aggregate use is also gaining traction.

Another major concern is the lack of strict environmental control over radioactivity levels in construction materials during production and sale. In Ukraine and several other countries, despite existing radiation safety legislation, enforcement is weak. As a result, materials with elevated radioactivity–like those containing natural uranium–may enter the market unchecked, increasing health risks for building occupants.

Inadequate inspection across the supply chain–from raw material extraction to processing and transport–means that radon-emitting materials can end up in residential construction without appropriate safety assessments. During crushing or firing of raw materials, radon emissions are difficult to track, making it essential to implement emissions control measures at all stages of production.

Another critical issue is the public's limited awareness of the risks associated with radon-containing construction materials. Most customers are unaware of potential radiation hazards and rarely demand certification or information on radioactivity levels. This ignorance allows unsafe materials to be used in residential projects, putting residents' health at risk.

The absence of standardized testing procedures for radioactive contamination in building products further compounds the problem. Manufacturers may exploit regulatory loopholes, often driven by economic motivations, as radioactive materials are usually cheaper. This financial incentive can lead to neglect of radiation safety protocols.

Lastly, the low level of environmental consciousness among both producers and consumers significantly contributes to the issue. If radon-emitting materials continue to be used irresponsibly, long-term health consequences may arise. The lack of widespread education and public outreach on radon-related risks worsens the situation.

3. Results and Discussion

The utilization of raw materials that contain radon in the production of building products poses significant threats to both human health and the environment. The primary health concern arises from radon inhalation. When radioactive radon particles are inhaled, they can settle in the lungs and undergo radioactive decay, releasing alpha particles that cause cellular damage (Table 2).

Table 2

Health Effects of Radon Exposure

Exposure Type	Health Effect	WHO Estimated Risk (%)
Inhalation	Lung Cancer	3–14 %
Water Ingestion	Gastrointestinal Cancer	~1–2 %
Chronic Exposure	Immune Disorders	Insufficient Data

Such cellular damage may trigger mutations, ultimately increasing the risk of developing lung cancer. Radon ranks just after tobacco smoking as the second leading cause of lung cancer, and studies suggest that even non-smokers face a significantly heightened risk from radon exposure. According to the World Health Organization (WHO), radon is responsible for 3–14 % of global lung cancer cases. Long-term exposure to elevated radon levels is also associated with other severe conditions, including cardiovascular diseases, hematologic disorders, and immune system impairments. Fig. 2 illustrates how lung cancer risk correlates with radon exposure levels.

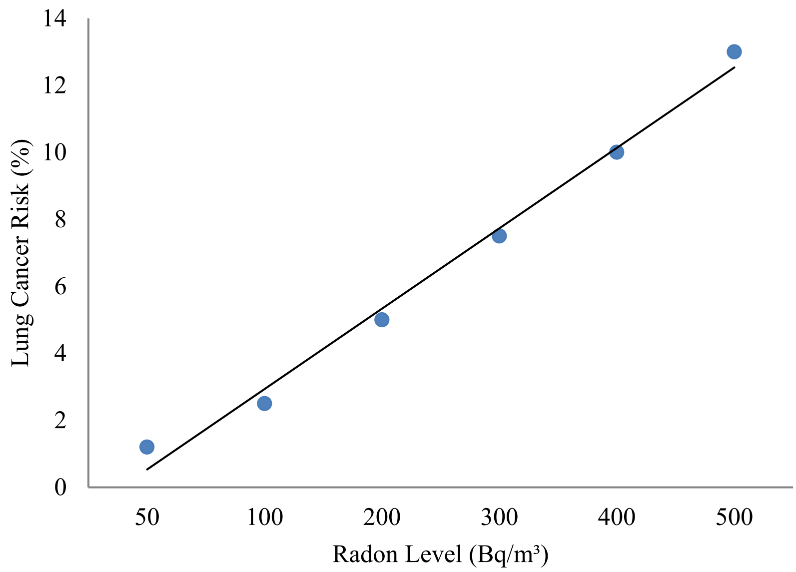

Fig. 2. Lung Cancer Risk vs. Radon Exposure

Radon also presents serious environmental hazards. It can seep into the atmosphere as a gas and contaminate groundwater sources. If radon enters water supplies used for drinking, it can cause additional internal exposure upon i ngestion. Furthermore, radon released into the air contributes to atmospheric pollution, particularly near mining sites where uranium- or thorium-bearing materials are extracted. In construction, the use of radon-emitting materials can lead to indoor radon accumulation, particularly in areas with inadequate ventilation like basements, underground garages, or older structures with poor air circulation.

This can lead to concentrations that exceed safe thresholds. A particular danger is that radon can accumulate in interior spaces where preventive measures are insufficient, such as buildings with wall or floor cracks that allow gas to penetrate. Construction materials–such as stone, brick, concrete, or granite–may emit radon if they contain uranium or thorium and have not undergone appropriate radioactive testing. Consequently, structures built with such materials and lacking proper ventilation can accumulate dangerous levels of radon. Fig. 3 shows the proportionate contribution of various sources to indoor radon levels.

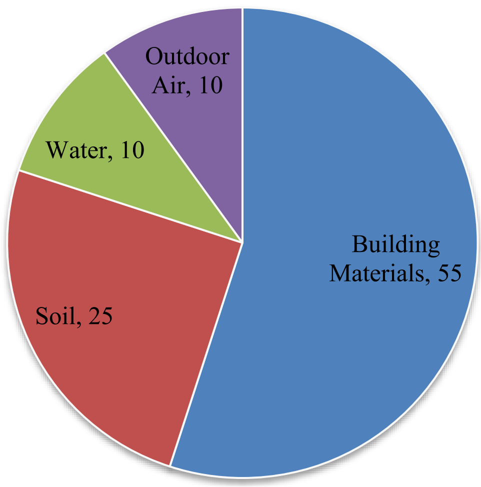

Fig. 3. Contribution of Different Sources to Indoor Radon, %

Another important aspect is the economic impact of using radon-containing materials in construction. An additional concern is the economic impact of using radon-containing materials. Buildings with high indoor radon levels may necessitate expensive diagnostic evaluations and the installation of enhanced ventilation systems or radon mitigation infrastructure. The market value of such properties may decline due to health risks and associated remediation costs. Developers and construction firms may also face higher expenses when sourcing certified low-radiation materials, thereby inflating the total construction budget.

To mitigate the risks linked to radon-containing materials, several measures are essential. Firstly, consistent monitoring of radioactive elements like uranium and thorium in construction materials must be implemented. This will help restrict radon-laden materials from entering the market and ensure consumer safety. Technologies that minimize radon emissions or prevent its infiltration into indoor environments also play a critical role in reducing exposure. Furthermore, routine indoor radon level assessments are necessary to detect and address elevated concentrations in a timely manner.

Enhancing ventilation systems in buildings is another crucial strategy for reducing indoor radon levels. Properly designed systems can effectively disperse and remove accumulated radon, ensuring occupant safety.

Radon also has considerable environmental consequences. When radon and its decay products enter ecosystems, they can disrupt ecological balance. Radon initially disperses into the atmosphere but its radioactive progeny–including polonium-218, lead-214, and bismuth-214–can settle onto soil and plant surfaces. These particles can be absorbed by vegetation and further integrated into the food chain. In areas of intense accumulation, radon may infiltrate built environments and spread through waste and evaporation.

These radioactive byproducts can adversely affect living organisms by accumulating in soil or water systems. Polonium and other heavy metals may settle in the topsoil or contaminate aquatic environments, subsequently entering food chains. Over time, they accumulate in plant tissues, interfere with biological functions like photosynthesis and respiration, and reduce overall plant vitality. Symptoms of radon-induced stress in plants include reduced leaf size, stunted growth, and diminished crop yields. Moreover, toxic effects on root systems may hinder nutrient uptake, resulting in soil degradation and compromised agricultural productivity.

Animals residing in radon-rich zones or consuming contaminated vegetation also face health risks. Ingested or inhaled radioactive particles may collect in body tissues, leading to mutations, immune suppression, reproductive issues, and respiratory illnesses. In aquatic environments, rainwater or soil leaching can introduce radioactive elements into water bodies, where they may settle in sediments and aquatic organisms. This bioaccumulation disrupts aquatic food webs and can lead to species decline or extinction.

Humans, being at the top of the food chain, are ultimately exposed to these radioactive contaminants through consumption of affected produce, meat, and fish. Long-term ingestion increases the probability of cancer and other radiation-induced conditions. Water supplies contaminated with radon further amplify health risks. The accumulation of radon and its progeny within ecosystems heightens environmental radioactive contamination, intensifying adverse health outcomes over time. Prolonged exposure exacerbates these effects across all biological systems.

The use of radon-laden raw materials in the building sector also carries broader socioeconomic consequences. Radon is among the most dangerous radioactive elements and its implications span human health and economic domains. Prolonged use of such materials influences public health, healthcare expenditures, property markets, and construction industry practices (Table 3).

Table 3

Socio-Economic Impact of Radon-Containing Materials

Category	Example of Impact
Economy	Real estate devaluation, ventilation costs
Health	Increased cancer cases, medical expenses
Environment	Soil, air and water pollution

To begin with, the presence of radon-containing materials in buildings can pose significant health risks to individuals residing in such structures. As a recognized carcinogen, prolonged exposure to radon through inhalation is linked to lung cancer and various other severe respiratory and systemic illnesses. A rise in the number of individuals suffering from cancers and chronic diseases associated with radiation exposure results in increased pressure on healthcare systems. Governments must allocate substantial funds not only for the direct treatment and rehabilitation of those affected but also for ongoing research and programs dedicated to monitoring radiation levels within inhabited buildings. Moreover, when radiation contamination is identified only after construction has been completed and the building is occupied, it may generate public concern and social unrest.

A notable socioeconomic repercussion involves the devaluation of real estate. When high levels of radon are discovered–whether during pre-sale inspections or post-occupancy evaluations–the market value of affected properties may drop considerably. Prospective buyers, worried about health risks, may avoid purchasing such homes or buildings. This reduction in demand depresses property prices and results in financial losses for owners. Furthermore, remedial actions necessitated by radon contamination–such as renovations, structural alterations, or even partial demolitions–can lead to significant unanticipated costs for property developers or owners seeking to reduce radon concentrations.

For companies involved in construction, sourcing and utilizing radon-emitting raw materials can drive up production expenses. These companies might be compelled to adopt new technologies aimed at lowering radon emissions, improve manufacturing processes, or secure additional material testing and certification. There may also be a need to invest in environmentally sound materials and modernize facilities to comply with safety standards. For small- and medium-sized enterprises, these requirements may prove financially burdensome, potentially reducing their ability to compete effectively within the industry.

On a broader scale, the economic implications tied to radon use in construction also touch upon labor and employment sectors. Elevated spending on healthcare services and environmental remediation could force both governmental bodies and private entities to reallocate budgets originally intended for other public priorities. This redirection of resources might cause reductions in funding for sectors like education, transportation, or urban development, thereby negatively affecting general societal well-being.

Nevertheless, there may also be beneficial outcomes associated with the identification of radon-related issues. Addressing these problems can promote the advancement of innovative, safe, and environmentally sustainable technologies in the construction field. Businesses might shift toward implementing novel production processes and opt for alternative, eco-friendly materials that meet stringent environmental standards. This evolution could spark the development of the green building sector, encourage job creation, and lead to cost savings in the long term by preventing environmental degradation and protecting public health.

Ultimately, government interventions–such as imposing restrictions on radon-rich materials, launching public education campaigns, and strengthening regulatory oversight–could significantly reshape the market for construction materials. As public awareness of environmental safety grows, so does the demand for safer, non-toxic materials. This trend could stimulate the expansion of environmentally responsible industries, including eco-construction, contributing positively to long-term socio-economic growth.

In conclusion, the socioeconomic consequences of using radon-bearing raw materials in construction are broad and multidimensional. They encompass increased healthcare and remediation expenditures but also pave the way for progress in technological development and ecological stewardship. Addressing these challenges demands a coordinated effort involving public authorities, industry stakeholders, and civil society to effectively reduce risks and optimize the potential benefits of adopting safer construction practices.

4. Conclusions

Following the comprehensive examination of the origins and consequences of the anthropogenic environmental impact resulting from the production of construction materials–particularly those involving radon-containing raw inputs–it is possible to outline key strategies for mitigating these adverse effects. One fundamental measure involves rigorous control over the selection of raw materials, prioritizing those with minimal concentrations of radioactive elements. This approach would significantly lower the initial levels of radon present in construction products. Additionally, maintaining adequate ventilation throughout all phases of production, storage, and application is critical to preventing radon accumulation in the ambient air. Systematic radon level monitoring must also be implemented to enable early detection of elevated concentrations and ensure timely remedial actions. Furthermore, effective management of construction waste containing radon is essential to preventing environmental emissions, thereby supporting overall ecological safety.

To address the current deficiency in environmental oversight surrounding the production and use of radon-bearing construction materials, it is necessary to enforce more stringent environmental standards at every stage–from raw material processing to final sale. This entails regular inspections, mandatory certification of materials, and the systematic assessment of their radiological properties. Increasing transparency by providing consumers with accessible information regarding material safety is equally vital. Public education campaigns should be implemented to raise awareness about the potential health hazards associated with radon exposure and to emphasize the importance of selecting safe materials for building projects. Moreover, the advancement of technologies for efficient processing and disposal of radon-laden waste is imperative to reduce the release of harmful substances during both production and construction activities.

Reducing the environmental footprint of the construction sector–especially where radon-containing materials are involved–requires a multifaceted approach. This includes the enhancement of technological processes, the tightening of compliance with environmental standards, and increased investment in research related to safe alternatives. A holistic, integrated strategy is essential to safeguard both environmental integrity and public health against the detrimental effects of radon exposure.

Prospects for Further Research

Future efforts should focus on the development of more efficient and economically viable technologies for the production and processing of construction materials that emit minimal amounts of radon. Additionally, further investigation into the ecological impact of radon contamination is required, along with the establishment of standardized regulations to ensure the safe incorporation of such materials in construction activities.

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