The Role of Water Absorption on Thermal Conductivity and Mechanical Properties for (Recycling HDPE-Coal Ash) Composite

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Abstract

Recycling high density polyethylene (rHDPE) has great attention because of their enticing elastic properties at ambient temperature, ability of flow at elevated temperatures, and ability to be remelted for recycling use. Thus, at the present work, compound substances consisting of recycling HDPE (rHDPE) and coal ash was prepared at a different concentration (0%, 5%, 10%, 15%) of coal ash for enhancing the thermostable, rigidity, firmness, water absorption, tensile and heat conductivity qualities. SEM images and EDX analysis of rHDPE/coal ash have been studied. The water absorption (weight gain) and diffusion coefficient increase for rHDPE and rHDPE/coal ash composite with the increase time immersion in water and coal ash content, the young modulus increases with increase time immersion, and then decreased, also elasticity coefficient decreases with increase the fraction content, this lead to increase the flexibility coefficient values. A decrease in hardness values was observed after immersion, the hardness increased with an increase in coal ash content. The water entering the rHDPE/coal ash caused a change in dimensions, thus generating internal stresses and resulting in a decrease in most mechanical properties. As well as, values of thermal conductivity rises by immersion time and coal ash content. Overall, the prepared composites after increasing immersion time and fraction content indicated better properties than the composites before increasing immersion time and fraction content.

Key Words: Plastic Waste, rHDPE-Coal Ash Composites, Water Absorption, Weight Gain, Mechanical Properties and Thermal Conductivity.

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Introduction

Plastic Waste (PW) area unit one in all the foremost elements of worldwide municipal Solid Waste (SW) and gift a promising material supply for composite production. The event of the latest added merchandise with the aim of utilizing agro and allied wastes and low value recycled thermoplastics are assumptive bigger importance. Polymers differ from metallic and ceramic materials by their ability to absorb water and solutions. High density poly ethylene (HDPE) is a thermoplastic polymer; means that it can be melted to a liquid and remolded it to a solid state. It is tough, relatively inexpensive and has excellent process ability. This polyethylene is very crystalline, small effect size, and have linearity, thus it gave good mechanical (characteristic) than other forms of polyethylene. Therefore, rHDPE is a best option to be utilized in composite matrix [1,2]. It is used in numerous applications ranging from plastic grocery bags to heavy duty plastics containers. Moreover, (HDPE) also widely been used in the construction industry for producing pipes and as insulator in electrical appliances. As s result of benefits of (rHDPE).

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Plastics, their use has raised significantly, in the applications and quantitative working. In addition, duo to that (rHDPE) plastic is consists of organic compounds, the basic problems are the decomposition operation take long. Since there is no way to avert plastic consuming, whom parallel with the evolution of modern technique, Reasonable solutions should be sought for problems caused by overuse of plastic materials, especially (rHDPE) plastics. This means, recycling process and the procedure of analyzing these recycled materials must be discovered [1].

It is an important parameters, so much water polymer composite (WPC) are useful in an outdoor environment where the probability of moisture levels being too high. Water absorption is fixed by lignocelluloses fibre concentration and the adherence between phased manner of the component, adding more content of coal ash in the recycling materials can enhance mechanical characteristic of the (rHDPE), but it then could rise the value of degradation and weight gain of (rHDPE) particles, particularly, if do not exist a great adherence evolution between the matrixes and fibre. In addition, absorption the water by polymer composites was difficult and rely on several variant comprising; existence of compatibiliser, total temp., matrix form, The weight portion of the fiber and interconnection level [3].

In this work coal ash was used as discontinuous reinforcements because it is one of the cheapest and least dense reinforcements available in large quantities as a by-product of solid waste while burning coal in thermal power. Many studies have been used coal as has auxiliary material and filler minerals and polymer.

[4]. The permeability of liquids is carried out by a mechanism which is known as a diffusion mechanics(DM), which includes the direct diffusion of water molecules in the base material and then into reinforcement material. Another mechanism for water permeability and chemical solutions is capillary property and micro-microscopic transmission. These mechanics are induced and become active only after a crash in the superposed material. In general, the polymer-based overlapping material after absorbing liquids and for long periods of time the material suffers from the phenomenon of bloating, this phenomenon creates stresses within the material called bulging stresses, which cause the destruction of the inner layers of the polymer [5,6]. The goal of this work is to manufacture composite materials from (rHDPE) and coal ash to reduce ecological difficult resulted from polymeric waste and enable Preserving the environment due to which major part of polymers are composed of a gas, and oil and the effects of water absorption for (rHDPE/Coalash) composites on the thermal conductivity and mechanical characterization have been estimated.

Experimental

The plastics were used after consumption of HDPE bottle caps as a matrix stage of the compound. It was washed and ground with dimensions of (1mm). Coal ash grain was baked for a day in oven at 100°C. To preparing a blend of (coal ash/rHDPE) composite, rHDPE polymer was heated in oven temperature at (250°C), after that, coal ash was mixed with rHDPE at a different content (0, 5%, 10%, 15%), when the mixture reaches melting point temp. The composition is completely stirred, time of heating is (15minute) and processing time is (30minute). Also, with laboratory hydraulic press (15Mpa) the samples were pressed in a metal mold with dimensions (100 x100 x2)mm.

Results and Discussions

Water Absorption (Weight Gain)

Diffusion was represent the transfer of matter from one place to another in the system due to random motion of molecular and its happened in all fluid due to the Continuous movement of atoms. The (rHDPE) composites samples were baked in furnace at 50°C, after that, it was cooled to RT. The weight gain measurement was done by immerse the samples for a day in a beaker with distilled water at RT at various duration time. Then the samples were clean by tissue paper and weighed at 24, 48, 72, 96, 168, 336, 504 and 672 hexposure. The water absorption was estimated from the difference of weight. The weight change percentage of the diffusivity samples after each period of immersion is calculated from the equation as follows? [7]:

$$\text{Weight Gain (W.G) \%} = ((W_a-W_b) /W_b)/ \times 100 \quad (1)$$

Where, W_a and W_b indicates the weight after and before immersion. The diffusion coefficient (D.C) represent the slope of the normalized weight gain as a function of immersion time with the formula [8]:

$$\text{Diffusion Coefficient}(\boldsymbol{D.C}) = \pi\left(\frac{kb}{4M_\infty}\right)^2 \quad (2)$$

Where thickness (b), saturation moisture mass

(M∞), the slope between weight gain and immersion time (K). Figure (1) show the behavior of samples rHDPE/coal ash after immersion in water at room temperature by using equation (1). The weight gain increase for (rHDPE) and (rHDPE/coal ash) with the increase time of water immersion, because water molecular absorption by the samples attractive the polarity groups of water molecules which lead to increase the absorption with increase of polarity groups numbers, whereas after the increase time immersion the increasing gradually started to reach its maximum value, the water absorption increasing as the number of reaching its maximum value of (0.035%). Due to the procedure connects water molecules to the material and fills in the blanks. Percentage of weight gain of composite material increased with an increase immersion time [9-12]. For all composite samples, the initial rate of water absorption, and the maximum water absorption increase with increasing fraction ratio. This can be clarified by taking into account in water absorption properties of particles swells. Matrix material absorbed the water molecules for the reason to attractive the polar groups of water molecules, and the weight gain will rise up with the amount of polar groups, and when immersed composite materials in water for long time, the capillary action conducts the water molecules to the material and fills in the cracks and voids at the interface result in interfacial bonding. The increase value of diffusion coefficient (D.C) as shown in Fig. (2) and table (I) of composites immersed in water because of the penetration of water through composites works to break down of linkages between the fillers and the polymer, these regions are centers permeate water within composites Also contributes to increase water penetration of the façade through voids caused by swelling of the particles which creates swelling pressures that lead to compound failure[10].

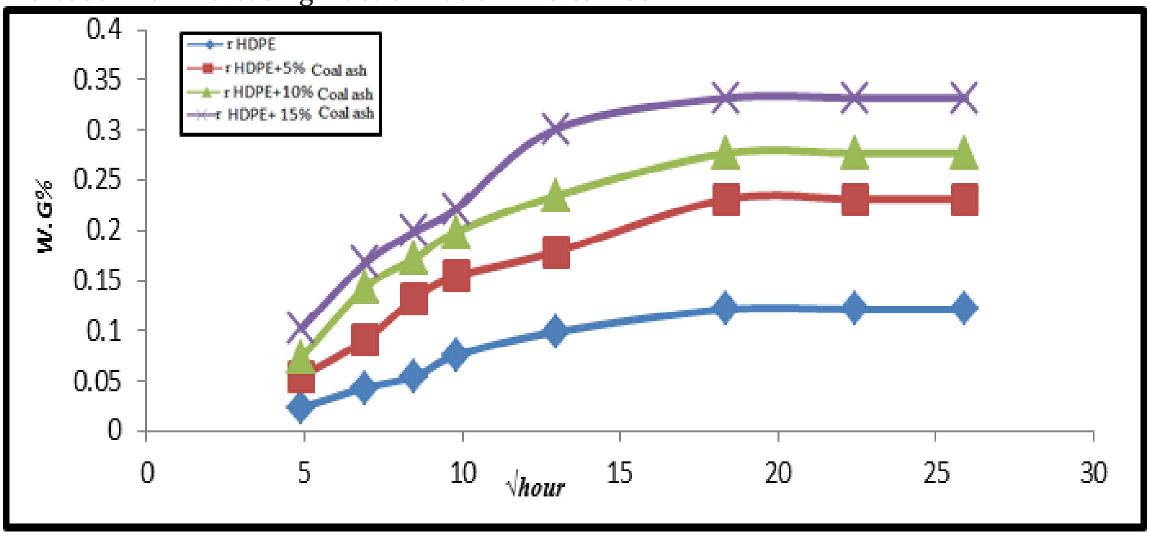

Fig. 1. The water absorption withimmersiontime of waterin(rHDPE/ coal ash)

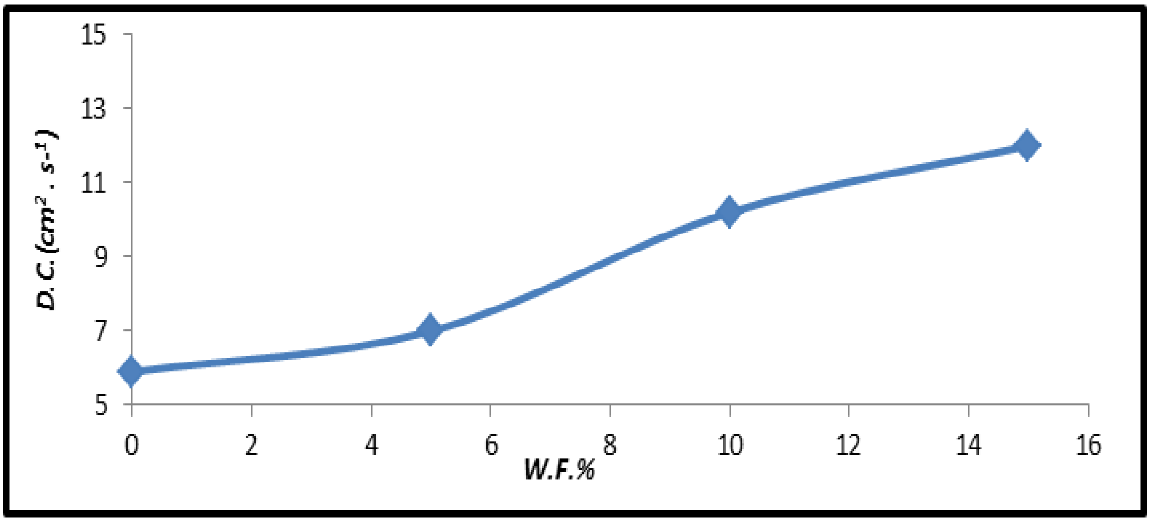

Fig. 2. The diffusion coefficient as a function of fraction content for (rHDPE/ coal ash)composites

Table 1. The results of Diffusion Coefficient (D.C) for all samples after immersion in water

sample	(D.C) $cm^2.s^{-1}$
HDPE	5.9×10^{-8}
HDPE+5% COAL ASH	7×10^{-8}
HDPE+10% COAL ASH	10.2×10^{-8}
HDPE+15% COAL ASH	12×10^{-8}

Compression Test

This test is one of the most important and complex tests because it involves exposure to two types of forces, the first compression force and the second tensile strength. The hydraulic press is supplied by the company (LEYBOLD HARRIS NO. 36110). Compression resistance is defined as the maximum stress tolerated by rigid material under vertical pressure. This resistance is measured empirically by the force projected vertically in the unit area to primary of specimen crosssection exposed to exhibitfor pregnancy and measured in unit (N/mm^2). The main purpose of the bending test is to identify the linear behavior, or what is often called (Hooken Behavior), the material under the influence of the load projected perpendicular to its surface level. The compression test of (rHDPE and rHDPE/coal ash) composites before, and after water immersion is presented in Figs. (3,4,5,6). It is observed that the stress increase with the increasing strain, and an increase in the fraction content (F.C) of coal ash produces a corresponding decrease in the young modulus . For any composite, the maximum stress depends on manyparameters, the most important is the characteristic of matrix, fraction content and reinforcement. Fig. (7) clarifies the relation between young modulus and the time immersion. It is observed the elasticity coefficient decreases with increase the fraction content, due to some shrinkage and insufficient saturation between the base material and the reinforcing material of the superposed material. Small cracks can arise on the surface and the gaps appear in the base material [11,12]. When this superposition is exposed to the water ocean, the water molecules will spread inthe base material, especially in the gaps formed during the molding stage, thus results in absorption, chemical reaction, and plasticity, but as the immersion time progresses it will gradually increase in immersion in water and then decreased, and this shows the saturation state which makes the model more effective when exposed to the forces of bending which leads to an increase flexibility coefficient values.

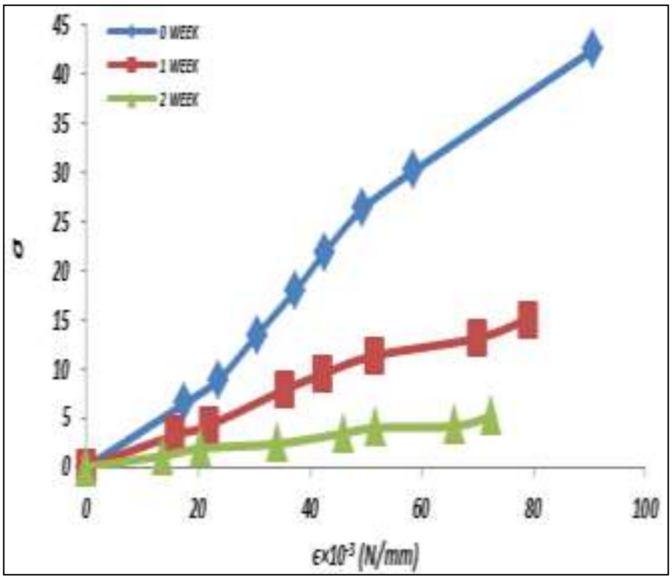

Fig. 3. The stress as a function of strain for (rHDPE)composites

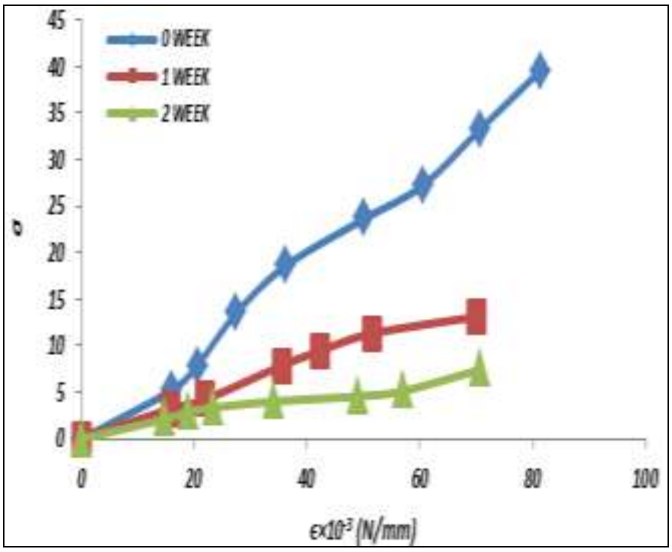

Fig. 4. The stress as a function of strain for (rHDPE/5% coal ash) composites.

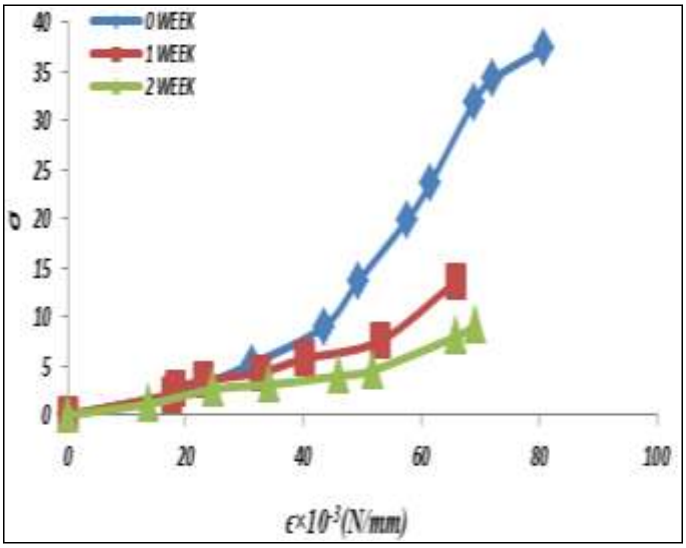

Fig. 5. The stress as a function of strain for (rHDPE/10%coal ash) composites

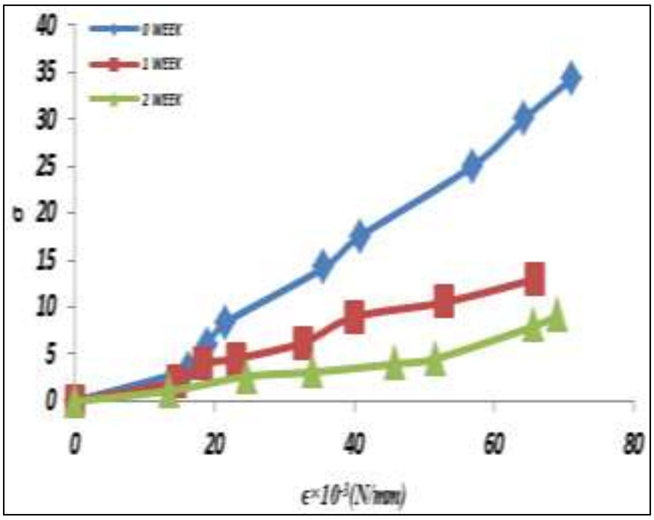

Fig. 6. The stress as a function of strain for (rHDPE/15%coal ash) composites.

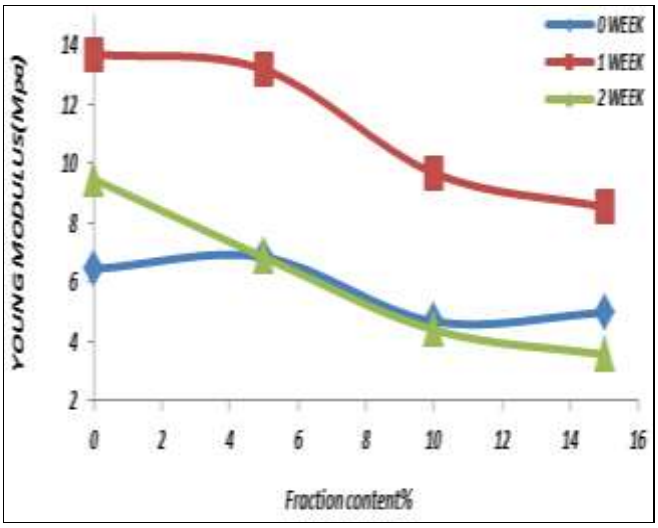

Fig. 7. The young modulus as a function of fraction content for rHDPE and rHDPE/coal ash composites

Brinell's Hardness test (B.H)

By applying a certain force on a solid material, the permanent shape will be changed for various kind, thehardness represents the measure of resistant.A hydraulic piston from Germany WOLPERT Company(D6700) has been used. Fixed load was shed by a stitching device represented by a steel ball of solid diameter (5 mm) and after the ball penetrated into the surface of the model for (15 seconds) using a standard fixed load. After removal of the projected load the diameter of the impact generated on the surface is measured and the hardness can be estimated from:

$$B.H=\frac{F}{\left(\frac{1}{2}\right)\pi D\left[\sqrt{D^2}-d^2\right.} \qquad (3)$$

Brinell hardness (Kg force),F: The applied load (KN),D and d is diameter of indenter and indentionin mm and.Hardness testing is the most commonly used mechanical test where we can guess the rest of the mechanical properties from hardness information such as tensile strength.

Fig.(9) shows the hardness results of the samples and the change in the fraction content ratio. An important observation was the hardness increased with an increase in coal ash content. The increase in hardness values due to an increase accumulating and interlacement, This reduces the amount of motion of the polymer particles, and then increases the material's resistance to scratching and cutting to become more and more resistant to crystalline deformation because of the hardness of the material depends on the forces that connect the molecules in the composite material, which leads to a confined space working to increase the hardness. Macroscopic hardness behavior is described by strong bonds between molecules, it's very complex and depend on plasticity, softness, elastic hardness, strain, durability and viscosity, strength. Hardness values was decreased after soak the samples with water, this led to breakage of bonds due to presence bubbles and the interpolar areas between the polymer and the reinforcing material. The water entering the samples caused a change in dimensions, thus generating internal stresses and this lead to reduce in most mechanical polymer properties. The Water amount absorbed by the superposed material and absorption of water is controlled by several factors including: chemical composition of the resin, the bonding agent, the extent of bonding and the adhesion strength of the support material.

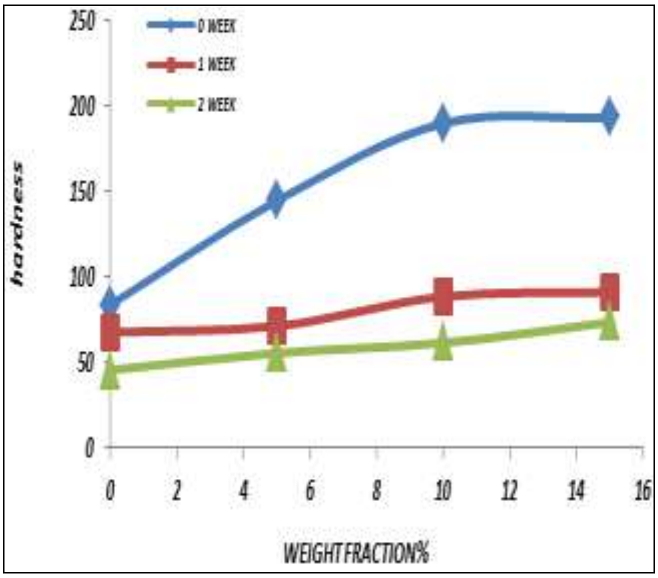

Fig. 9. The hardness as a function of weight fraction for rHDPE and rHDPE/coal ash composites

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Thermal Conductivity (K)

To calculate the coefficient of thermal conductivity of all samples, useDisk s' Lee is manufactured by (George & Griffin) British.

From Fig. (10) the conductivity values change (K) with immersion time for samples at laboratory temperature with different fraction contentand for different period of time.Thermal conductivity for composites (rHDPE, rHDPE/5%coal ash, rHDPE/10%coal ash and rHDPE/15%coal ash) increases when immersion time increases, is due towater entering through the interface areaand cracks within the material and areas of weak interconnection and also it reduces the molecular binding forces of the base material and workson the relaxation of bonds and increasing the viability of molecular chainsmovement which increases the thermal conductivity values after immersion in water due to tolerancefiller and weak bonding forces between the particles of the medium[11]. The proliferation of water through the overlapping materials workson breaking the bonds and appearance some bubbles on aspects. Therefore, it can be said that the change in the impact of water configuration counts on bonding force of matter molecules. Especially the fillers used and the superposed materials submerged inwater lead to micromechanical crashes such as internal crashesand the substance was cracked.It is observed that the values of thermal conductivity increase when increasing immersion time in water t because the water particles enter through the interface area and cracks inside the composite and areas of weak bonding and so onit reduces the molecular binding forces of the base material and works loosening the bonds and increasing the susceptibility of the molecular chains to movement which increases the thermal conductivity. As in the composite(rHDPE/5% coal ash), It is noticed a decrease in the values of K after immersion due to weak binding forces between the intermediate particles [12,13]. As the spread of water through the sample worksto break the bonds and the appearance of some bubbles on the sides if the exposure period is prolonged, this will affect in (rHDPE/5% coal ash) as a whole, which reduces the rate of thermal conductivity. Therefore, it can be said that the change in the influence of matter with water counts on force of bonding among the molecules of matter water leads to a mechanical breakdown like an internal breakdown. The material cracked the foundation [14] .

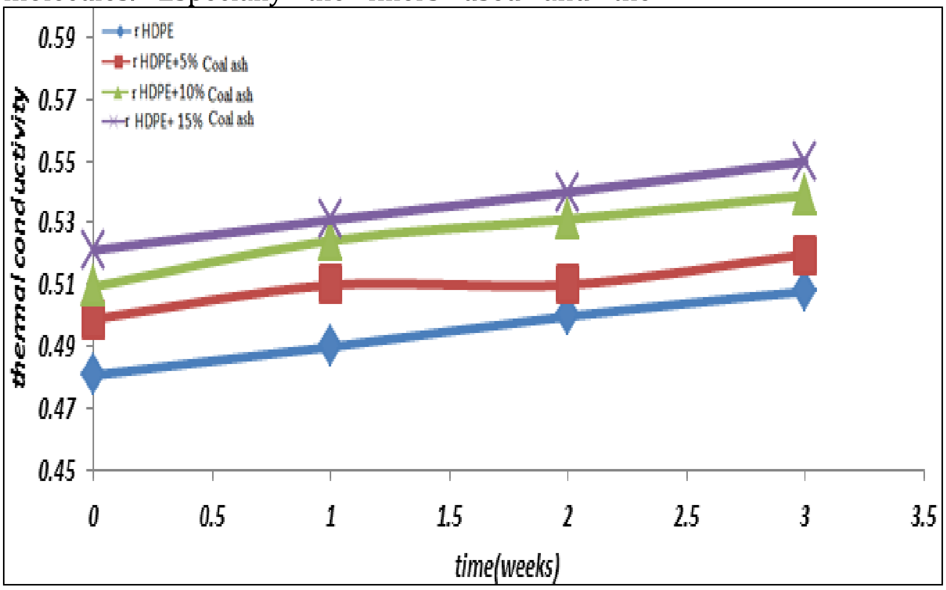

Fig. 10. The thermal conductivity as a function of immersion time in water for recycling composites rHDPE/ and rHDPE/coal ash

SEM Images

SEM images of Coal ash, rHDPE and rHDPE/coal ash at different concentration (5%, 10%, 15%) composites are shown in Fig.(11). The shape of coal ash is usually spherical as in Fig. (11- a) and the distribution of coalash is regular and uniform in rHDPE matrix as in Fig.(11-d). The images showed fibre degradation could be clearly seen for composites. This phenomenon was also observed by[6]. Also, it is observed a clear inclination to take shape a small clusters with rising Coal ash particles was observed Fig.(11-d), This appearance is very important due to that physical properties of mixture are connected to the dispersal of filling material and its adherence to the matrix[2]. The loss of adhesion between Coal ash and rHDPE matrix and fibre degradation could be clearly seen

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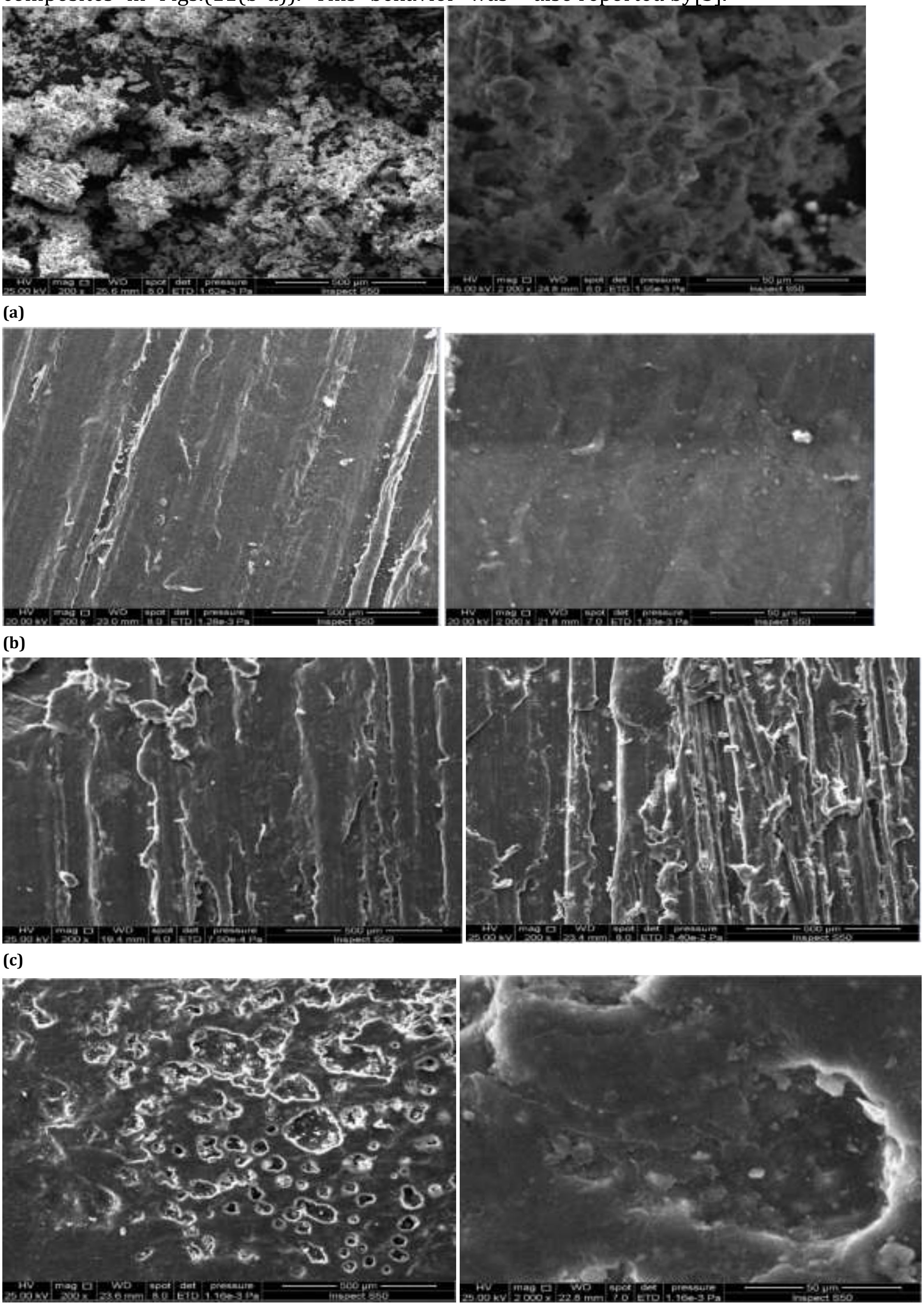
composites in Figs.(11(b-d)). This behavior was also reported by[3].



(d)

Fig. 11. The SEM pictures of the a-Coal ash, b- rHDPE,c-rHDPE/5%coal ash and d-rHDPE/10% coal ash composites

The chemical structures of Coal ash were estimated by EDX analysis by (Bruker Nano GmbH, Germany) Fig.(12). The EDX analysis shows that Ruthenium(24.41%) and calcium(25.01%) are the main ingredients for Coalash which employed in this work. Table (2)clarify the most content of Coalash particles.

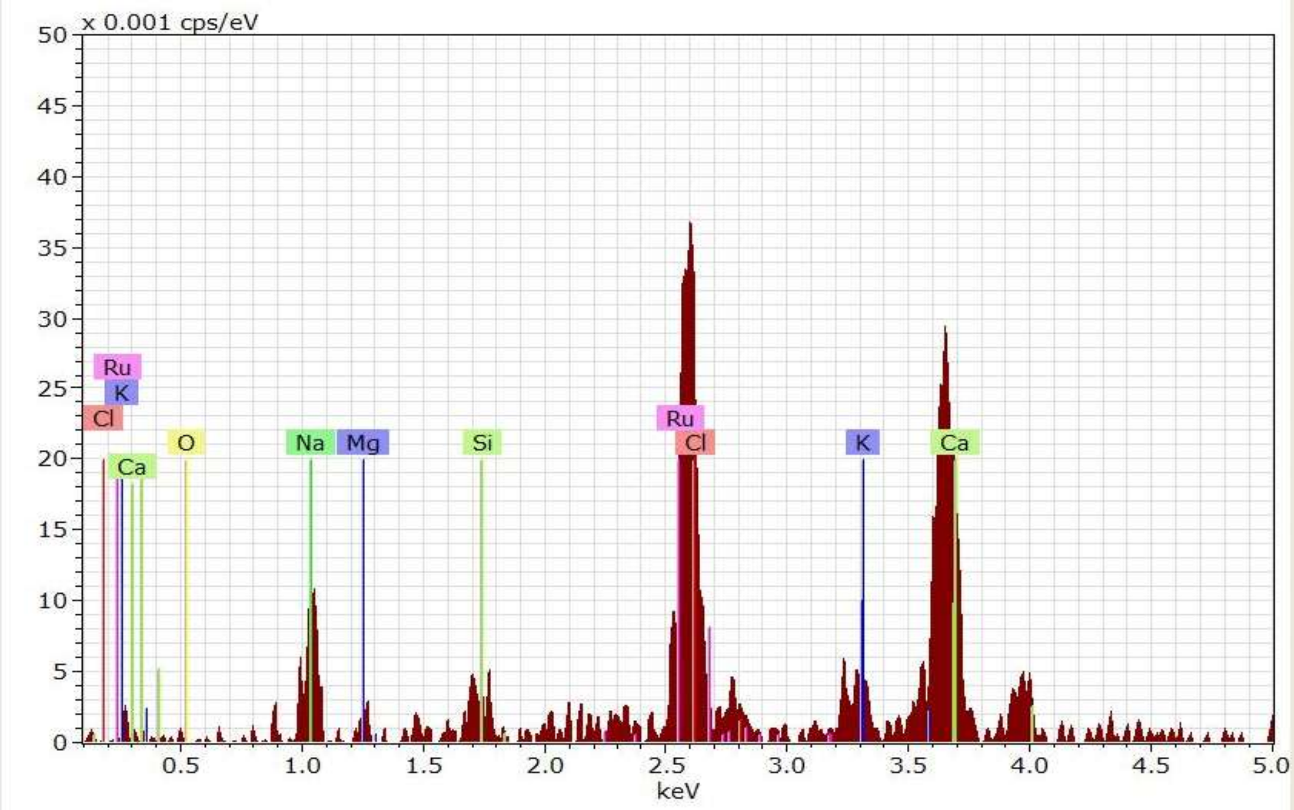


Fig. 12. The EDXspectrum of Coal ash.

Table 2. Different elements of Coal ash by EDX analysis

metal	Portion of metal %	At. %	Compound	Compound %	At. %]
Calcium	25.01	20.20	**CaO**	34.11	34.99
Ruthenium	24.41	7.818		23.79	24.40
Sodium	10.03	14.12	**Na_2O**	13.18	13.51
Chlorine	13.28	12.12		12.94	13.27
Potassium	5.415	4.484	**K_2O**	6.363	6.524
Silicon	2.111	2.433	**SiO_2**	4.402	4.516
Magnesium	1.667	2.221	**MgO**	2.696	2.765
Oxygen	18.08	36.59		4.E-09	4.E-09
	100	100			

Conclusion

The rHDPEand rHDPE/coal ash composites have been prepared successfully. The water absorption and diffusion coefficient increases for the prepared composite with increase of time immersionand coal ash content.It is observed the elasticity coefficient decreases with increase the fraction content, due to some shrinkage and insufficient saturation between the base material and the reinforcing material of the superposed material. The hardness values increases after immersion in water increased with an increase in coal ash content. The water entering the rHDPE/coal ash caused a change indimensions, thus generating internal stresses and resulting in a decrease in most mechanical properties. The conductivity of (rHDPE-coal ash) composite rise up with immersion time and adding of coalash. An improvement in some mechanical properties and thermal conductivity have been observed after adding coal ash and immersing in.

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