Glass and Glass-Ceramics Based on Weathered Basaltic Rock for Radiation Shielding Applications

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Abstract
Different batches of weathered basalt ranging from 100 to 50 %, in combination with by-pass cement dust, were used to prepare the glass compositions. Different techniques utilized such as differential thermal analysis, X-ray diffraction, density, FTIR, the mass attenuation coefficients, appropriate atomic number (Z_{eff}), and effective electron density (N_{eff}), were examined for the prepared glass and glass-ceramics samples at different photon energies. In the present study, it was revealed that as the molar volume decreases, the density increases. The experimental and theoretical effects of the mass attenuation component were mostly consistent at different energies. The results revealed that glass samples (WB100) containing a higher percentage of basaltic rocks demonstrated higher radiation protection than those with lower rate (WB50). In addition, glass-ceramics displayed enhanced radiation and gamma rays protection than glass. Therefore, we recommend using glass- ceramics containing 100 % basalt as a protective shield against gamma rays with a lower thickness and higher protection.

Keywords XRD · DTA · FT-IR · Radiation shielding · Basalt · Mass attenuation coefficient · Half-value layer · Effective atomic number

1 Introduction
Nuclear technologies are applicable to many industries such as laboratory-scale medical physics and nuclear research. For example, insect control with sterile insect technology, gene mutation of plants and preservation of foodstuff in the food industry, radiotherapy in the medicine field, radiography in the non-destructive testing field, structural characterization of materials in the radiation protection field and radiation dosage dosing, etc., which are known as radiation applications [1].

Radiation shielding is a common problem that has received significant attention to date. In various radiation technologies and applications, the interaction of energetic X/\gamma ray radiation and a neutron with the material is essential [2]. The advantage of ceramic glass is its fine-grained crystalline texture formed by the glass heat treatment.

Only specific glass composition can be the appropriate precursors for glass-ceramic productions, although some glasses are very stable, such as ordinary window glass, and are difficult to crystallize. Most glass-ceramic materials contain a high percentage of crystalline materials, ranging from 50 to 95 %, and the rest is residual glass.

Glass-ceramic materials have a range of excellent compositional properties that make them suitable for corrosion-resistant applications in applied manufacturing, electronics, and other fields.

With regard to the traditional method of making glass-ceramics from pure chemicals, which raises the cost of manufactured products, this article focuses on preparing glass-ceramics from weathered basalt and industrial wastes, which can be used in various ways to improve the economic state [3].

Basalt is an extensive magmatic rock that makes up 95 % of continental and oceanic lava and pyroxene andesite. It is dark, almost micaomatic black (generally containing only small amounts of glass) and composed primarily of feldspar, plagioclase, and ferromagnesian minerals (mainly augite), whereas
the accessory minerals are olivine, apatite, and magnetite. Khater et al. managed to using basalt rocks with industrial waste to obtain a high-performance ceramic glass that can be used for construction purposes [4, 5].

During the manufacture of cement and iron, waste materials such as by-pass cement dust and iron slag are produced. If these large amounts of industrial waste are not adequately treated, they will cause significant environmental and ecological issues, consequently their use is deemed profitable [6]. According to the Central Pollution Control Board (CPCB), cement processing is one of the most polluting sectors [7]. Cement kiln by-pass dust is a hazardous waste material from the manufacture of P. C. clinker, and it is considered one of the leading direct reasons for air pollution, especially in the dwelling zone near or close to the cement factories. Since this dust is positively loaded with chlorine and alkaline, this dust in the cement mills is limited. Furthermore, this dust disposal quite expensive due to the high chlorine content and it is often categorized as hazardous waste.

Several types of glasses have been investigated by several researchers in the past few decades for use as alternative shield materials in a variety of nuclear applications due to a variety of intriguing physical properties such as good light transparency, ease of preparation, composition stability, and density when exposed to an external field, in addition to their ability to absorb high-energy photons [8–13].

It is known that the studied wastes used in the prepared glasses consist of alkali and alkaline earth ions, especially Ca²⁺ or Mg²⁺ occupying interstices or holes within the networks in the same time presences of alkali and alkaline earth oxides of sodium and calcium, which play an essential role in increasing non bridging oxygen (NBO) in the glass [14].

The addition of various ions to the glass modifies the density based on where these ions are located in the network structure. The results obtained are described by considering the glass system analyzed as well as cations added in the glassy network. When considering the glass structure under investigation and the form of cations included in the glassy network [15].

Glass batches have a high percentage of monovalent and divalent metals are applied to the silica, single-bonded or non-bridging oxygen atoms are formed, which indicates that oxygen is bonded to only one silicon atom in alkali silicate glasses. Sodium ions are attached to the underlying oxygen by much more and weaker bonds than silicon-oxygen bonds, or the weathered basalt (WB) structure, primarily composed of silicon, calcium, and aluminum oxides. The presence of AlO₃ in the form of SiO₄ tetrahedra AlO₄ groups around divalent cations makes them more stable than similar groups found around monovalent cations. As a result, the structure is expected to form a series of fairly regular interstices around the Ca²⁺ and Mg²⁺ cations, with a proportion of large irregular interstices containing Na⁺ ions, likely with several Na⁺ ions in each of the large, irregular rings. Consequently, sodium ions are only marginally maintained in the system, with divalent cations taking up most of the most frequent interstices [16].

In this paper the author explore the possibility of using weathered basalt and by-pass cement dust to produce materials made of glass and glass-ceramic that can be used in radiation shielding applications. For this goal, some physical and radiation shielding parameters have been studied.

2 Methodology

2.1 Glass Preparation

Tables 1 and 2 demonstrates the chemical analysis of the raw materials used in preparing glass samples. Six glass samples based on weathered basalt and cement dust were designed, and named WB100-WB50. These batches were well mixed and melted in platinum crucibles in an electric furnace at temperatures ranging from 1350 to 1400 °C. The melt was stirred every half hour until the sample became utterly homogeneous, and then poured in the hot-plate form of discs and rods. Subsequently, the model was transferred directly to an annealing furnace at a temperature of 550 °C for two h to release the thermal stress, keep via gradual cooling. Then, the prepared mother glasses were heat-treated at the required temperatures according to DTA results to obtain glass-ceramic materials.

2.2 Differential Thermal Analysis

DTA measurements were presented via DTG60 (Shimadzu, Japan) using 30 mg of powdered glass samples with a grain size of fewer than 60 microns, the powdered glass samples placed in platinum crucibles and heated from room temperature to 1000 °C with a heating rate of 10 °C/min. At the same time, Al₂O₃ powder was used as reference material.

2.3 X-ray Diffraction

An X-ray diffraction analysis device was used to find out the crystalline phases formed during the crystallization process. X-ray diffraction used a Bruker D8 (Germany) adopting Cu radiation with Ni-filter at a speed of 2° 2θ/min. The reference data of the interpretation of X-ray were obtained from American Standard for Testing Materials (ASTM).

2.3.1 Density, Molar Volume and Oxygen Packing Density

The formula below can be used to measure density values for the prepared samples, which is based on Archimedes’ principle:

$$\rho = (a/a-b) \times 0.86 \text{ g/cm}^3$$ (1)
The glass weights in air and xylene are a and b, respectively, and the density of xylene at 20 °C is 0.86. To detect the validity of the measurement, the experiment was repeated three times. The molar volume can be evaluated as

\[ V_m = \frac{M}{\rho} \]  

(2)

Where M the molar weight of the glass.

Oxygen packing density (OPD) the formula was calculated: where M is the molecular weight of each sample of glass and C is the number of oxygen atoms per unit of the formula.

\[ \text{OPD} = \left( \frac{1000 \times C \times \rho}{M} \right) \text{ g atom/l} \]  

(3)

Fourier Transform infrared spectrometer was used to test the FTIR absorption spectra of the glass samples at room temperature in the wavelength range 400–4000 cm⁻¹ (Thermo Nicolet 380 spectrometer).

2.3.2 Attenuation Parameters

The attenuation coefficients of the proposed glass system in the narrow beam transmission geometry were calculated with a 2 * 2 NaI (TI) crystal detector with an energy resolution of 12.5 % at 662 keV and a multichannel analyzer (MCA). ¹³¹Ba, ⁶⁶Co, ⁹⁰Th, and ¹³⁷Cs are radioactive sources with varying photon energies. For each sample, incident and

Table 1 Chemical analysis of raw materials used (wt%)

| Elements | SiO₂ | Al₂O₃ | Fe₂O₃ | TiO₂ | CaO | MgO | Na₂O | K₂O |
|----------|------|-------|-------|------|-----|-----|------|-----|
| Weathered Basalt | 37.85 | 11.51 | 23.93 | 2.37 | 11.85 | 4.37 | 2.05 | 1.11 |
| Bypass cement | 19.03 | 4.97  | 3.37  | 2.23 | 48.77 | 0.78 | 1.67 | 4.52 |

Table 2 Chemical composition of the studied glasses (mol. %)

| Glass ID | Raw material used | Calculated Composition (mol%) |
|----------|------------------|-------------------------------|
|          | WB % | Bypass % | SiO₂ | Al₂O₃ | Fe₂O₃ | TiO₂ | CaO | MgO | Na₂O | K₂O |
| WB100    | 100  | 0.00     | 49.22 | 8.59 | 11.72 | 2.34 | 16.41 | 8.59 | 2.34 | 0.78 |
| WB90     | 90   | 10       | 46.15 | 8.46 | 10.77 | 2.31 | 21.54 | 7.69 | 2.31 | 0.77 |
| WB80     | 80   | 20       | 43.85 | 7.69 | 9.23  | 2.31 | 26.15 | 6.92 | 2.31 | 1.54 |
| WB70     | 70   | 30       | 41.22 | 6.87 | 8.40  | 2.29 | 31.30 | 6.11 | 2.29 | 1.53 |
| WB60     | 60   | 40       | 37.59 | 6.77 | 7.52  | 2.26 | 36.09 | 5.26 | 2.26 | 2.26 |
| WB50     | 50   | 50       | 35.34 | 6.02 | 6.77  | 2.26 | 40.60 | 4.51 | 2.26 | 2.26 |

Where: WB= weathered basalt

Fig. 1 Experimental setup used to determine the linear attenuation coefficients
transmitted photon intensities were measured on MCA for a fixed preset period by selecting a narrow region symmetrical with respect to the centroid of the image peak. The experimental setup is depicted schematically, as shown in Fig. 1.

Linear attenuation coefficient (LAC) is the main shielding factor that describes the power of shielding material to reduce radiation intensity. The LAC is determined experimentally by means of Lambert Beers’ law, as demonstrated in Eq. (4) [17].

$$\mu t = \ln \frac{I}{I_0}$$  \hspace{1cm} (4)

The $\mu$, $t$, $I_0$, and $I$ denote the LAC of the fabricated glass, glass thickness, the incident, and transmitted gamma-ray intensity, respectively.

The Half Value Layer (HVL) of the studied glass sample is the glass thickness required to reduce the intensity of gamma-ray photons to half of their initial value and is calculated using Eq. (5) [10].

$$HVL \ (cm) = \frac{\ln 2}{\mu}$$  \hspace{1cm} (5)

An effective atomic number $Z_{\text{eff}}$ can describe a multi-element sample in terms of its equivalent element.

The $Z_{\text{eff}}$ for the examples can be determined through Eq. (6).

$$Z_{\text{eff}} = \frac{\sigma_a}{\sigma_e}$$  \hspace{1cm} (6)

Where

$$\sigma_a = 1/\text{NA} \sum_i^a (f_i A_i \mu_i m_i)$$  \hspace{1cm} (7)

$$\sigma_e = 1/\text{NA} \sum_i^e (f_i A_i \mu_i m_i)$$  \hspace{1cm} (8)

Equations 7 and 8 $\sigma_a$, $\sigma_e$, $f_i$, $A_i$, and $z_i$ are the atomic cross-sections, electric cross-section, fractional abundance, mass number, and atomic number of the content of samples.

3 Results and Discussion

3.1 Differential Thermal Analysis DTA

The DTA of the investigated glasses (Fig. 2) shows a slight dip between 718 and 740 °C, which corresponds to the glass change temperature ($T_g$). It was found that $T_g$ decrease, with increasing of by-pass content from 10 to 50 wt%. The major exothermic peaks in the temperature range of 821 - 915 °C, which agrees to the glass crystallization temperature ($T_c$). Thermal parameters include crystallization temperature ($T_c$) and the temperature of glass transition ($T_g$). Glasses with low by-pass cement content (WB100-WB70 samples) have a lower crystallization temperature, whereas glasses with elevated by-pass cement content (WB60 &WB50) have a rapid crystallization growth. Additionally, SiO2 decreases from 49.22 (WB100) to 35.34wt% (WB50), while in calcium oxide it increases from 16.41 to 40.60wt% in glasses WB100 to WB50, respectively. The release of thermal energy with the consequent exothermic peaks is caused by glass devitrification. Glass samples rich in SiO2, Fe2O3, and Al2O3 (WB100-WB70) showed crystallization difficulty that resulted in broad exothermic peaks. Meanwhile, samples rich in by-pass (CaO)
WB60 and WB50) displayed a faster crystallization rate with more defined exothermic peaks. The broad exothermic peaks from WB100 to WB70 reveal the large temperature choice overhead which crystallization can happen in these samples; however, the broad peak height to the prolonged times needed to achieve a fair amount of crystallization. It was hypothesized that WB60 and WB50 also exhibit exothermic peaks, representative of the progress of crystallization, which was confirmed via the heat-treated temperature.

SiO₂, Al₂O₃, Fe₂O₃ significantly change and decrease when the content of by-pass increases from zero to 50wt%. In contrast, CaO significantly increases in glasses WB100 to WB50, correspondingly. Moreover, its value reveals that the Al³⁺ ion cannot induce glass formation alone. Instead, it combines with another positively charged ion to reach electrical equilibrium and get into the building in the form of AlO₄. Additionally, the combination of Al³⁺ and Na⁺ reinforces the glass structure.

On the contrary, the increase in CaO, increases the viscosity of the glass, and thus the Tg elevates significantly in Tg corresponds to the visually detected high viscosity in the studied samples with a higher bypass percentage. Tg values increase with increasing Ca²⁺ field strength; and this result is reflected in a decrease in mobility, weakening of the silica network, and weakening the stability of glass structure. El-Shennawi et al. [18] illustrated that this endotherm shows the glass transition temperatures (Tg) and is attributed to the change of the glass structure. Devekey [19, 20] described this event of “preceding glass crystallization,” in which the glassy components start to arrange themselves at this degree, and is correlated with this endotherm.

### 3.2 X-ray Diffraction

X-ray diffraction graphs (Fig. 3) for the examined glasses WB100 – WB50 after heat treatment at 1000 °C for two hours.
showing that the diopside (CaMgSi$_2$O$_6$) (ASTM. card no.11-654), wollastonite (CaSiO$_3$) (JCPDS card no. 29-372), anorthite (CaAl$_2$Si$_2$O$_8$) (ASTM. card no. 20-20), magnetite (Fe$_3$O$_4$) (ASTM. 19-629), hematite (Fe$_2$O$_3$) (JCPDS 33-664) are the main crystalline minerals grown in the present glass-ceramic materials. However, the amount of these phases varies based on the glass composition. In glass samples (WB100 to WB70), diopside (CaMgSi$_2$O$_6$), anorthite (CaAl$_2$Si$_2$O$_8$), wollastonite (CaSiO$_3$), magnetite (Fe$_3$O$_4$), and hematite (Fe$_2$O$_3$) are the main crystalline phases (Fig. 3). Whereas, samples WB60 and WB50 (Fig. 3) reveal that galenite (CaAl$_2$SiO$_7$) is the primary crystalline phase with appearance lines; 3.72, 2.85, 2.43, 2.04, and 1.75Å, the anorthite mineral disappeared, with decreased amounts of diopside, magnetite, and hematite. The reduction in the diopside phase was attributed to the diminished MgO content in these investigated samples (Table 3), and this element is responsible for forming the diopside mineral. That is why the diopside phase could not maintain the Ca-Tschermak (CaAl$_2$SiO$_6$) from within its lattice. In addition to increasing the ratio of CaO in cement dust, and consequently the increase in these samples facilitated the creation of gehlenite mineral as follows:

\[
\text{CaAl}_2\text{SiO}_6 \text{ (in the lattice of diopside plus CaO (additional from cement-dust samples WB60 and WB50) } \rightarrow \text{Ca}_2\text{Al}_2\text{SiO}_7 \text{ (gehlenite main phase) plus the small intensity of diopside lines (Fig. 2). Concerning the vanishing of the anorthite phase,}
\]

the reaction was as follows; CaAl$_2$SiO$_3$ (Anorthite) $\rightarrow$ Ca-Tschermak (CaAl$_2$SiO$_6$) + SiO$_2$ (remaining glasses). Moreover, the decrease in hematite and magnetite is due to the weathering process of samples WB60 &WB50 that caused a reduction in the iron content (Table 3).

### 3.3 Density, Molar Volume and Oxygen Packing Density

Figure 4 demonstrates the density of the investigated glass and shows that the highest density is glass as it contains 100 % basalt. The presence of a high concentration of Fe$_2$O$_3$ in basalt causes changes in the glass networks by filling the interstitial spaces, which become denser and heavier, as revealed in the results given in Table 2. Furthermore, it is evident that the increased density that may be due to the formation of bridging oxygen that reduce the voids within the configuration\[21\].

The molar volume also increases with an increase in By-pass cement, which indicates the expansion of the network and growth of NBO (non-bridging oxygens). This can be related to the replacement of Weathered Basalt (WB) by By-pass cement which contains ions with a higher atomic radius such as potassium and calcium existing in the By-pass cement. This can be attributed to the contribution of large ionic radius to the increased distortion by elevating the number of NBO
Oxygen bridges to provide a more open structure with a large volume added, and then a decrease in density can occur [22]. OPD decreases by elevating the concentration of By-pass cement in the glass network. Thus, it may be considered that the replacement of Bypass cement leads to a loose structure and reduced the bridging oxygen in the glass system [23]. The oxygen packing density with decreasing density decreases, \( V_m \) increases, while OPD decreases, which means that the increase in the NBO bonds in the glass structure [24].

### 3.4 Interpretation of the FTIR Spectra

Figures 5 and 6 of FTIR charts demonstrates the absorbance as a wavenumber function where a peak is induced by each absorption process. Molecular or chemical bond vibration, the peaks at 450–500 cm\(^{-1}\) can be related to bending modes of Si–O–Si or O–Si–O [25]. 470 cm\(^{-1}\) due to the high concentration of P2O5 and assigned to O – P – O and P – O – Si bonds [26]. The one band at 570 cm\(^{-1}\) and can also be related to the vibrations of silicon-oxygen rings [27]. The peak at 680 cm\(^{-1}\) is due to the beats of silicon-oxygen rings. The medium band at 720–780 cm\(^{-1}\) can be due to Si–O–Si symmetric stretching vibrations of bridging oxygen (BO) between tetrahedral [28]. The band 1080 cm\(^{-1}\) symmetric stretching of Si-O-Si bonds. The intensity of this band diminishes when the Al\(_2\)O\(_3\) quantity increases [29, 30].

The infrared absorption bands at 1228 and 1291 cm\(^{-1}\) are related to the asymmetric stretching vibrations of the silicate tetrahedral network 1620–1650 cm\(^{-1}\) with molecular water as shown in Table 4.

New information on changes to the glass matrix are difficult to be obtained, except that mentioned in the literature [31], which depends on the nature and/or quality of alkali oxide in silicate glasses, the deconvolution method is used to evaluate the established concentration of silicate structural units for the study of the infrared spectra silicate glasses. Each spectrum was de-convoluted to individual peaks using Peak Fit v4.12.

| Silicate groups                                                                 | 100 Basalt Peaks | 50 Basalt Peaks |
|---------------------------------------------------------------------------------|------------------|----------------|
| Attributed to bending modes of Si–O–Si or O–Si–O.                               | Area 105         | Area 85        |
|                                                                                 | Position 417     | Position 484   |
| Assigned to Si–O–Si symmetric stretching vibrations of bridging oxygens between tetrahedra | 7.09 | 32            |
| Related to Si–O– stretching with nonbridging oxygens.                          | 929             | 911           |
| Symmetric stretching of Si–O–Si bonds                                           | 968             | 67            |
| assigned to the asymmetric stretching vibrations of the silicate tetrahedral network | 1157           | 1237          |
| The weak peak at 1350–1450 cm\(^{-1}\) is related to a carbonate group and the peak at 1620–1650 cm\(^{-1}\) is due to molecular water. | 1405           | 1396          |
|                                                                                 | 1322            | 1616          |
with $R^2 \sim 0.999$ to give different vibrations to the silicate groups and suggest the center of the (C) band and the region (A) of the component band and the region below SiO$_4$ units [32], which demonstrates that the amount of areas involved under these peaks equals the whole area below the original area. Spectrum as in Fig. 6 for $x = 0$ mol%. The band at 420–450 cm$^{-1}$ correlates modifier cations in their residing sites as bridging and non-bridging types (e.g., Na$^+$, Ca$^{2+}$). This broad-band reveals a peak at 920–980 cm$^{-1}$ due to Si–O–stretching with non-bridging oxygen NBO, and 750-979 cm$^{-1}$ is due to the stretching vibrations of the Al-O bonds with Al$^{3+}$ ions in 4-fold coordination. By increasing the silica ratio, this peak shifts to higher wave numbers [33]. The most intense band at 1160 cm$^{-1}$ was related to O-P-O groups asymmetric and symmetric respectively) (34–36).

3.5 The Radiation Shielding Features

Incident and transmitted intensities were determined with experimental confirmation of linear attenuation coefficients values of glass. Linear attenuation coefficients ($\mu$) for glass were measured at photon energies of [0.08-2164] MeV. The results obtained are shown in Fig. 7. It is evident that the measured results decrease with increasing the thickness of the prepared glass and increase with increasing photon energies.

The values of the total mass attenuation coefficients ($\mu / \rho$) are essential in many applications such as radiological physics and nuclear, radiation dosimetry, biological, medical, agricultural, environmental, and industrial sectors. The half-value layer (HVL) is a essential parameter in order to test the shielding properties of the radiation of the material, as illustrated in Fig. 8, which demonstrates the function of the photon energy.
energy of glass based on weathered Basalt and cement wastes [37–40]. Therefore, Fig. 8 illustrates that a greater thickness of this glass is needed to stop the high-energy photons. The absorption of X-rays, scattering, and gamma rays are correlated to the density and atomic numbers of an element [41, 42]. However, as for glass, it is made up of a group of composite materials, so it has to do with the effective electron density (Ne) and the effective atomic number (Z_{eff}).

Therefore, a single number cannot uniquely signify the atomic number across the entire energy range, and then the cross-sections of the partial reaction have a different atomic number. Therefore, we determine the adequate atomic number, Z_{eff}, which is a very valuable parameter for many fields of scientific, technological and engineering applications. Z_{eff} is a suitable parameter to signify the γ-ray attenuation in the medium. The mass attenuation coefficients (µ /ρ) of the current glass are plotted in Fig. 9. The µ /ρ depend on the energy of the photon and the concentration of weathered Basalt within the glass. From Fig. 9, we conclude that the addition of basalt to bypass cement affects mass attenuation coefficients [22, 43]. The experimental and theoretical values are moderately compatible.

The calculated Z_{eff}, Ne, and Zeq of the current glass are also shown in Figs. 10, 11, and 12. Changes in Z_{eff}, Ne, and Zeq exhibited approximately similar behavior to µ /ρ. The values for all of these are lower because the absorption probability decreases with increasing energies of the incident photon. Ne and Zeq are closely associated with Z_{eff} and have the exact specific energy requirement as Z_{eff} since the three parameters are linked through µ /ρ. Z_{eff}, Zeq, and Ne results confirmed the ability to use this glass for shielding radiation.

### 3.6 Glass-ceramics

The values of density and mass attenuation obtained from glass-ceramics have relatively higher values than glass samples. Thus, all values of the previous gamma-ray protection. This is illustrated in Figs. 13 and 14. The higher values of glass-ceramics are due to the inclusion of crystalline materials such as diopside, anorthite, magnetite, and hematite phases which increases the closely packed structure. Consequently, the crystalline phases increased the density, increased network cohesion, and increased absorption of gamma rays. From the results obtained, it is evident that the glass structure is weaker than that of glass-ceramics, thus the density and lower mass attenuation values of the glass samples can be regarded as an evidence of the amorphous nature and short-term arrangement characteristics of glasses. Therefore, we recommend
using the glass-ceramics as a protective shield against gamma rays.

4 Conclusions

Based on results, it can conclude that:

- Glass and glass-ceramics have been successfully prepared from weathered basaltic rocks and cement dust that can be used as radiation shielding materials.
- Density of glass increases as presence of a high concentration of Fe₂O₃ in basalt, whereas oxygen packing density decreases.
- FTIR spectra of the glasses system indicate that the vibrational modes of silicate glass are present.
- Zeff, Zeq, and Ne results confirmed the ability to use this glass for shielding radiation.
- Glass-ceramic samples with a high percentage of weathered basalt (WB100) give more significant mass attenuation coefficient than that of glass samples.
- The findings suggest that this approach could also be useful for using the investigated weathered basalt (WB100) as a protective shield against gamma rays with a lower thickness and higher protection.

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Data Availability My manuscript and associated personal data will be shared with Research Square for the delivery of the author dashboard.

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