Araştırma Makalesi / Research Article

Examination of Radiation Absorption Properties of $Pb(NO_3)_2$ Doped Wallpapers

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Abstract
The harmful effects of radiation on human health have long been recognized. These effects include radiation burns, radiation diseases, shortening of life span, cancer and hereditary disorders. Therefore, the absorption properties and applicability of the material used in radiation shielding are very important. Hence, studies are underway on the development of different types of shielding materials. In this study, radiation absorption properties of lead (II) nitrate $Pb(NO_3)_2$ coated wall papers were investigated. The wall papers in different densities (100% precipitated calcium carbonate (PCC), 2.5 g, 5 g, and 7.5 g amounts of $Pb(NO_3)_2$) and various thicknesses (0.176-0.236 mm) were prepared and investigated. 4 MeV-energized electrons were applied to the $Pb(NO_3)_2$ coated wall papers and measurements were taken with the PTW brand electron detector. Also, theoretical calculations have been done by using WinXCom program. According to the obtained results, these wallpapers' absorption properties increased depending on thickness. Thus, it has been seen that the $Pb(NO_3)_2$ coated wallpapers can be used with other materials in radiation shielding.

Keywords: Radiation, shielding, wallpaper, lead (II) nitrate.

$Pb(NO_3)_2$ Katkılı Duvar Kâğıtlarının Radyasyon Soğurma Özelliklerinin İncelenmesi

Öz
Radyasyonun insan sağlığı üzerindeki zararlı etkileri uzun zamandır bilinmektedir. Bu etkiler radyasyon yanıkları, radyasyon hastalıkları, yaşam süresinin kısalması, kanser ve kalıtsal bozuklukları içerir. Bu nedenle, radyasyon zırhlamada kullanılan malzemenin soğurma özellikleri ve uygulanabilirliği çok önemlidir. Bu nedenle, farklı koruyucu malzemelerin geliştirilmesi üzerine çalışmalar devam etmektedir. Bu çalışmada kurşun(II) nitrat $Pb(NO_3)_2$ kaplamalı duvar kâğıtlarının radyasyon soğurma özellikleri araştırılmıştır. Farklı yoğunluklarda (%100 çökeltilmiş kalsiyum karbonat (PCC), 2.5 g, 5 g ve 7.5 g $Pb(NO_3)_2$) ve çeşitli kalınlıklarda (0.176-0.236 mm) duvar kağıtları hazırlandı ve araştırıldı. $Pb(NO_3)_2$ kaplanmış kağıtlara 4 MeV-enerjili elektron uygulandı ve PTW marka elektron detektörü ile ölçümler alındı. Ayrıca, WinXCom programı kullanılarak teorik hesaplamalar yapıldı. Elde edilen sonuçlara göre, bu duvar kâğıtlarının soğurma özellikleri kalınlığa bağlı olarak artmıştır. Böylece, $Pb(NO_3)_2$ kaplı duvar kağıtlarının diğer malzemelerle birlikte radyasyon zırhlamada kullanılabileceği görülmüştür.

Anahtar kelimeler: Radyasyon, zırhlama, duvar kâğıdı, kurşun (II) nitrat.

1. Introduction

Radiation has been a part of our world since the formation of the universe. In this process, humanity has always been exposed to natural radiation from Earth and space. However, it is available in situations where radiation is artificially produced and used. For example, X-rays can be used to diagnose and treat diseases and can be used in industrial applications. In addition, the radiation released by accidents as a result of failures in nuclear facilities can damage humanity and nature. In all these cases, the most

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important principles of radiation protection are exposure time, shielding and distance. In this way the amount of dose exposed can be prevented or reduced by using simple preventive measures. In cases where radiation is used, exposure time should be limited to as much as necessary, the distance from the radiation source should be maximized and the source should be protected wherever possible [1]. To measure personal dose intake in the event of occupational or emergency exposure, personal dosimeters should be used for external radiation and bioassay techniques should be applied for the internal dose due to ingestion of radioactive contamination [2].

In radiation shielding, the radioactive particles are blocked by a barrier or barrier material to provide absorption of radiation. charged particle energies are reduced by methods such as photoelectric, scattering or double formation according to the attenuation principle of energy by interacting with the electrons of the material in the barrier. Thus, the particles can be rendered less harmful by, for example, elastic or inelastic scattering events of neutrons [3].

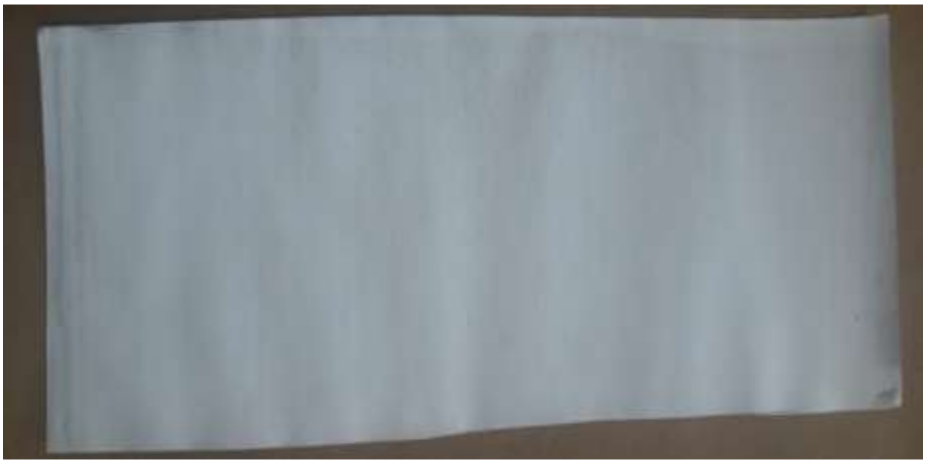

Figure 1. Example of $Pb(NO_2)_3$ doped wallpaper

To date, many materials have been developed for radiation shielding purposes. The amount of absorption varies according to the properties of the material to be produced. $Pb(NO_3)_2$ can be a good shielding material in terms of properties. Its molar mass 331.2 g/mol and density are 4.53 g/cm^3 (20°C). $Pb(NO_3)_2$ is used in textile dyeing, nylon and polyesters as heat stabilizers and as photo thermographic paper. $Pb(NO_3)_2$ is used to improve speed and yield, particularly in the processing of partially oxidized ores. It is also an oxidant in the paint industry [4].

In this study, $Pb(NO_3)_2$ doped wallpapers were used for radiation shielding (Figure 1). 100% precipitated calcium carbonate (PCC) and $Pb(NO_3)_2$ materials of different densities and thicknesses were added to the surfaces of these papers. These wallpapers can be used for the purpose of shielding radiation in different places. For example, it can be used in radiation treatment centres to prevent exposure of patients and workers to radiation doses.

2. Material and Method

In this study, $Pb(NO_3)_2$ salts (100% precipitated calcium carbonate (PCC), 2.5 g., 5 g. and 7.5 g.) were applied to 85 g. wallpaper surface obtained from markets. By using VARIAN brand [5,6] linear accelerator, 4 MeV energized electrons are applied to wallpaper that are placed between solid phantoms. PTW [7] brand electron detector was used for dose measurements. Every measurement was repeated 3 times following the same method. The wallpapers samples were placed at a distance of 100 cm from the gantry and the detector was placed just below the samples as can be seen in Figure 2.

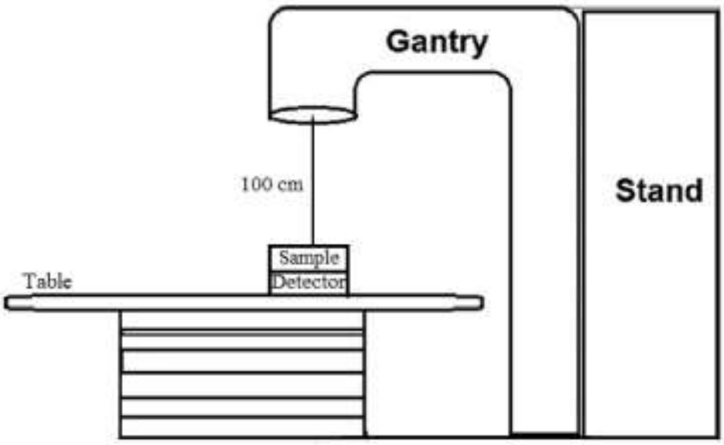

Figure 2. Experimental setup

The amount of radiation absorption of wallpaper is determined by Beer-Lambert's law [1,3];

$$I = I_0 \, . \, e^{-\mu t} \quad (1)$$

Here, I is sample counts, t (cm) is the thickness of the sample, I_0 is the sample-free counts and μ (cm^{-1}) is the linear absorption coefficient. Equation (1) was used in the calculation of linear absorption coefficient and results were obtained according to the properties of the absorber material. Description of the half-layer (HVL) is the thickness of the material which can pass half of the radiation interacting with the material. Also, description of tenth value layer (TVL) are the thickness of material capable of passing one-tenth of the radiation interacting with the material [3,8].

$$HVL = \frac{\ln 2}{\mu} \quad (2)$$

$$TVL = \frac{\ln 10}{\mu} \quad (3)$$

Preparation of the mortar to be applied to the wallpaper's surface is as follows: In order to develop shielding materials, mixtures containing lead(II)nitrate $Pb(NO_3)_2$ salts were prepared separately by taking calcium carbonate (PCC) precipitated in 5%, 10% and 15% ratios, 15% starch and 85%, 80%, 75% and 70% ratios specified in the table below. Prepared mixtures and their ratios are shown in Table 1.

Table 1. Preparation of $Pb(NO_3)_2$ doped coated mortar at different mixing ratios

Group	$Pb(NO_3)_2$ (%)	Starch (%)	PCC(%)
1	0	15	85
2	5	15	80
3	10	15	75
4	15	15	70

Also, the radiation shielding quantities of $Pb(NO_3)_2$ doped wallpapers systems were investigated using WinXCom package software [9] in the energy of 14 MeV. The total linear absorption coefficient (μ) value of wallpapers systems were calculated by using WinXCom software based on the mixture rule [9]. The calculation results can be seen in Table 2.

3. Results and Discussion

The structure of the shielding material is important in terms of radiation permeability. In controlled and uncontrolled areas, the shielding design is designed to meet the recommended effective dose limits for staff and patient. Equivalent radiation dose is 0.02mSv per week, except in public and uncontrolled areas.

The radiation permeability of some produced materials is shown in Figure 3. Here can be seen the absorption coefficients obtained by adding some quantities of $Pb(NO_3)_2$ (PCC, 2.5 g., 5g. and 7.5g.)

to the coating mortar used for coating the wallpaper surface. The wallpaper thickness and attenuation coefficients obtained by applying the mortar prepared using lead nitrate in different proportions to the wallpaper surface are given in Table 2. Also, the total absorption coefficients calculated by the WinXCom program are also given in the Table 2. The ratios in Table 1 are used for the values calculated with the WinXCom program. Table 2 shows that values calculated with the WinXCom program have been given higher results. Furthermore, the linear attenuation coefficients have been increased as the thickness increases. The half-value thickness (HVL) and one-tenth thickness (TVL) values calculated using these linear attenuation coefficients are given in Table 3. HVL and TVL values decreased as thickness increased. This indicates that the absorption efficiency of the wallpaper increases according to the thickness of the material. Figure 4 shows the comparison of HVL and TVL values obtained by using (2) and (3) equations.

Table 2. Thickness and linear attenuation coefficient values of wallpapers doped with $Pb(NO_3)_2$

Layer	PCC Thick. (mm)	μ(cm^{-1})	2.5 g Thick. (mm)	μ(cm^{-1})	5.0 g Thick. (mm)	μ(cm^{-1})	7.5 g Thick. (mm)	μ(cm^{-1})
3	0.192	0.0047	0.187	0.0048	0.212	0.0099	0.201	0.01203
6	0.196	0.0055	0.211	0.0071	0.221	0.0110	0.207	0.01422
9	0.206	0.0080	0.216	0.0087	0.231	0.0124	0.224	0.01685
WinXCom		0.0255		0.0308		0.0337		0.0355

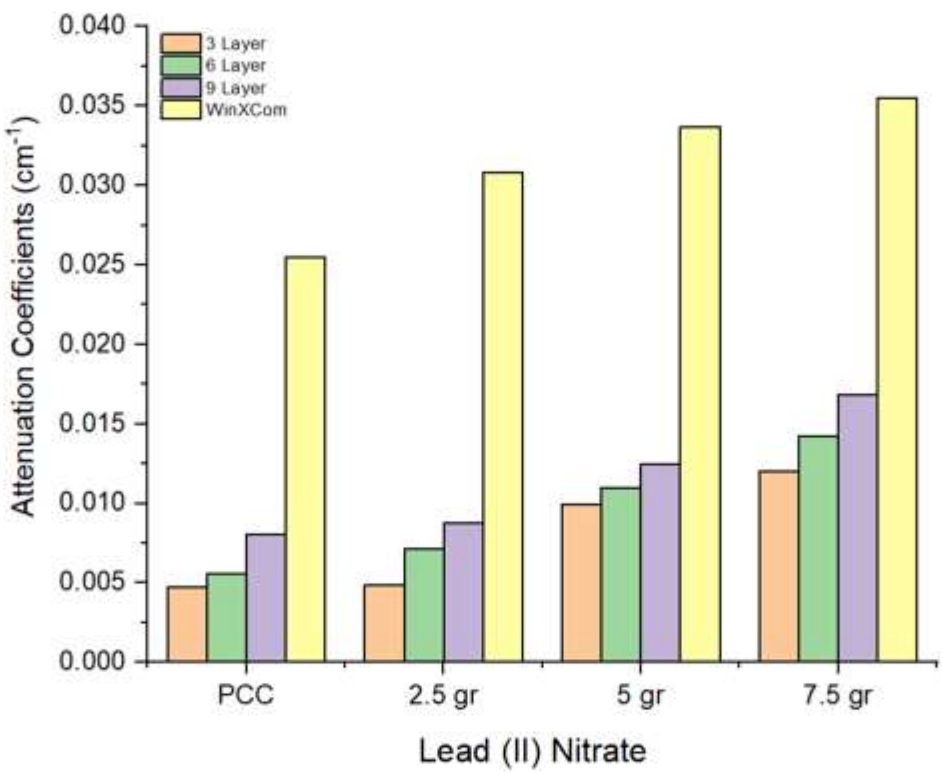

Figure 3. Linear attenuation coefficient values of wallpapers coated with $Pb(NO_3)_2$ obtained by applying 4 MeV energy electrons

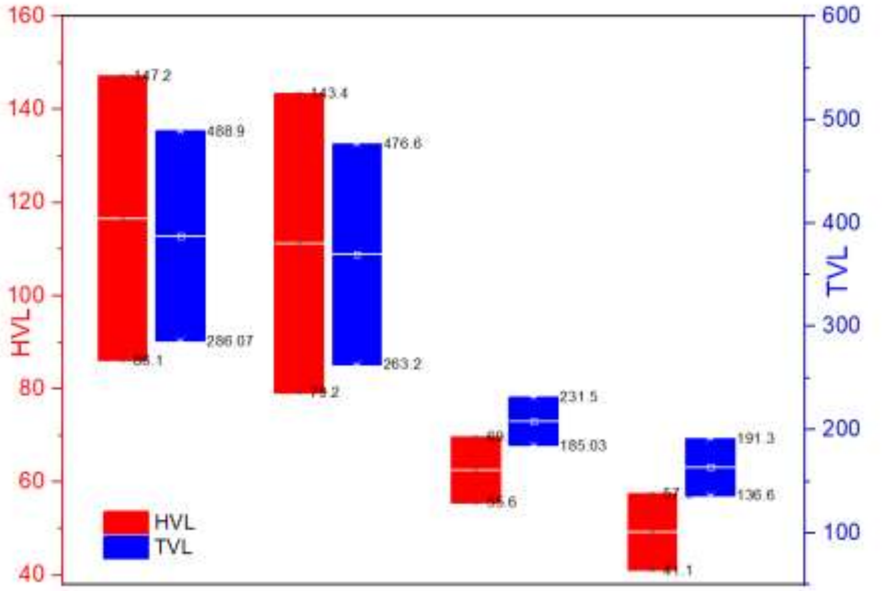

Figure 4. The comparison of HVL and TVL values of $Pb(NO_3)_2$

Table 3. Calculated HVL and TVL values of $Pb(NO_3)_2$

Thickness	HVL	TVL
PCC Thickness		
0.192	147.2	488.9
0.196	124.5	413.8
0.206	86.1	286.0
2.5 g Thickness		
0.187	143.4	476.6
0.211	96.8	321.6
0.216	79.2	263.2
5.0 g Thickness		
0.212	69.7	231.5
0.221	62.9	209.2
0.231	55.6	185.03
7.5 g Thickness		
0.201	57.6	191.3
0.207	48.7	161.8
0.224	41.1	136.6

4. Conclusion

In this study, the absorption coefficients of Lead (II) Nitrate ($Pb(NO_3)_2$) doped wallpapers were calculated and its radiation shielding properties were examined. Linear absorption coefficients obtained using 4 MeV energy electrons have been increased as the thickness of the material covered in the wallpaper increased. HVL and TVL values decreased due to these linear absorption coefficients. As can be seen from these results, radiation shielding materials can be derivable by using $Pb(NO_3)_2$. Lead (II) nitrate can be used for shielding in controlled or uncontrolled areas where radiation is used by mixing various percentages in building materials such as wallpapers or cement as examined in this study.

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