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Research Article

Seashell as Radiation Shielding Material

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Abstract: *This study investigates the potential of seashell waste as an alternative sustainable material for radiation shielding applications. Seashells, which contain high concentrations of calcium carbonate ($CaCO_3$), will be processed into fine powders and incorporated into a suitable binding matrix to produce composite samples with different compositions. The physical, structural and morphological properties will be characterized using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM). Radiation attenuation performance will be evaluated using Am-241, Cs-137 and Co-60 sources. The findings are expected to identify the optimum composition for sustainable radiation shielding applications.*

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1. INTRODUCTION

Radiation shielding is an essential component of radiation protection in medical, industrial, research and nuclear facilities. The primary purpose of shielding materials is to reduce the intensity of ionizing radiation and minimize unnecessary exposure to radiation workers, patients and members of the public. Conventional radiation shielding materials commonly include lead, concrete, steel and other high-density materials. Although these materials provide effective radiation attenuation, some have limitations related to toxicity, weight, environmental impact, cost and disposal. Lead is widely used for diagnostic X-ray shielding because of its high atomic number and density (Attix, 1986). However, its toxicity and potential environmental hazards have encouraged researchers to explore alternative materials that are safer, more sustainable and environmentally friendly. Consequently, the development of shielding materials using industrial and agricultural waste has gained increasing attention.

Seashell waste is a promising alternative material because it contains a high proportion of calcium carbonate ($CaCO_3$), which is a naturally occurring mineral compound. Common seashells, including cockle, clam, mussel and oyster shells, are generated in large quantities by seafood processing industries, restaurants and coastal communities. Improper disposal of these wastes may contribute to environmental pollution, unpleasant odours and waste management problems. Converting seashell

waste into useful shielding materials could therefore provide an environmentally sustainable waste management solution. Calcium carbonate has potential applications in radiation shielding composites due to its mineral composition, availability and compatibility with various binding materials. When processed into fine powder, seashell-derived $CaCO_3$ can be incorporated into suitable matrices to produce composite materials with different compositions and physical properties. The shielding performance of these materials can be investigated by measuring their ability to attenuate X-rays and gamma rays.

The effectiveness of a radiation shielding material is commonly evaluated using the linear attenuation coefficient (μ), mass attenuation coefficient (μ/ϱ), half-value layer (HVL) and tenth-value layer (TVL). These parameters describe the ability of a material to reduce radiation intensity as radiation passes through it. The attenuation performance depends on several factors, including photon energy, material density, chemical composition, thickness and elemental composition. Recent research has demonstrated the potential of shell-derived waste in radiation shielding applications. For example, a 2024 study investigated shrimp-shell waste incorporated into silicone rubber and reported improved X-ray attenuation with increasing shell concentration (Berger and Hubbell, 1987). More recently, a 2025 study investigated seashell powder in Portland cement composites and demonstrated improvements in X-ray attenuation with increasing seashell content, although mechanical strength decreased at higher concentrations (Moonkum & Tochaikul, 2025). Therefore, this research aims to investigate the potential of seashell waste as an alternative sustainable material for radiation shielding applications. The study will focus on the preparation of seashell-based composite samples, characterization of their physical, structural and morphological properties, and evaluation of their radiation attenuation performance. The findings are expected to contribute towards the development of low-cost, environmentally friendly and sustainable radiation shielding materials.

2. LITERATURE REVIEW

Radiation shielding materials are selected based on the type and energy of radiation, required attenuation efficiency, material density and application requirements. Lead is commonly used for X-ray and gamma-ray shielding because of its high atomic number and density, which contribute to photon attenuation. Concrete is also widely used in radiation facilities, particularly for structural shielding in diagnostic radiology, radiotherapy and nuclear installations. Photon attenuation occurs mainly through three interaction mechanisms: photoelectric absorption, Compton scattering and pair production. The relative importance of these mechanisms depends on photon energy and the atomic number of the shielding material (Knoll, 2010). At lower photon energies, photoelectric absorption is particularly important, while Compton scattering becomes more dominant at intermediate energies. Pair production becomes possible when photon energy exceeds 1.022 MeV.

Seashells are natural biomineralized structures primarily composed of calcium carbonate ($CaCO_3$), with small quantities of organic substances and other mineral components. Calcium carbonate generally occurs in two crystalline forms, namely calcite and aragonite. The chemical composition and crystalline structure of seashells depend on their species, geographical origin and environmental conditions (Hubbell, 1982). These characteristics influence their physical and mechanical properties and potential applications in composite materials.

Seashell waste has been investigated for various applications, including construction materials, cement production, bioceramics, water treatment and environmental remediation. The high calcium carbonate content makes seashells particularly attractive as an alternative mineral source for

developing sustainable composite materials. In radiation shielding research, the presence of calcium, carbon and oxygen provides a basis for investigating the attenuation properties of seashell-derived materials. However, calcium carbonate should not automatically be considered equivalent to conventional high-density shielding materials. Its effectiveness must be experimentally established at different photon energies and material thicknesses.

3. METHODOLOGY

The seashells will be collected, washed thoroughly, dried in an oven, crushed and ground into fine powder. The powder will then be sieved to obtain uniform particle sizes before being mixed with a suitable binding material at different concentrations (0%, 10%, 20%, 30%, 40% and 50%). The mixtures will be poured into moulds and allowed to dry or cure to produce composite samples. The prepared samples will be characterized using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) to determine their crystalline structure, chemical composition and surface morphology. Finally, radiation attenuation measurements will be conducted using Am-241, Cs-137 and Co-60 radioactive sources. The shielding performance will be evaluated by calculating the attenuation percentage, linear attenuation coefficient, mass attenuation coefficient and half-value layer (HVL).

4. FINDINGS

The study is expected to show that seashell waste can be used as an alternative material for radiation shielding. The characterization results will provide information on its chemical composition, crystalline structure and surface morphology (NIST, 1990). The radiation attenuation results are expected to show how different seashell concentrations affect shielding performance. The optimum composition will be identified based on its ability to reduce radiation intensity, supporting the potential use of seashell waste as a low-cost and environmentally friendly shielding material.

Although previous studies have demonstrated the potential of shell-derived waste for radiation shielding applications, several aspects still require further investigation. In particular, the effects of different seashell concentrations on radiation attenuation need to be evaluated to determine the most effective composition. The relationship between crystalline phases, chemical composition, surface morphology and material density with radiation shielding performance also needs to be explored. Furthermore, experimental studies involving different radiation energies are necessary to understand the suitability of seashell-based materials for various radiation applications. The influence of seashell concentration on the mechanical properties of the composites should also be considered to ensure their potential for practical radiation shielding applications.

5. DISCUSSION

Seashell waste has considerable potential as an alternative material for radiation shielding due to its high calcium carbonate ($CaCO_3$) content. Calcium carbonate is a naturally occurring mineral that can be processed into fine powder and incorporated into different binding materials to produce composite shielding materials. The use of seashell waste also provides an opportunity to reduce environmental pollution while promoting the development of sustainable and low-cost materials. One important factor influencing the radiation shielding performance of seashell-based materials is their

chemical composition (ICRP, 2007). Seashells mainly contain calcium carbonate, which consists of calcium, carbon and oxygen. The presence of calcium may contribute to photon attenuation, particularly through photoelectric absorption at lower photon energies. However, the shielding effectiveness also depends on the photon energy, material density and thickness. Therefore, seashell-based composites may have different attenuation capabilities when exposed to low-, medium- and high-energy radiation.

The concentration of seashell powder in the composite is another important consideration. Increasing the seashell content may increase the amount of calcium carbonate within the material, potentially improving its radiation attenuation properties. However, excessive seashell powder may affect the uniformity, porosity and mechanical strength of the composite. Therefore, an optimum concentration should be identified to achieve a balance between radiation attenuation and physical stability. The physical and structural properties of seashell-based composites also play an important role in determining their shielding performance. X-ray diffraction (XRD) can identify the crystalline phases of calcium carbonate, particularly calcite and aragonite. Fourier transform infrared spectroscopy (FTIR) can confirm the presence of carbonate functional groups, while scanning electron microscopy (SEM) can provide information about particle distribution, surface morphology and porosity. These characteristics are important because non-uniform particle distribution and excessive pores may affect the consistency and effectiveness of radiation attenuation. One advantage of seashell waste is its availability and relatively low material cost. Seashells are commonly discarded by seafood industries and coastal communities, making them an accessible source of calcium carbonate. Converting this waste into useful shielding composites could reduce the amount of waste sent to landfills and provide additional value to discarded materials.

Apart from radiation attenuation, the mechanical properties of seashell-based composites should also be considered. A shielding material must maintain sufficient structural strength and durability to withstand handling, installation and long-term use. Increasing the seashell powder concentration may improve the mineral content but could also reduce the bonding strength between particles and the binder. Mechanical tests, such as tensile strength, compressive strength and hardness measurements, may therefore be useful in determining the practical suitability of the prepared composites. The relationship between mechanical strength and radiation attenuation should be investigated to identify a suitable composition that provides both acceptable shielding performance and physical stability.

Furthermore, seashell powder can be combined with different binding materials, such as cement, epoxy resin, polyester and polymer matrices. The selection of binder will influence the mechanical strength, flexibility, durability and density of the final composite. For example, polymer-based composites may be suitable for lightweight and flexible shielding applications, whereas cement-based composites may be more appropriate for building and structural shielding applications. The possibility of combining seashell powder with other high-density materials could also be explored to improve radiation attenuation. Such combinations may provide better shielding performance while maintaining the environmental benefits of utilizing waste-derived materials.

Furthermore, the radiation shielding performance of seashell-based materials can be evaluated using different radioactive sources, such as Am-241, Cs-137 and Co-60. These sources provide different photon energies, allowing the investigation of material performance under different radiation conditions. The linear attenuation coefficient (μ), mass attenuation coefficient (μ/ϱ) and half-value layer (HVL) can be used to compare the shielding effectiveness of different composite compositions. A higher attenuation coefficient and lower HVL indicate better photon attenuation under comparable

experimental conditions. Despite its potential, seashell-based materials may not provide shielding performance comparable to conventional materials such as lead and high-density concrete, particularly for high-energy gamma radiation. Therefore, further improvements may be required through the selection of suitable binders, optimization of seashell concentration and incorporation of other materials to enhance density and attenuation properties.

The utilization of seashell waste offers environmental and economic advantages. Large quantities of seashell waste are generated from seafood processing activities, and improper disposal can create environmental and waste management problems (NCRP, 2004). Recycling this material into radiation shielding composites provides an alternative approach to waste utilization and supports the principles of a circular economy. Further research should investigate the optimization of seashell-based composite formulations to improve their radiation shielding performance. Different seashell sources, particle sizes, binder types and powder concentrations could be evaluated to determine their influence on material properties. In addition, Monte Carlo simulation using software such as Geant4, MCNP or FLUKA could be employed to compare theoretical and experimental radiation attenuation results.

Future studies could also investigate the incorporation of additional materials, such as barium sulphate, iron oxide or other mineral fillers, to improve the density and photon attenuation properties of the composites. Long-term stability, water absorption, thermal resistance and mechanical durability should also be evaluated before considering practical applications. In addition, the use of locally available seashell resources may reduce dependence on imported raw materials and lower the overall production cost of certain composite formulations. Nevertheless, the economic feasibility of the proposed material should consider processing costs, including washing, drying, grinding, sieving, mixing and fabrication.

Overall, the utilization of seashell waste in radiation shielding offers an interesting approach to combining waste recycling with the development of sustainable functional materials. Although further experimental investigation is necessary, seashell-based composites may have potential for selected low-energy radiation shielding applications and as an additive in conventional shielding materials (IAEA, 2024). Their suitability will ultimately depend on their measured attenuation performance, mechanical strength, durability and practical shielding requirements.

6. CONCLUSION

This research proposes the development and evaluation of seashell waste as an alternative sustainable material for radiation shielding applications. The high calcium carbonate content of seashells provides an opportunity to investigate their potential as an additive in composite shielding materials. The study will involve the preparation of seashell powder, fabrication of composite samples with different seashell concentrations, and characterization using XRD, FTIR and SEM. Their radiation attenuation performance will subsequently be evaluated using selected radioactive sources at different photon energies. The determination of linear attenuation coefficient, mass attenuation coefficient, half-value layer and tenth-value layer will provide quantitative information regarding the shielding effectiveness of the prepared materials. Furthermore, the relationship between the material's physical, chemical and structural properties and its radiation attenuation performance will be investigated.

Overall, this research is expected to contribute to the development of environmentally friendly and cost-effective radiation shielding materials through the recycling and utilization of seashell waste. The findings may provide a foundation for further research into sustainable shielding composites for selected applications in medical, industrial and research facilities. However, practical implementation

will require further assessment of mechanical strength, durability, radiation protection performance and compliance with applicable shielding requirements.

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