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Research Article

ANN Prediction of Linear Attenuation Coefficients for 40MgO–30B_2O_3–30SiO_2 System

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Abstract: Radiation shielding is of great importance for protecting human health, which has led to increasing research on alternative shielding materials. Glass materials are widely used in various applications, making it essential to investigate their radiation attenuation properties. In this study, the radiation shielding characteristics of magnesium borosilicate glasses were predicted by partially substituting B_2O_3 with MgO using Artificial Neural Network (ANN). The glass samples were prepared with compositions of 30SiO_2–30B_2O_3–40MgO. The linear attenuation coefficient (LAC) was obtained and compared with the results obtained Phy-X/PSD.

1. Introduction

Ionising radiation is widely used in various fields such as agriculture, industry, scientific research, and medicine. However, if not handled with appropriate safety measures, ionising radiation can cause severe damage to both humans and the environment. In particular, it can alter the structure of human cells and induce DNA damage. Although radiation protection strategies depend on the radiation type and energy range, the fundamental protection principles remain similar; only the thickness and structural properties of the shielding materials vary. This approach is commonly referred to as radiation shielding through the use of suitable materials [1-10].

Historically, lead has been the most widely used shielding material for protection against X-rays and γ-rays due to its high attenuation capability. Nevertheless, its toxicity, high density, rigidity, and limited portability have motivated researchers to seek alternative radiation shielding materials. Consequently, a wide range of materials, including glasses and composite structures, have been extensively investigated as potential substitutes for conventional shielding materials. These studies have been conducted using both experimental methods and simulation-based approaches [11-21].

Among the materials employed for radiation protection, glass plays a significant role owing to its ability to be fabricated in various shapes and thicknesses, as well as its favorable optical and mechanical properties. In particular, for radiation-protective eyewear designed to shield the face and eyes, transparency to visible light is a critical requirement. Therefore, glass-based materials represent promising candidates for the development of environmentally friendly and transparent radiation shielding solutions for gamma radiation applications [22-29].

In this study, the radiation shielding performance of magnesium borosilicate glasses was investigated. The glass compositions were formulated as $30SiO_2–30B_2O_3–40MgO$. To assess the radiation protection capabilities of these glass systems the linear attenuation coefficient (LAC) were evaluated.

Although these parameters can be determined experimentally, experimental investigations are often limited by practical constraints such as the unavailability of radioactive sources and insufficient laboratory facilities. Therefore, theoretical methods provide a reliable and efficient alternative for evaluating radiation shielding properties. In this work, a theoretical approach was adopted to estimate the radiation attenuation characteristics of the $30SiO_2–30B_2O_3–40MgO$.

2. Materials and Methods

In this study, the gamma-ray shielding characteristics of magnesium borosilicate glass with a composition of $40MgO–30B_2O_3–30SiO_2$ were predicted using the Artificial Neural Network (ANN) method, and the obtained results were compared with those calculated using the Phy-X/PSD software [30].

Artificial Neural Networks (ANNs) are mathematical models inspired by the biological nervous system and are widely used for data processing, pattern recognition, and predictive modeling [31]. ANNs are composed of interconnected neurons organized into layers. In their basic architecture, three main types of layers are defined: the input layer, hidden layers, and the output layer. The input layer receives data from external sources and transfers it to the network for further processing [32]. The hidden layers are responsible for feature extraction and data transformation, and each hidden layer may consist of one or more neurons. These layers are positioned between the input and output layers, and increasing the number of hidden layers generally allows the model to capture more complex relationships within the data [33]. The output layer produces the final predictions or results.

Each neuron processes the incoming signals by applying a weighted sum followed by an activation function to generate the output. The mathematical expressions governing the weighted sum and activation function are presented in Equations (3) and (4), respectively [34].

$$z = \sum_{i=1}^{n} (w_i \cdot x_i) + b \quad (3)$$

$$f(z) = \frac{1}{1+e^{-z}} \quad (4)$$

here, z represents the weighted sum, where, w_i signifies the weight, x_i stands for the input, and b represents the bias value, while, $f(z)$ denotes the activation function. Figure 1 shows proposed ANN model structure (with 3 input layer nodes; 5 and 10 hidden layer nodes; and 1 output layer node).

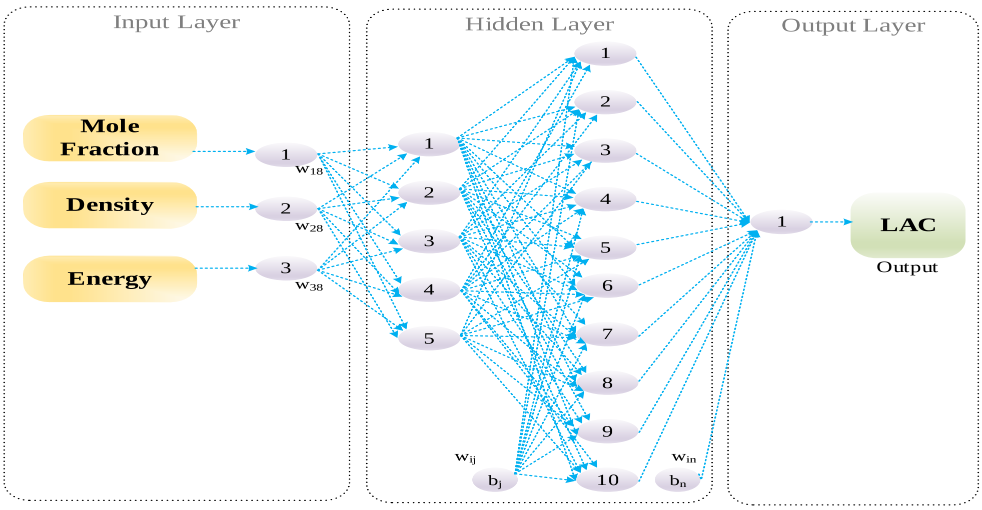

Figure 1. *Proposed ANN model structure*

3. Results and Discussions

The gamma-ray shielding performance of magnesium borosilicate glass with a composition of 40MgO–$30B_2O_3$–$30SiO_2$ was predicted using the Artificial Neural Network (ANN) method, and the results were compared with those obtained from Phy-X/PSD calculations [30]. The shielding characteristics were evaluated in terms of the linear attenuation coefficient (LAC).

The predicted LAC values are presented in Figure 4 as a function of gamma-ray energy. The variation in LAC across different energy regions reflects the dominance of different photon interaction mechanisms over a wide energy range, extending from the keV to the MeV scale. Higher LAC values are observed in the low-energy region, followed by a sharp decrease as the incident gamma-ray energy increases. This behavior is attributed to the dominance of the photoelectric (PE) effect at low energies, where the interaction cross-section is strongly dependent on the atomic number ($\propto Z^{3.5}$) and inversely proportional to photon energy. At higher energies, a more gradual decrease in LAC is observed due to the predominance of Compton scattering (CS), where the interaction shows weaker dependence on atomic number and is inversely proportional to photon energy ($\propto E^{-1}$).A strong agreement between the predicted ANN results and the Phy-X/PSD calculations is clearly observed in Figure 2. As shown in Figure 3, the correlation coefficient (R^2) between the calculated and predicted LAC values exceeds 99%, indicating excellent predictive accuracy.

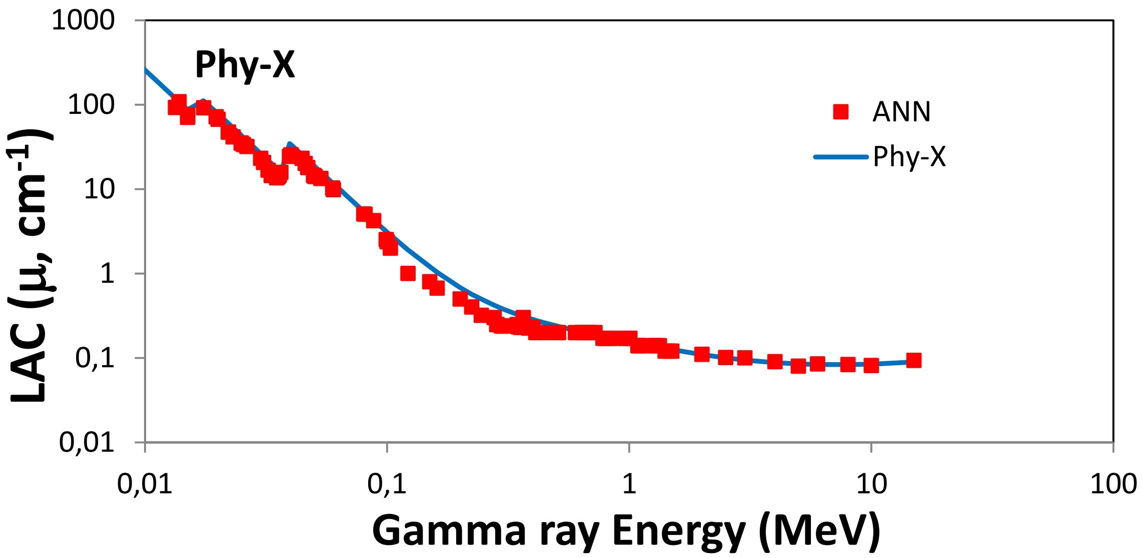

Figure 2 *ANN prediction and Phy-X calculation of LAC for glass as function of gamma ray energy*

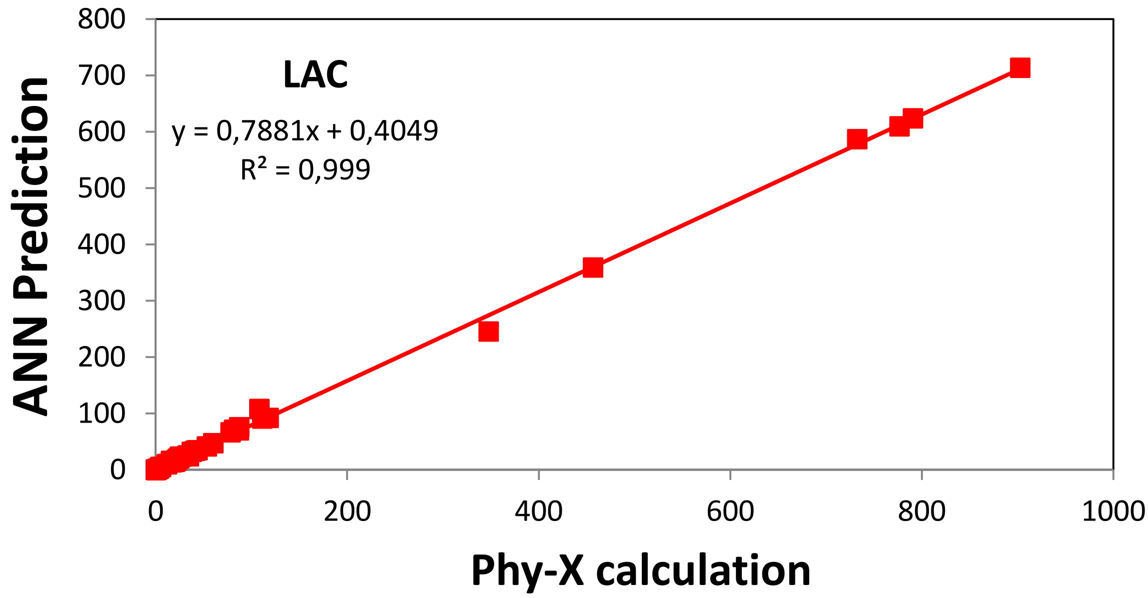

Figure 3 *Correlation between ANN prediction and Phy-X calculation*

4. Conclusions

In this study, the radiation shielding properties of magnesium borosilicate glass with a composition of $40MgO–30B_2O_3–30SiO_2$ were investigated using both Phy-X/PSD calculations and the Artificial Neural Network (ANN) method. Gamma-ray energies, material density, and molar fractions were used as input parameters for the ANN model, while the linear attenuation coefficient (LAC) values were obtained as the output to predict the radiation shielding performance of the glass. The predicted ANN results showed good agreement with the values calculated using Phy-X/PSD. These findings indicate that ANN is an effective and reliable tool for predicting the gamma-ray shielding properties of glass materials.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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