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Thermal properties and EMI shielding leverage of HDPE/RH composites.

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Abstract

Although the subject of this study has previously been addressed through various approaches, such as the using of recycled process, polymer blends, and to obtaining of silica or rice husk ash, the objective of our study is to analyze of the chemical composition of Iraqi rice husks and conduct a comprehensive study of all the properties required to determine their application.[1-2] In this work, the rice husk is brought from al-Najaf/Iraq. The rice husk (RH) which be considered as an agriculture waste, was analyzed using X-ray diffraction (XRD) with the utility of X'Pert High Score Plus software to define the chemical components of rice husk, the results of the inspection of RH at room temperature showed the predicted constituents that comprise the rice husk in addition to the cellulosic component. The effect of using RH as a filler to high-density polyethylene board samples on the configuration, thermal properties and water absorption as a function of the concentration of rice husk were studied, so that the X-ray shielding of the composites was investigated.

DSC analysis results of pure and composite samples of HDPE with rice husk are described as exothermic crystallization and endothermic melting, and its explained RH effect reduces the heat amount required to raise the temperature compared to pure HDPE sample, which may be due to the lower specific heat of rice husk compounds (silicates compounds in almost) relative to pure HDPE, meanwhile, the melting temperature of HDPE was directly raised with the addition of RH, as the melting temperature was related to additional material and smaller crystals, which is for HDPE almost between (120-130)˚C, as a result to the inclusion of rice husk the crystallinity indexes of HDPE matrix was influences. While the thermal conductivity and burning rate decrease and the water absorption a few increased with the increasing of the addition of RH to HDPE. HDPE films were been studied as an attenuation material for x-ray, the obtained results of the linear attenuation coefficients showed that the attenuation of x-ray rays increased with the addition of rice husk. The best-added concentration of rice husk is 25%. All obtained results candidate this boards to be a good alternative to those in thermal insulation and x-ray attenuation application.

Keywords: *HDPE, rice husk (RH), composite, XRD, DSC, EMI shielding, water absorption, linear attenuation.*

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I. Introduction:

The intensity of X-rays was reduced when it travels through some media, this process called attenuation. The radiation attenuation or weakening happens as a result of the processes of absorption and dispersion of the material to radiation, which expresses the interaction between the X-ray photon and the molecules of matter.[3-4] In general, the attenuation is related to the incident X-ray beam and the properties of the material through which the radiation traverses. the factors include the incident beam energy, the thickness, atomic number, and density of the material. Thus, the phrase total radiation attenuation.[5-7] We chose HDPE based on the matrix to minimize the heaviness and increase the flexibility and because of the singular properties like the lightweight, resistance to chemical compounds, easy processing, oxidation availability, wide applications field, and far insoluble in popular solvents.[8]

There are many ways to control external radiation exposure and reduce it to a minimum, particularly the method of casings or protective shields because they lead to safe practical levels, and although different materials are used to shield against harmful rays, lead comes to the forefront with its high holding power that helps to reduce the thickness of the shield. Excessive X-ray exposure might be detrimental to both radiation users and the general population, and it is necessary to be defend against the energy released by X-rays, thick, dense shielding, such as lead, is required.[9-12] In addition to X-ray protective fillers, the choice of the main matrix is critical in determining the usability of the developed materials in actual attenuation, because other important properties of the composites, such as mechanical strength, water absorption, and flexibility, are heavily dependent on the properties of the main matrix.[13-14] Polymers seem promising because of their mechanical, electrical, thermal, and multifunctional capabilities. Furthermore, composites comprised of polymers and high atomic number fillers should enable the production of materials with low weight, excellent flexibility, and processability.[15-18]

In the field of get the advantages of using an agriculture waste as a substituent of a standard materials industry, we have studied the mechanical properties of HDPE/RH composites as an insulator board in a previous study, with an additional concentration of RH (0%, 5%, 10%, 15%, 20%, and 25%) wt., we find that 10% and 15% was the best ratios, the addition of RH with 10% was recorded for the mechanical parameters. We find 25% is the best addition which gave proportional limits 155 N. [19]

In this paper, we used a high-density polyethylene modified with the Iraqi rice husks as a filler to manufacture a new panel that can attenuate the x-ray, and how the rice husks ratio affects that attenuation leverage was investigated.

II. Experimental:

The high-density polyethylene (HDPE) provided by the State Company of Petrochemical Industry (Basrah/ Iraq) with the qualities (Trade Name Scpilex (M624), Density 0.961 g/cm^3, and Melt Index 5-7 g/10 min). Rice husks are brought from rice plantations in Najaf, Iraq. Firstly, the rice husk has received a washing process with ionized water and dried at room temperature. Then the RH was ground into small particles, which shows the rice husk before and after grinding. The 75 micrometer sieve was used to get a particle size equal to or less than 75 micrometers, as seen in figure (1). Then HDPE was thermal mixed at different concentrations (5%, 10%, 15%, 20%, and 25%) with rice husk powder.

Under the following circumstances, RH is blended with HDPE utilizing Rheomix mixer 600 instruments coupled to a Haake Rehochard meter: the mixing period is 15 minutes, the temperature is 160ºC, and the mixing velocity is 32 rotations per minute. The finished mold product is then placed in a laboratory compress under 5 tons at 175°C for 3 minutes in a square frame, where the pressure gradually climbs to 15 tons for 6 minutes before the sample sheet is cooled to room temperature.

The differential scanning calorimeter (DSC-60, Shimadzu Corporation, and Kyoto-Japan) was used to investigate the thermodynamic characteristics. We picked weight percentages of 10% and 25% Of RH, so the pure HDPE, to clearly illustrate the impacts of RH powder combinations on the thermal characteristics of HDPE composite samples.

The thermal conductivity was test for the manufacturing samples in (76 mm) diameter, and 4mm thickness. Holmarc's Lee's Disc apparatus, model (HO-AE-LD18), provide by Holmarc Opto-Mechatronics Ltd. manufactures, Kochi-India, was used to get a thermal conductivity coefficient (K) of the prepared samples by using Fourier's law from the relation: [20]

$$K = \frac{qx}{AT} \quad \dots\dots\dots\dots(1)$$

Where K in (W/m.ºC) is the thermal conductivity, x in (m) is the sample thickness, q in (W) is the heat energy, A in (m^2) is the area of sample, and T in (ºC or ºK) temperature difference on the both side of sample.

The attenuation samples are created using this final product sheet. The prepared samples were cut into little squares with 1 cm sides and various thicknesses. All measurements of the X-ray attenuation coefficient factor as a function of the RH ratio were performed in the laboratory of contemporary physics at the University of Basrah, College of Education of Pure Science. It is worth noting that the anode voltage is 39 KV for pure HDPE and all concentrations of RH addition in 2mm thickness of samples.

Figure (1): the used Rice husks before and after grinding.

III. Results and Discussion:

X-ray diffraction (XRD) examination of RH powder was performed at room temperature using (XRD-X'pert Phillips Holland, Kashan University-Iran) was used to define the components of RH, and peaks were identified and matched using (X'Pert HighScore Plus) software. The XRD pattern of RH powder is shown in figure (2), and the list of XRD major peaks is presented in table (1). Table (2) shows the results of the search and match function utilizing (X'Pert HighScore Plus) software, which includes the major predicted constituents that comprise the RH with weight %, as well as cellulosic matter. [21-22]

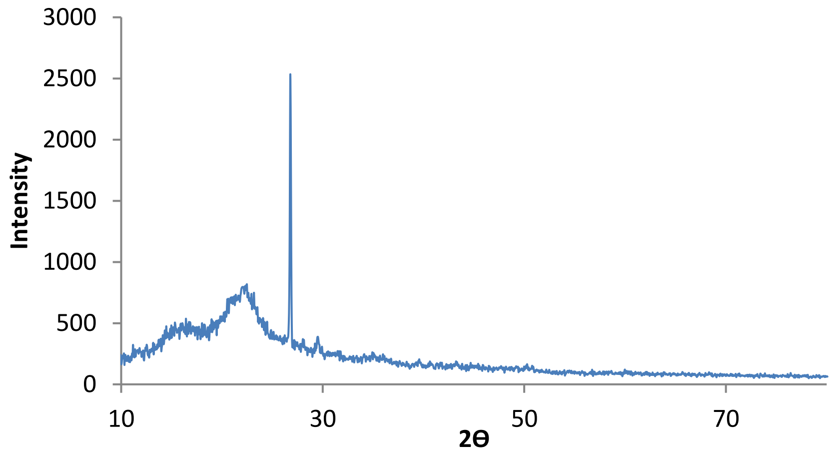

Figure (2): The XRD pattern of rice husk.

Table (1): The main peak list of XRD for RH.

Pos.[°2Th.]	FWHM[°2Th.]	spacing[Å]	Rel.Int.[%]	Tip width[°2Th.]	d-Matched by
22.2652	0.7872	3.99283	16.10	0.9446	
26.7940	0.1476	3.32735	100.00	0.1771	00-033-1161
29.5212	0.1968	3.02588	6.59	0.2362	00-005-0586

Table (2): Major elements consisting of rice husk obtained from X'Pert for RH.

Ref. Code	Score	Compound Name	Chem. Formula	Scale Fac.
00-033-1	34	silica	SiO_2	0.107
00-005-0	30	Calcite, syn	$CaCO_3$	0.031
01-077-2	4	Sodium Erbium Fluoride	$NaErF_4$	0.005
00-035-0	8	Fluorite, syn	CaF_2	0.004
00-027-1	7	Silicon, syn	Si	0.011
00-006-0	6	Praseodymium Oxide	$PrO_{1.83}$	0.009
00-046-1	25	Quartz, syn	SiO_2	0.050
01-073-1	11	Bornite	$Cu_5Fe\ S_4$	0.014

The findings of the DSC analysis of pure and composite samples of HDPE with RH are displayed in figure (3) and table (3). The DSC curves show substantial changes in figure (3) and table (3) of RH addition samples compared to pure HDPE.

As shown in figure (3) and table (3), we find two main peaks, which are described as exothermic crystallization and endothermic melting of HDPE, respectively. The addition of RH to HDPE reduces the amount of heat required to raise the temperature compared to pure HDPE sample, which may be due to the lower specific heat of RH compounds (silicates compounds in almost) relative to pure HDPE, so the various crystallinity indexes effect of HDPE.

As a result, the inclusion of RH influences the crystallinity indexes of HDPE, where the melting temperature of HDPE was directly raised with the addition of RH amount for composites for pure HDPE, 10% RH, and 25% RH accordingly, as the melting temperature was related to additional material and smaller crystals. The melting temperature of HDPE is almost between (120 -130)˚C. [23-26]

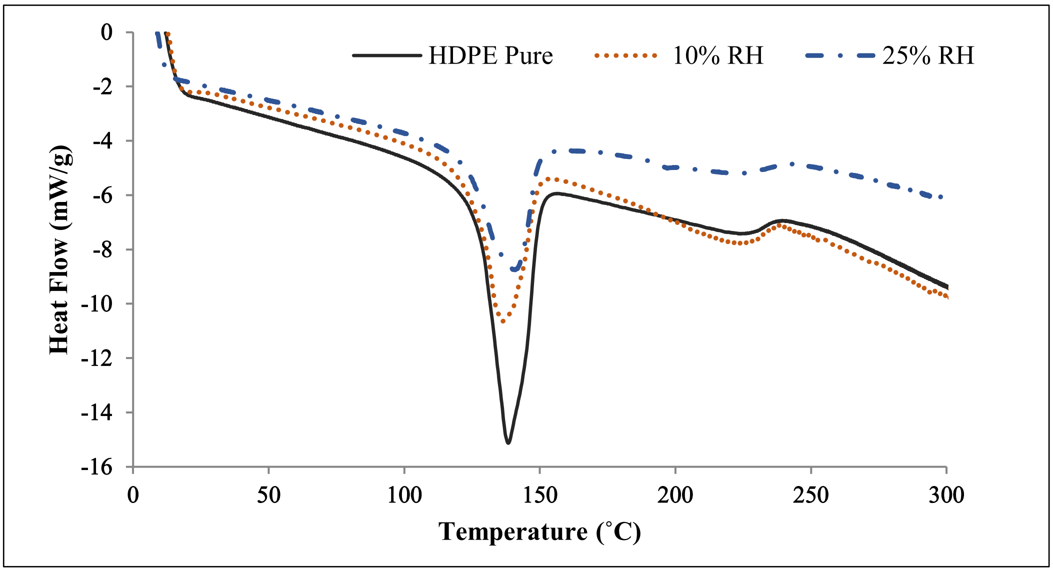

Table (3): The results obtained from DSC analysis of neat and composites of HDPE.

The data of the crystallinity region			
	HDPE Pure	**10% RH**	**25% RH**
Peak (˚C)	137.03	137.64	140.92
Onset (˚C)	127.57	128.08	124.53
Endset (˚C)	148.92	149.49	149.09
Heat (J/g)	-85.97	-55.59	-60.66
The data of the molting region			
	HDPE Pure	**10% RH**	**25% RH**
Peak (˚C)	227.36	239.24	259.44
Onset (˚C)	221.93	228.44	256.21
Endset (˚C)	218.49	239.19	236.72

Thermal conductivity

Figure (4) shows the variation of thermal conductivity coefficient of HDPE with the addition ratios of RH. The reciprocal relationship of amount of RH and the thermal conductivity coefficient of the HDPE, these results denominate on the homogeneous distribution of RH in the HDPE. The decreasing of thermal conductivity of HDPE with increasing of RH% addition ratio due to the main effect of the dominant cellulosic nature of RH on other components, which leads to decrease in thermal conductivity of pure DHPE for 5% of addition ratio up to 25%.

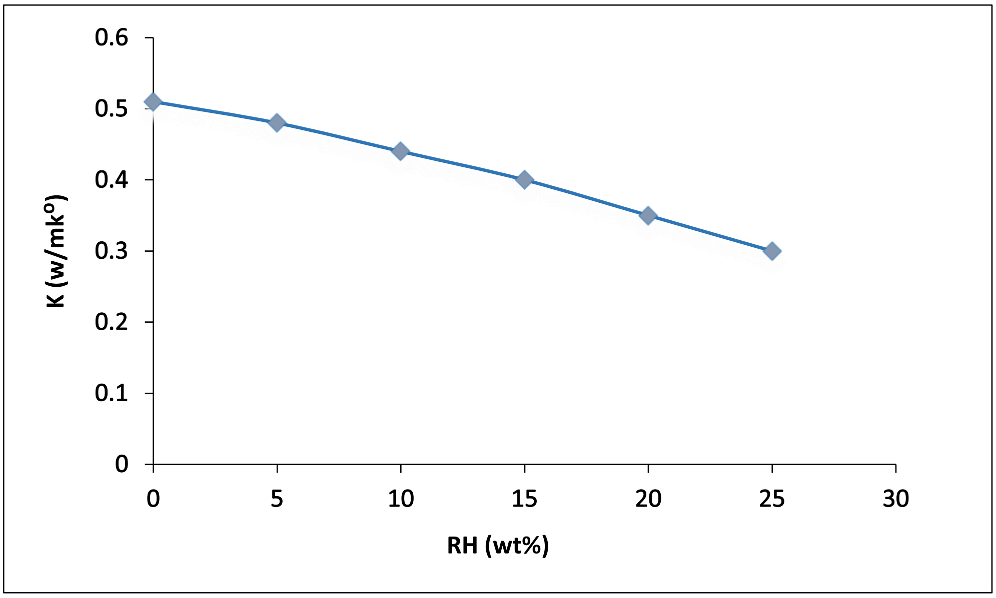

Figure (4):Thermal conductivity (K(w/mk°)) of HDPE:RH%.

The flammability test of pure HDPE and HDPE/RH composites was done according to ASTM D635-81. [28-29] The burning time rate was shown in figure (5), which illustrates the variation in the burning time of HDPE as a function of the weight percentage of RH addition. A general trend is observed regarding the induction time: the HDPE is affected by adding RH to their matrix and how the addition affects to reducing the flammability in HDPE/RH matrix by increasing of recured time to burn 7.5 cm of samples.

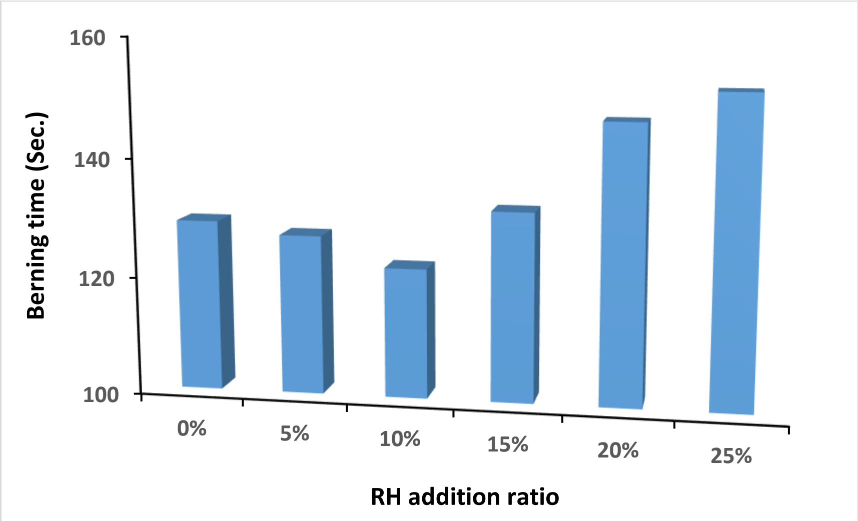

Figure (5): the variation of burning time of HDPE/RH composites.

Water absorption was estimated was tested for 24 hours and 48 hours of samples immersion in water in lab temperature. The relative uptake of weight by the relation; $\{M_t=[(W_t - W_o)/W_o] \text{ x } 100\}$. [30]
where M_t the relative uptake of weight, W_0 is the weight of dry specimen and W_t is the weight of wet specimen at each aging time.
Figure (6) shown the results for the water relative uptake of HDPE/RH composites weight, which is illustrated the general effect of increasing RH ratio to a few increasing in water absorption, which related to the cellulosic content of RH, where in the 25% the relative uptake of weight rises to 1.955 and 3.843 percentage for 24 h and 48 h, respectively.

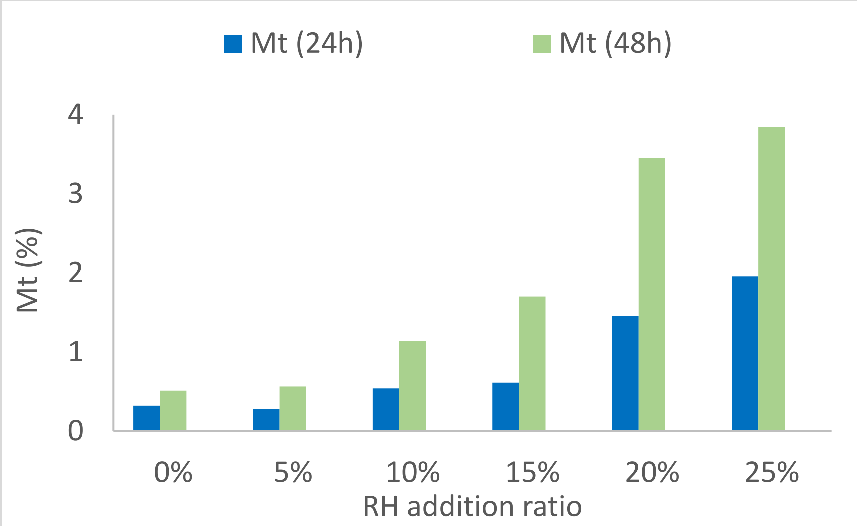

Figure (6): the water relative uptake of HDPE/RH composites weight.

The first item of the test and a highly valuable indicator of how extra affects attenuation is a linear attenuation coefficient which is a constant that defines the proportion of attenuated incident photons in a monenergistic beam per unit thickness of a material where the linear attenuation coefficient (μ) is depending on the energy of the falling photon, the attenuated medium's atomic number (z), and the mean density (ρ). [31-33]

The attenuation coefficient and modified polyethylene have a linear relationship. This direct relationship indicates that the added RH tend to increase the density of the polyethylene matrix by filling the voids between the polyethylene matrix's long chains. As a result of filling that matrix, more blocks and absorbers are formed in the face of incident X-rays, resulting in more reflection for that ray and an increase in the linear attenuation coefficient. Figure (7): shows those changes made to the linear attenuation coefficient due to the increased addition of RH to the polyethylene matrix,

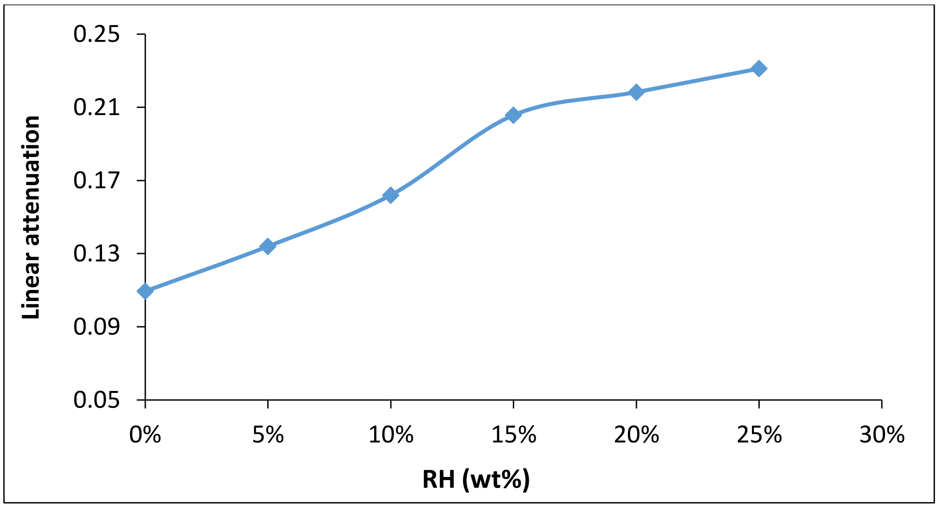

Figure (7): The relationship between linear attenuation coefficient and added RH ratio.

IV. Conclusions:

The incorporation of Al-Najaf/Iraq rice husk into high-density polyethylene reduces the heat amount required to raise the temperature compared to pure HDPE sample as a results of DSC, which may be due to the lower specific heat of rice husk compounds (silicates compounds in almost) relative to pure HDPE, where the melting temperature of HDPE was directly raised with the addition of RH, as the melting temperature was related to additional material and smaller crystals, which is for HDPE (120-130)˚C.

The thermal conductivity and burning rate decrease and the water absorption a few increase with the increasing of the addition concentration of RH to HDPE. HDPE films with a thickness of 2mm were been studied as an attenuation material for x-ray, the obtained results of the linear attenuation coefficients showed an improving in an attenuation coefficient, the increased concentration of rice husks causes an increase in polyethylene density, which increases the number of blocks that fight the incident ray's passage.

The best-added concentration of rice husk is 25%. All obtained results candidate this boards to be a good alternative to those in thermal and moisture insolation and x-ray attenuation application.

References

[1]. R. S. Chen, S. Ahmad, and S. Gan, Rice Husk Bio-Filler Reinforced Polymer Blends of Recycled HDPE/PET: Three-Dimensional Stability Under Water Immersion and Mechanical Performance, Polymer Composites 39(8), (2016).

[2]. V.P. Della, I. Kuhn, and D. Hotza, Rice husk ash as an alternate source for active silica production, Materials Letters. 57, (2002).

[3]. S.D. Huse, S. S. Obaid, A. A. Joshi, D. K. Gaikwad, P.P. Pawar and A.R. Shitre, Gamma Ray Attenuation Properties Biomedical Important Organic Compounds. Journal of Physics: Conference Series 1644, 012062, (2020).

[4]. Cristian morari, jana pintea, jenica neamţu and ionuţ balan, electromagnetic shields attenuation, Rev. Roum. Sci. Techn.-electrotechn. ET energy, 53, suppl., 123–128, (2008).

[5]. Rameshwar R. Bhosale, chaitali V. More, dhammajyot K. Gaikwad, pravina P. Pawar and madhav N. Rode, Radiation shielding and gamma ray attenuation properties of some polymers. Nuclear tech neology & radiation protection, vol. 32, no. 3, 288-293, (2017).

[6]. Rabie A. Abu Saleem, Nisrin Abdelal, Ahmad Alsabbagh, Maram Al-Jarrah, and Fatima Al-Jawarneh, Radiation Shielding of Fiber Reinforced Polymer Composites Incorporating Lead Nanoparticles-An Empirical Approach, Polymers, 13, 3699, (2021).

[7]. Muhammad Arif Sazali1, Nahrul Khair Alang Md Rashid1 and Khaidzir Hamzah, A review on multilayer radiation shielding. IOP Conf. Ser., Mater. Sci. Eng. 555 012008.

[8]. A. Obeid, H. EL Balaa, O. EL Samad, R. Awad, and M. S. Badawi, Attenuation parameters of HDPE filled with different nano-size and bulk WO3 for X-ray shielding applications, Eur. Phys. J. Plus 137:1229, (2022).

[9]. Mansour Almurayshid, Yousif Alssalim, Farouk Aksouh, Rashed Almsalam, Meshari ALQahtani, M. I. Sayyed and Fahad Almasoud, Development of New Lead-Free Composite Materials as Potential Radiation Shields. Materials, 14, 4957, (2021).

[10]. Mon Bryan Z. Gili and Frederick C. Hila, Characterization and Radiation Shielding Properties of Philippine Natural Bentonite and Zeolite, Philippine Journal of Science, Vol. 150 No. 6A, (2021).

[11]. Salah Ud-Din Khana, Shahab Ud-Din Khanc, Zeyad Almutairia, Sajjad Haiderf and Syed Mansoor Alig, Development of Theoretical-Computational Model For Radiation Shielding, Journal of Radiation Research and Applied Sciences, Vol. 13, No. 1, 606–615, (2020).

[12]. N.K. Libeesh, K.A. Naseer, S. Arivazhagan, A.F. Abd El-Rehim, K.A. Mahmoud, M. I. Sayyed and M. U. Khandakeri, Advanced nuclear radiation shielding studies of some mafic and ultramafic complexes with lithological mapping. Radiation Physics and Chemistry 189, 109777, (2021).

[13]. Frank Verhaegen, Francesca M Buffa and Charles Deehan, Quantifying effects of lead shielding in electron beams: a Monte Carlo study. Phys. Med. Biol., 46, 757–769, (2001).

[14]. S M Tajudin, A. H Aminordin Sabri, M Z Abdul Aziz, F Tabbakh. Gadolinium-doped polymeric as a shielding material for X-ray. IOP Conf. Series: Materials Science and Engineering 1106, 012010, (2021).

[15]. Zefeng Li, Wei Zhou, Xianlong Zhang, Yue Gao and Shaoyun Guo, High-efciency fexibility and lead-free X-ray shielding multilayered polymer composites: layered structure design and shielding mechanism, Scientifc Reports, 11:4384, (2021).

[16]. Crissia Carem Paiva Fontainhaa, Annibal Theotonio Baptista Netob, Adelina Pinheiro Santosb and Luiz Oliveira de Fariab, P(VDF-TrFE)/ZrO2 Polymer-Composites for X-ray Shielding, Materials Research, 19(2), (2016), 426-433.

[17]. Shruti Nambiar, Ernest K. Osei and John T.W. Yeow, Polymer nanocomposite-based shielding against diagnostic X-rays, Journal of Applied Polymer science, V.127, Issue6, 4939-4946, (2013).

[18]. P. McCaffrey, H. Shen, B. Downton and E. Mainegra-Hing, Radiation attenuation by lead and nonlead materials used in radiation shielding garments, Med. Phys, 34, 2, (2007).

[19]. Parinaz Mehnati, Reza Malekzadeh and Mohammad Yousefi Sooteh, Application of personal non-lead nano-composite shields for radiation protection in diagnostic radiology: a systematic review and meta-analysis. Nanomed. J., 7(3), 170-182, (2020).

[20]. Muhsen Chelab Muhsen, Ahmed J. Mohammed, Ziyad T. AL-Malki, and Dalal K. Thbayh, Investigation on the influence of waste-based fillers on the mechanical and thermal characteristics of rigid polyurethane foams, eureka: Physics and Engineering, 4, (2024).

[21]. Nadhim A. Abdullah, Ahmed J. Mohammed, Ibrahim K. Ibrahim and Faise J. Mohammed, Effect of the adding of rice husk on the Mechanical Properties for High Density Polyethylene (HDPE), American Journal of Engineering Research (AJER), Volume-5, Issue-11, 221-226, (2016).

[22]. R. L. Hadimani, "Chapter 12: Rare-Earth Magnetocaloric Thin Films", Magnetic Nanostr. Materials: From Lab to Fab, Elsevier, 269-294, (2018).

[23]. J Paulo Davim, The Design and Manufacture of Medical Devices, Woodhead publishing, 29, (2012).

[24]. Q. Zhang, W. Yi, Li, L. Wang and H. Cai, Mechanical Properties of Rice Husk Biochar Reinforced High Density Polyethylene Composites, Polymers, 10, 286, (2018).

[25]. A.H. Awad, A. A. Abd El-Wahab, R. El-Gamsy and M. H. Abdel-latif, A study of some thermal and mechanical properties of HDPE blend with marble and granite dust, ain shamas engin. journal, sci. direct, 353-358, 10, (2019).

[26]. P.Pandey, S.G.Bajwa, D.S. Bajwa and K. Englund, Performance of UV weathered HDPE composites containing hull fiber from DDGS and corn grain, Industrial crops and products, 409-419, 107, (2017).

[27]. Nadhim A. Abdullah, The Effect of Egg Shell on Low-Density Polyethylene (LDPE) Flame Retardant Properties, journal of Al-Qadisiya (pure, science) vol. 17, No.3, 2012.

[28]. S. Mohd Izwan, S.M. Sapuan, M.Y.M. Zuhri and A.R. Mohamed, Thermal Stability and Dynamic Mechanical Analysis of Benzoylation Treated Sugar Palm/Kenaf Fiber Reinforced Polypropylene Hybrid Composites, Polymers, 13, 2961, (2021).

[29]. B. Enciso, J. Abenojar, E. Paz, and M.A. Martínez, Influence of Low-Pressure Plasma Treatment on the Durability of Thermoplastic Composites LDPE-flax/coconut under Thermal and Humidity Conditions, Fibers and Polymers, Vol.19, No.6, 1327-1334, (2018).

[30]. M. Yu, H. Mao, R. Huang, Z. Ge, P. Tian, L. Sun, Q. Wu and Kai Sun, Mechanical and Thermal Properties of R-High Density Polyethylene Composites Reinforced with Wheat Straw Particleboard Dust and Basalt Fiber, Intern. J. of Polymer Science Volume, Article ID 5101937, (2018).

[31]. Pravina P. Pawar and Govind K. Bichile, Measurement of mass and linear attenuation coefficients of gamma-rays of alanine for 0.662, 1.170, 1.280 and 1.330 Mev Photons, Journal of Applicable Chemistry, 1 (1): 53-58, (2012).
[32]. Samir Yousha El-Kameesy, Sahar Abd El-Ghany, Moenis Abd El-Hakam Azooz and Yaser Abd Allah El-Gamnam, Shielding Properties of Lead Zinc Borate Glasses, World J. of Condensed Matter Physics, 3, 198-202, (2013).
[33]. H.A. Elgabry, A. A. El-Gamal, G. M. Nasr, T. M. El-Basheer and A. Abdel-Hakim, Sustainable Acoustic Bio-Nanocomposites from Recycled HDPE and Modified Rice Straw Nanofillers: Performance and Biodegradability, Sustainability, 18, 7005, (2026).