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Investigation of Beta Radiation Absorption Properties of Tungstate and Molybdate Doped Wallpapers

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Abstract. It is very important that the shielding material used in radiation treatment and imaging centers can effectively protect against radiation and that this material is cost-effective. Therefore, studies are underway on the development of different types of shielding materials. In this study, radiation absorption properties of sodium tungstate (Na2WO4) and sodium molybdate (Na2MoO4) coated wall papers were investigated. The beta radiation absorption properties of these elements which are applied on wall papers in different densities (100% precipitated calcium carbonate (PCC), 2.5 g, 5 g, and 7.5 g amounts of Na2WO4 and Na2MoO4 and various thicknesses (0.172-0.258 mm) were investigated. The wallpapers were irradiated with 4 MeV-energized electrons and measurements were taken with the PTW brand electron detector. The linear absorption coefficients of the wallpapers were obtained and half value layer (HVL) and one-tenth value layer (TVL) were calculated from these results. According to the results, it is observed that the beta radiation absorption properties of these wallpapers increase as the density of Na2WO4 and Na2MoO4 increases and as the coating thickness increases in the coating materials used to cover the surface of the wallpapers.

***Keywords*:** Wallpaper, Radiation shielding, Attenuation coefficient, Na2WO4, Na2MoO4.

Tungstat ve Molibdat Katkılı Duvar Kâğıtlarının Beta Radyasyon Absorbsiyon Özelliklerinin İncelenmesi

Özet. Radyasyonla tedavi ve görüntüleme merkezlerinde kullanılan zırhlama materyalinin etkin bir şekilde radyasyona karşı koruma sağlaması ve bu malzemenin düşük maliyetli olması çok önemlidir. Bu nedenle faklı zırhlama materyallerinin geliştirilmesi üzerinde çalışmalar devam etmektedir. Bu çalışmada, farklı yüzdelerde sodyum tungstat (Na2WO4) ve sodyum molibdat (Na2MoO4) ile kaplanmış duvar kâğıtlarının beta radyasyon soğurma özellikleri araştırılmıştır. Duvar kâğıtları üzerine farklı yoğunluklarda (% 100 çöktürülmüş kalsiyum karbonat (PCC), 2.5 gr, 5 gr, ve 7.5 gr.) Na2WO4 ve Na2MoO4 kaplanarak (0.172-0.258 mm aralığında) duvar kağıtlarının radyasyon soğurma özellikleri incelenmiştir. 4 MeV enerjili elektronlar ile kâğıtlar ışınlanmış ve PTW marka elektron detektörü ile ölçümler alınmıştır. Duvar kâğıtlarının lineer soğurma katsayıları elde edilerek bu sonuçlardan yarı değer kalınlığı (HVL) ve onda bir değer kalınlığı (TVL) hesaplanmıştır. Elde edilen sonuçlara göre duvar kâğıtlarının yüzeyini kaplamak için kullanılan kaplama materyallerinde Na2WO4 ve Na2MoO4 yoğunluğu arttıkça ve kaplama kalınlığı arttıkça bu kâğıtların beta radyasyonu soğurma özelliklerinin arttığı görülmektedir.

Anahtar Kelimeler: Duvar kâğıdı, Radyasyon zırhlama, Soğurma katsayısı, Na2WO4, Na2MoO4.

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1. INTRODUCTION

The use of radiation in the diagnosis and treatment of diseases and use in medical applications has been widely used. While technologically developed the diagnosis and imaging using radiation, it has some risks during application of radiation in treatment centers [1]. Therefore, radiation treatment centers have to take various precautions against any radiation leakage that may occur. Effective shielding during the various radiological applications is the first of these measures [2]. The various materials have been placed between a source and the target may affect the amount of radiation delivered from the source to the target [3]. The type of radiation-emitting substance, the released particle and energy level change the material to be used in shielding [4-6]. For example, Plexi glass is an effective way for the shielding against for Beta particles, X-ray and gamma ray. Radiation-protective materials are often used in hospitals, clinics, and dental practices to protect the patients and staffs from direct and secondary radiation during diagnostic imaging [7]. The radiation permeability depends on the structure of the protective materials [8].

In controlled and uncontrolled areas, the effective shielding can be designed to meet the recommended effective dose limits for staff and patients. These designs can be varied according to the characteristics of the devices to be used in the application and have certain standards [9]. Such as, while selecting the type of the material to form the shielding walls, it is assumed that the closest interaction must be the closest 0.3 m distance from the wall. In addition, the effective dose limits for the staff that are exposed to radiation are evaluated monthly in order to control the effectiveness of shielding [7]. In this study, as shown in figure 1, the beta radiation absorption properties of sodium tungstate (Na_2WO_4) and sodium molybdate (Na_2MoO_4) doped wallpaper samples were investigated. The beta radiation shielding properties of these doped wall paper samples in different densities and thicknesses were investigated.

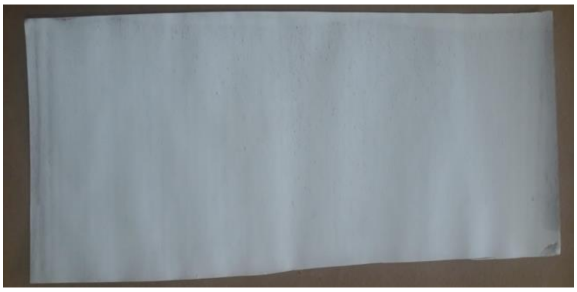


Figure 1. An example of Na_2WO_4 and Na_2MoO_4 doped wallpaper

2. MATERIALS AND METHODS

Within the scope of this research, 85 grams of wall papers were obtained from the market and used. Mixtures of sodium tungstate (Na_2WO_4) and sodium molybdate (Na_2MoO_4) salts (100% precipitated calcium carbonate (PCC), 2.5 gr., 5 gr., and 7.5 gr. of Na_2WO_4 and Na_2MoO_4) were applied on the surface of the wallpapers. The prepared wallpapers placed between solid phantoms using 4 MeV energy electrons were irradiated. VARIAN brand [9] linear accelerator was used for irradiation and PTW [10] brand electron detector was used for dose measurements. As can be seen in Figure 2, samples were placed at a distance of 100 cm from the gantry and the detector was placed just below the samples. Measurements were made in triplicate for each sample.

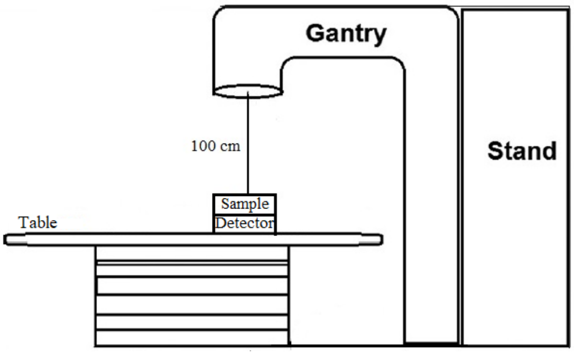


Figure 2. Experimental setup

The X-ray applied to the prepared wallpaper samples and solid phantom behave according to the properties of the absorber through which it passes. According to Beer-Lambert Law;

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

I_0 is the sample-free counts, I sample counts, t (cm) is the thickness of the sample 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. The half value layer (HVL) [11, 12] is the material thickness required to reduce the intensity of the beam interacting with the material in half. One-tenth (1/10) value layer (TVL) is the material thickness required to reduce the intensity of the beam interacting with the material to 1/10 [12, 13].

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

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

High atomic and water soluble chemicals were selected for the study. According to these properties, sodium molybdate (Na_2MoO_4) with a density of 3.78 g / cm3 and sodium tungstate (Na_2WO_4) with 4.18 g / cm^3 were studied. The process of preparing the mortar and applying it on the wallpaper was done as follows: In order to develop different shielding materials that can be used in radiation application centers, mixtures containing sodium tungstate (Na_2WO_4) and sodium molybdate (Na_2MoO_4) 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 Tables 1 and 2.

Table 1. Preparation of Na_2MoO_4 doped coated mortar at different mixing ratios

Group	Na_2MoO_4 (%)	Starch (%)	PCC(%)
1	0	15	85
2	5	15	80
3	10	15	75
4	15	15	70

Table 2. Preparation of Na_2WO_4 doped coated mortar at different mixing ratios

Group	Na_2WO_4 (%)	Starch (%)	PCC (%)
1	0	15	85
2	5	15	80
3	10	15	75
4	15	15	70

3. RESULTS AND DISCUSSION

The main purpose of shielding in radiation treatment centers is to prevent the radiation released from the linear accelerator out of the treatment room as much as possible. This equivalent radiation dose is 0.02 mSv per week, except in public and uncontrolled areas [13]. The energy and amount of radiation interacting with the material determine the quality of material in shielding. HVL represents the material thickness required to reduce the amount of radiation to half and TVL to one tenth. The linear absorption coefficients, HVL and TVL values were calculated by applying 4 MeV energy electrons shown in Table 5. The HVL values of sodium molybdate (Na_2MoO_4) applied wallpaper samples having different densities ranged from the range of 16.91 to 115.52. The TVL values were between 9.36 and 383.76. The HVL values for sodium tungstate (Na_2WO_4) were between 14.44 and 63.01. The TVL values varied between 47.97 and 209.33. Figures 4 and 5 show the attenuation coefficient values applied 4 MeV energy electrons to the wallpaper samples doped with sodium molybdate (Na_2MoO_4) and sodium tungstate (Na_2WO_4). It was observed that the attenuation coefficient values increased depending on the thickness of the wallpapers doped with 3, 6 and 9 layers of material with different thicknesses. Accordingly, Figure 3 and 4 show the variation of HVL and TVL values. Figure 5 shows the comparison of HVL and TVL values obtained by using (2) and (3) equations. In Table 6, HVL and TVL values of concrete, steel and lead obtained at different energies used as radiation shielding materials in some radiotherapy centers are given. As shown in this table 6, lead has the lowest HVL and TVL values while concrete has the highest values. when in table 6 the HVL and TVL values of some materials values are compared with the Na_2MoO_4 and Na_2WO_4 in Table 5, it can be seen in table 5 that the values we obtained have higher HVL and TVL values. Accordingly, it is understood that these materials are not suitable for shielding use alone.

Table 3. Thickness and linear attenuation coefficient vales of wallpapers doped with sodium molybdate (Na_2MoO_4)

Layer	PCC Thick. (mm)	$\mu(cm^{-1})$	2.5 gr Thick. (mm)	$\mu(cm^{-1})$	5.0 gr Thick. (mm)	$\mu(cm^{-1})$	7.5 gr Thick. (mm)	$\mu(cm^{-1})$
3	0.172	0.021	0.199	0.006	0.197	0.013	0.183	0.009
6	0.181	0.029	0.225	0.011	0.213	0.020	0.213	0.023
9	0.184	0.041	0.246	0.017	0.235	0.023	0.241	0.028

Table 4. Thickness and linear attenuation coefficient vales of wallpapers coated with sodium tungstat (Na_2WO_4)

Layer	PCC Thick.(mm)	$\mu(cm^{-1})$	2.5 gr Thick. (mm)	$\mu(cm^{-1})$	5.0 gr Thick. (mm)	$\mu(cm^{-1})$	7.5 gr Thick. (mm)	$\mu(cm^{-1})$
3	0.186	0.044	0.212	0.017	0.208	0.014	0.209	0.011
6	0.192	0.046	0.223	0.024	0.236	0.018	0.226	0.021
9	0.197	0.048	0.230	0.027	0.258	0.026	0.243	0.025

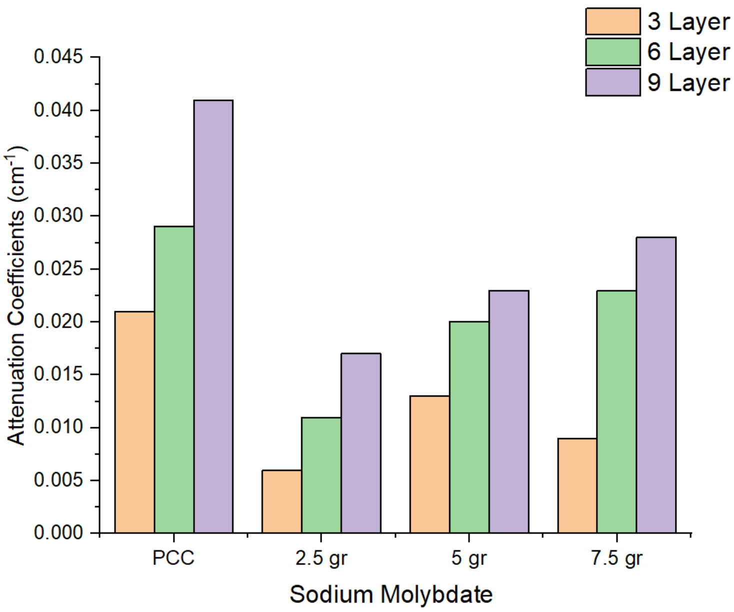


Figure 3. Linear attenuation coefficient values of wallpapers coated with sodium molybdate (Na_2MoO_4) obtained by applying 4 MeV energy electrons

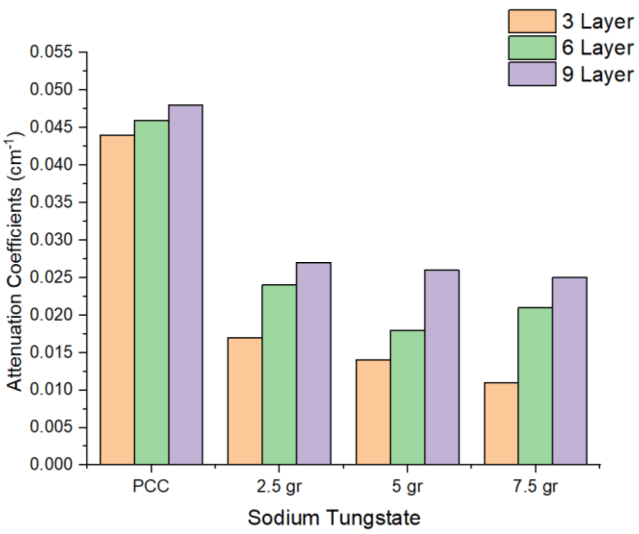
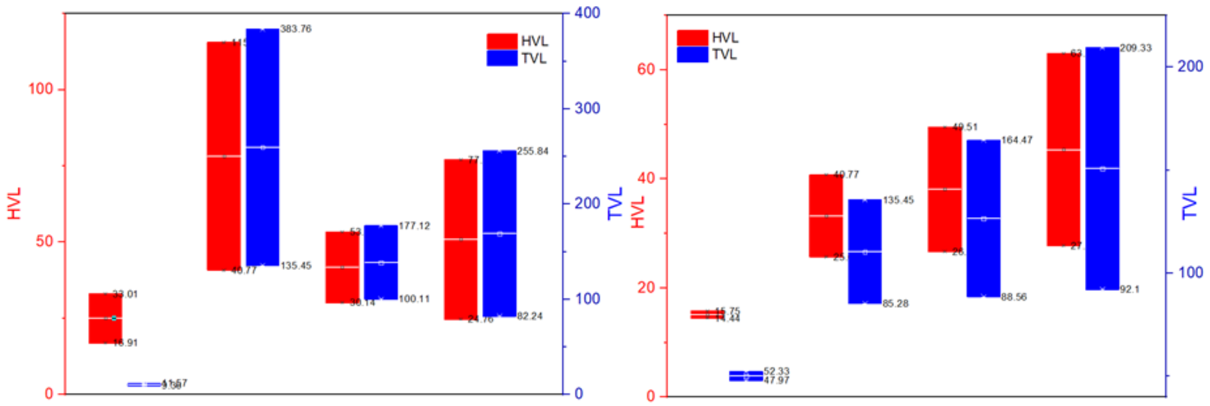


Figure 4. Linear attenuation coefficient values of wallpapers coated with sodium tungstate (Na_2WO_4) obtained by applying 4 MeV energy electrons

Table 5. Calculated HVL and TVL values

(Na_2MoO_4)				(Na_2WO_4)			
PCC Thickness	**μ(cm-1)**	**HVL**	**TVL**	**PCC Thickness**	**μ(cm-1)**	**HVL**	**TVL**
0.172	0.021	33.01	11.57	0.186	0.044	15.75	52.33
0.181	0.029	23.90	10.23	0.192	0.046	15.07	50.06
0.184	0.041	16.91	9.36	0.197	0.048	14.44	47.97
2.5 gr Thickness				**2.5 gr Thickness**			
0.199	0.006	115.52	383.76	0.212	0.017	40.77	135.45
0.225	0.011	63.01	209.33	0.223	0.024	28.88	95.94
0.246	0.017	40.77	135.45	0.23	0.027	25.67	85.28
5.0 gr Thickness				**5.0 gr Thickness**			
0.197	0.013	53.32	177.12	0.208	0.014	49.51	164.47
0.213	0.02	34.66	115.13	0.236	0.018	38.51	127.92
0.235	0.023	30.14	100.11	0.258	0.026	26.66	88.56
7.5 gr Thickness				**7.5 gr Thickness**			
0.183	0.009	77.02	255.84	0.209	0.011	63.01	209.33
0.213	0.023	30.14	100.11	0.226	0.021	33.01	109.65
0.241	0.028	24.76	82.24	0.243	0.025	27.73	92.10



Na_2MoO_4 Na_2WO_4

Figure 5. Calculated HVL and TVL values

Table 6. HVL and TVL values of some materials [14].

		HVL (cm)			TVL (cm)		
Isotope	**(MeV)**	**Concrete**	**Steel**	**Lead**	**Concrete**	**Steel**	**Lead**
^{137}Cs	0.66	4.8	1.6	0.65	15.7	5.3	2.1
^{60}Co	1.17, 1.33	6.2	2.1	1.2	20.6	6.9	4
^{198}Au	0.41	4.1		0.33	13.5		1.1
^{192}Ir	0.13 to 1.06	4.3	1.3	0.6	14.7	4.3	2
^{226}Ra	0.047 to 204	6.9	2.2	1.66	23.4	7.4	5.5

4. CONCLUSION

In this study, sodium tungstate (Na_2WO_4) and sodium molybdate (Na_2MoO_4) doped wallpaper samples prepared and used as the radiation shielding materials. The linear absorption coefficients were raised while the thickness of the doped material applied to the wallpapers and the amount of Na_2WO_4 and Na_2MoO_4 using 4 MeV energy electrons. Accordingly, HVL and TVL values of these materials were decreased. As understood from these results, beta radiation permeability decreases with increasing amount of sodium tungstate and sodium molybdate. Therefore, sodium tungstate (Na_2WO_4) and sodium molybdate (Na_2MoO_4) salts can be used in radiation treatment by mixing together with other materials in the radiation treatment centers that require radiation shielding or in many areas where beta radiation is applied. These materials are not sufficient for use alone. Because, the obtained HVL-TVL values of sodium tungstate (Na_2WO_4) and sodium molybdate (Na_2MoO_4) were high when compared to the literature [14] (table 6). A successful shielding can be achieved when these materials are used in conjunction with low HVL and TVL materials in the future studies.

Na_2WO_4 and Na_2MoO_4 salts are used in different agent such as paints, textiles, plastics, crops, cleaning washings and pesticides [15]. As seen in the applications, it can be said that these compounds can be stable in the air having moisture. Nevertheless, to preserve the properties of these materials, it is suitable to coat the wallpaper surface with a coating material. Also, radiation treatment centers should be well ventilated and preserve against moisture. In addition, the chemical properties of the wallpaper surfaces can be preserved for a long time by coating them with materials such as gel or paint.

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