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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□O□ with MgO using Artificial Neural Network (ANN). The glass samples were prepared with compositions of 30SiO□–30B□O□–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 $30SiO_2$ –$30B_2$ O_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 $30SiO_2$ –$30B_2$ O_3 –40MgO.

2. Materials and Methods

In this study, the gamma-ray shielding characteristics of magnesium borosilicate glass with a composition of 40MgO–$30B_2$ O_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).

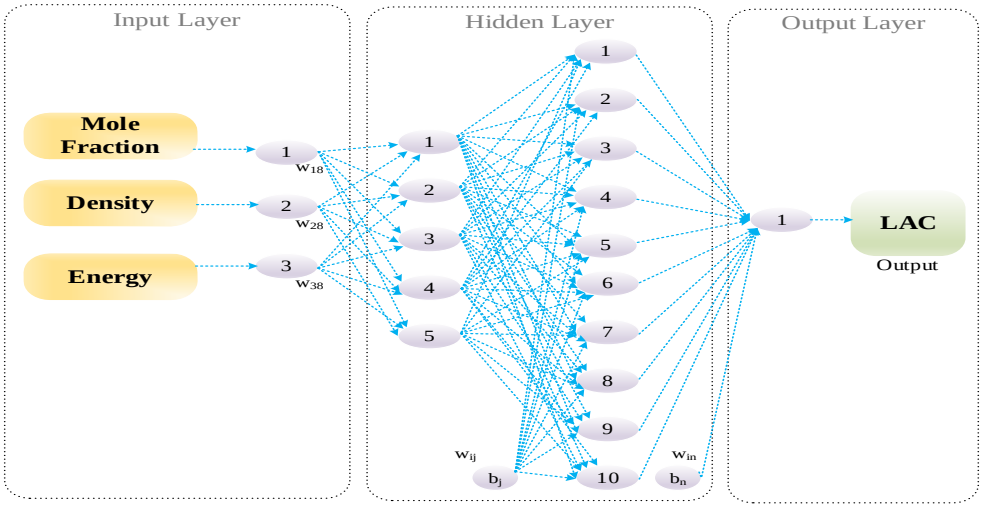

Figure 1. *Proposed ANN model structure*

3. Results and Discussions

The gamma-ray shielding performance of magnesium borosilicate glass with a composition of 40MgO–30B_2 O_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.

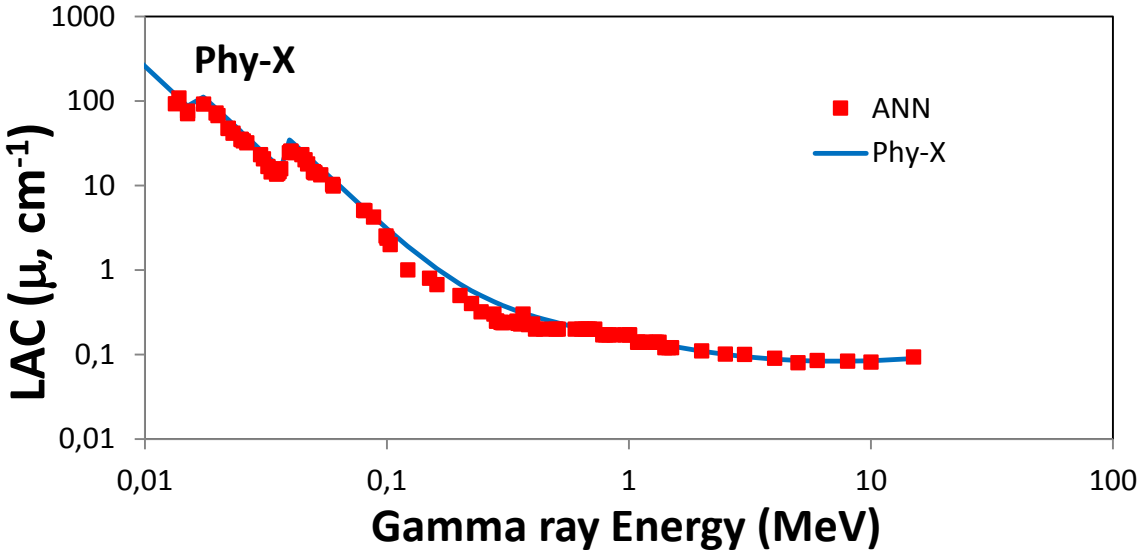

Figure 2 *ANN prediction and Phy-X calculation of LAC for glass as function of gamma ray energy*

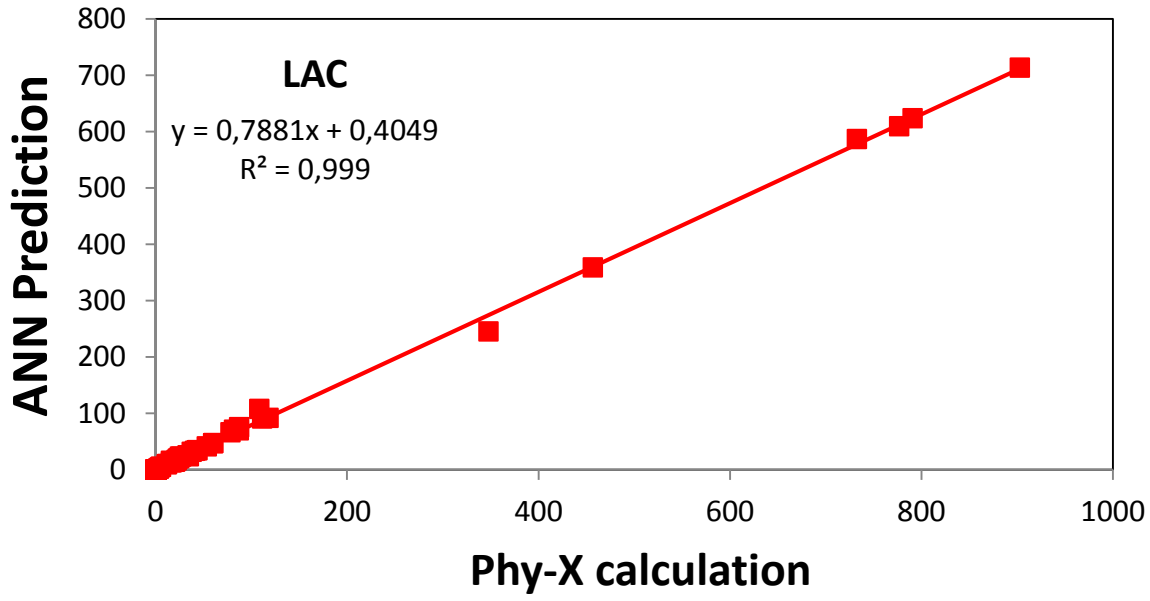

Figure 3 *Correlation between ANN prediction and Phy-X calculation*

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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References

[1]Hessa ALKARRANI, Şen Baykal, D., Ghada ALMISNED, & H.O. TEKIN. (2024). Exploring the Radiation Shielding Efficiency of High-Density Aluminosilicate Glasses and Low-Calcium SCMs. International Journal of Computational and Experimental Science and Engineering, 10(4). https://doi.org/10.22399/ijcesen.441

[2]Şen Baykal, D., ALMISNED , G., ALKARRANI , H., & TEKIN, H. O. (2024). Exploring gamma-ray and neutron attenuation properties of some high-density alloy samples through MCNP Monte Carlo code . International Journal of Computational and Experimental Science and Engineering, 10(3). https://doi.org/10.22399/ijcesen.422

[3]A.M.El-Khayatt, İ.Akkurt Photon interaction, energy absorption and neutron removal cross section of concrete including marble . Annals of Nuclear Energy.60 (2013)8-14. https://doi.org/10.1016/j.anucene.2013.04.021

[4]Avcı, H., Bulcar, K., Oğlakçı, M., & Atav, Ülfet. (2024). Dose Rate Calibration of β Radiation Source in Risø TL/OSL-DA-20 Reader Device. International Journal of Computational and Experimental Science and Engineering, 10(1). https://doi.org/10.22399/ijcesen.299

[5]Waheed, F., Mohamed Abdulhusein Mohsin Al-Sudani, & Iskender Akkurt. (2025). The Experimental Enhancing of the Radiation Shield Properties of Some Produced Compounds. International Journal of Applied Sciences and Radiation Research , 2(1). https://doi.org/10.22399/ijasrar.1

[6]Günoğlu, K., & Akkurt, İskender. (2023). Gamma-ray attenuation properties carbide compounds (WC, Mo2C, TiC, SiC, B4C) using Phy-X/PSD software. International Journal of Applied Sciences and Radiation Research , 1(1), 1–8. https://doi.org/10.22399/ijasrar.6

[7] Sarihan, Mucize. "Simulation of gamma-ray shielding properties for materials of medical interest" Open Chemistry, vol. 20, no. 1, 2022, pp. 81-87. https://doi.org/10.1515/chem-2021-0118

[8] Nuray Kutu. (2026). Radiation Shielding Properties of recycled waste glass color doped powder cement pastes. International Journal of Applied Sciences and Radiation Research , 3(1). https://doi.org/10.22399/ijasrar.55

[9] Morad Kh. Hamad. (2025). Synergistic Evaluation of Ionizing Radiation Shielding in Novel Lead-Free Alloys Using Geant4 MC toolkit. International Journal of Applied Sciences and Radiation Research , 2(1). https://doi.org/10.22399/ijasrar.47

[10] Betul Cetin, & Betul Sezer. (2025). Comparison of the radiation shielding effect of travertine and gasconcrete. International Journal of Natural-Applied Sciences and Engineering, 3(1). https://doi.org/10.22399/ijnasen.31

[11] Woods J (1982) Computational Methods in Reactor Shielding. Pergamon Press, NewYork-USA

[12] Iskender Akkurt "Effective atomic and electron numbers of some steels at different energies" Ann. Nucl. En. 36-11,12(2009)1702-1705 DOI: 10.1016/j.anucene.2009.09.005

[13] Demet Sarıyer. (2025). A FLUKA-Based Study on the Effect of Boron-Enhanced Concrete on Secondary Neutron Dose under Proton Beam Loss Scenarios. International Journal of Natural-Applied Sciences and Engineering, 3(1). https://doi.org/10.22399/ijnasen.30

[14] Iskender Akkurt 2007. Effective Atomic Numbers for Fe–Mn Alloy Using Transmission Experiment *Chinese Phys. Lett.* 24 2812. https://doi.org/10.1088/0256-307X/24/10/027

[15]Roya Boodaghi Malidarre, Iskender Akkurt, Parisa Boodaghi Malidarreh, Seher Arslankaya,Investigation and ANN-based prediction of the radiation shielding, structural and mechanical properties of the Hydroxyapatite (HAP) bio-composite as artificial bone,Radiation Physics and Chemistry. 197(2022)110208. https://doi.org/10.1016/j.radphyschem.2022.110208

[16] SARIHAN KARA, B. S. (2024). Interior design model proposal for nuclear medicine imaging rooms. International Journal of Computational and Experimental Science and Engineering, 10(4). https://doi.org/10.22399/ijcesen.518

[17] Şen BAYKAL, D., Ghada ALMISNED, Hessa ALKARRANI, & H.O. TEKIN. (2024). Radiation Shielding Characteristics and Transmission Factor values of some Selected Alloys: A Monte Carlo-Based Study . International Journal of Computational and Experimental Science and Engineering, 10(4). https://doi.org/10.22399/ijcesen.421

[18] Varone G, Ieracitano C, Çiftçioğlu AÖ, Hussain T, Gogate M, Dashtipour K, Al-Tamimi BN, Almoamari H, Akkurt I, Hussain A. A Novel Hierarchical Extreme Machine-Learning-Based Approach for Linear Attenuation Coefficient Forecasting. Entropy. 2023; 25(2):253. https://doi.org/10.3390/e25020253

[19] Karpuz, N. (2024). Effective Atomic Numbers of Glass Samples. International Journal of Computational and Experimental Science and Engineering, 10(2). https://doi.org/10.22399/ijcesen.340

[20]Basyigit, C, Akkurt I, Kilincarslan S, Beycioglu A. Prediction of compressive strength of heavyweight concrete by ANN and FL models. NEURAL COMPUTING & APPLICATIONS 19-4(2010)507-513 DOI: 10.1007/s00521-009-0292-9

[21]ALKARRANI, H., ŞEN BAYKAL, D., ALMISNED, G., & TEKIN, H. O. (2024). High-Density Lead Germanate Glasses with Enhanced Gamma and Neutron Shielding Performance: Impact of PbO Concentration on Attenuation Properties. International Journal of Computational and Experimental Science and Engineering, 11(1). https://doi.org/10.22399/ijcesen.635

[22]Akkurt, I Basyigit C., Kilincarslan S., Beycioglu, A. Prediction of photon attenuation coefficients of heavy concrete by fuzzy logic. JOURNAL OF THE FRANKLIN INSTITUTE-ENGINEERING AND APPLIED MATHEMATICS. 347-9 (2010)1589-1597. DOI: 10.1016/j.jfranklin.2010.06.002

[23]Alalkawı, M. D. J. , Al Shehabı, S. & Yıldırım Imamoglu, M. (2023). PTGNG: An Evolutionary Approach for Parameter Optimization in the Growing Neural Gas Algorithm . International Journal of Computational and Experimental Science and Engineering , 9 (2) , 91-101 . DOI: 10.22399/ijcesen.1282146

[24]KUTU, N. (2024). Neutron Shielding Properties of Cellulose Acetate CdO-ZnO Polymer Composites. International Journal of Computational and Experimental Science and Engineering, 10(2). https://doi.org/10.22399/ijcesen.322

[25]Şen BAYKAL, D. (2024). A novel approach for Technetium-99m radioisotope transportation and storage in lead-free glass containers: A comprehensive assessment through Monte Carlo simulation technique . International Journal of Computational and Experimental Science and Engineering, 10(2). https://doi.org/10.22399/ijcesen.304

[26]Cena, B. (2024). Determination of the type of radioactive nuclei and gamma spectrometry analysis for radioactive sources. International Journal of Computational and Experimental Science and Engineering, 10(2). https://doi.org/10.22399/ijcesen.321

[27]KUTU, N. (2024). Gamma ray Shielding Properties of the 57.6TeO2-38.4ZnO-4NiO system. International Journal of Computational and Experimental Science and Engineering, 10(2). https://doi.org/10.22399/ijcesen.310

[28]Betul Cetin, Arzu Poyraz, & Melek Gul. (2026). Examination of the radiation absorption parameters of CuO coatings prepared at different ratios. International Journal of Sustainable Science and Technology, 4(1). https://doi.org/10.22399/ijsusat.35

[29]Soyal, H., & Sarıhan, M. (2025). The Place, Importance and Development Approaches of Radiation Safety and Protection Education in Associate Degree Health Programs. International Journal of Sustainable Science and Technology, 3(1). https://doi.org/10.22399/ijsusat.11

[30] Erdem Şakar, Özgür Fırat Özpolat, Bünyamin Alım, M.I. Sayyed, Murat Kurudirek. Radiation Physics and Chemistry 166 (2020) 108496 https://doi.org/10.1016/j.radphyschem.2019.108496

[31] I. Atik, "A Hybrid Prediction Approach Based on ANN and NAR Neural Networks for Annual Electric Energy Demand in Turkey," UPB Sci Bull Ser. C, vol. 83, no. 4, pp. 311–330, 2021.

[32] S. Zhao, W. Xu, and L. Chen, "The modeling and products prediction for biomass oxidative pyrolysis based on PSO-ANN method: An artificial intelligence algorithm approach," Fuel, vol. 312, p. 122966, 2022.

[33] İ. Atik, "Comparison of Short-Term Electricity Load Forecasting Using Different Deep Learning Methods," Avrupa Bilim Ve Teknol. Derg., no. 31, pp. 616–623, Dec. 2021.

[34] M. Y. Imamoglu, I. Akkurt, S. Arslankaya, R. B. Malidarre, and I. Y. D. Erdamar, "Prediction of radiation shielding properties for concrete by artificial neural networks," Eur. Phys. J. Plus, vol. 137, no. 7, p. 865, 2022.