



DIFFUSION COEFFICIENT OF EPOXY/ NBR/BENTONITE TRI- COMPOSITE IN THE PRESENCE OF CHEMICAL SOLUTIONS

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ABSTRACT

Polymeric composite materials vary in their ability to allow chemical solutions and solvents to penetrate through them depending on the type and quantity of the reinforcement material and the immersion time in the chemical solution. This research included studying the diffusion property of an epoxy resin that is 80 % mixed with 20% nitrile rubber and reinforced with (1, 1.5, 3, 5%) bentonite by weight. The composite material was immersed in distilled water, diluted hydrochloric acid HCl (1:1), and sodium hydroxide NaOH at 5 M for eight weeks to determine the weight gain ratio and diffusion coefficient. The results showed that the weight gain values increased with an increase in the immersion time, but they decreased with the increase in the amount of bentonite at the same immersion time, so the diffusion coefficient was reduced with an increase of bentonite. SEM images show the surface morphology of the composite material.

KEYWORDS

Bentonite; composite material; diffusion coefficient; epoxy resin; nitrile rubber; weight gain.



1. INTRODUCTION

The sorption behavior and diffusion coefficient of composite materials apply in membrane applications because it is necessary to treat metal-contaminated wastewater before its discharge into the environment (Awham& Raghad, 2013, Mahmood et al.,2019, (Adekunle et al., 2024)). composite materials (Mundher et al., 2023) contain two or more components that differ in physical and chemical properties (Verzhbovskiy, 2016). Epoxy compounds were adsorbed by many solvents like water and different colorants, which led to chemical decomposition and surface erosion (Ji-Deok et al., 2015). Several techniques, scanning electron microscopy (SEM) and differential scanning calorimetry (DSC) are used to study the ternary systems consisting of synthetic rubber or natural rubber in the epoxy system by adding chemically modified natural organic montmorillonite clay (Nor, 2017).In addition, the polymer nanocomposites improve the mechanical properties of the materials (Omid et al., 2018, Asif et al., 2013, Shanaz et al., 2024) such as hardness and compressive strength (Ghaith et al., 2023). The incorporation of clay minerals such as montmorillonite into synthetic rubber with the presence of polymeric compounds contributes significantly to improving the physical, chemical, and thermal properties (Huda et al., 2023, Fayq et al., 2013). Proved that the dielectric, thermal conductivity and diffusivity values for binary blends of unsaturated polyester and nitrile rubber vary according to reinforced different ratios with zinc oxide (ZnO) (Rafah et al., 2024). Studied the diffusion behavior and calculated the diffusion coefficients according to Fick's law for binary polymer blend prepared from unsaturated polyester resin and natural rubber immersed in many variable types of water, different groups containing the same concentration of diluted HCl, H₂SO₄, and NaCl, solvents such as ethanol, kerosene, benzene at the same time. results show benzene had behavior called (non-Fickian diffusion) and the remaining samples had the same diffusion behavior (Awham& Raghad, 2013). Prepared a mixture of polynorbornene rubber and natural rubber with different compositions, the activation energies of diffusion, permeation, enthalpy of adsorption, and adsorption kinetics were measured. the results show changes in the transport behavior of the mixtures (Nand et al., 2022). In this research, a composite material was prepared whose matrix was epoxy resin reinforced with 20% nitrile rubber and different amounts of bentonite. The composite material was immersed in various types of solutions. Determined weight gain and diffusion coefficient for eight weeks, and SEM examination was performed for each case.

2. EXPERIMENTAL PART

2.1. Materials

1- Epoxy resin and hardener were supplied by the Ciba-Geigy company.

- 2- Nitrile rubber (NBR) was supplied by Saudi Industrial Resins Limited Company (SIR)TM.
- 3- Toluene was supplied by Chinese Toluene supplier, traders and manufacturers.
- 4- Bentonite was supplied by the Iraq Geological Survey.
- 5- Hydrochloric acid HCl, sodium hydroxide NaOH supplied from Central Drug House CDH company.
- 6- Distilled water supplied from the Applied Science department.

2.2. Tri-composite preparation

Epoxy resin and hardener were mixed in a ratio of 3: 1. Nitrile rubber (NBR) was dissolved by toluene to become a homogeneous liquid. Nitrile rubber 20% mixed with 80% epoxy resin to obtain a homogeneous mixture. Bentonite (>0.45 μm) was added to the mixture with a content ratio (0, 1, 1.5, 3, 5%) was measured by sensitive balance (Kern) model (ACB 120-4) and continuous stirring using a hot plate stirrer supplied by Daihan Labtech Co. Ltd. for 30 min to obtain an epoxy/ NBR/bentonite composite. Then, it was left to dry at laboratory temperature for 24 hours. Samples were cut in thickness 3 mm, length 10 mm, and width 10mm according to ASTM D2240.

2.3. Samples immersion in chemical solutions

Samples were weighed before immersion and then immersed in diluted HCl, and NaOH at 5 M, distilled water for one week to eight weeks. After a week had passed since immersing the sample, it was taken out of the solution, dried, and weighed, then returned to the solution again to be taken out of the solution and weighed again after a week passed, so the process was repeated for eight weeks, the weight of gain was determined according to [Eq. 1 \(Vinu et al., 2020\)](#):

$$W(t) = \frac{W_x - W_o}{W_o} \times 100\% \quad (1)$$

Where: W_x and W_o are the mass of the sample before and after immersion in chemical solutions $W(t)$ is the percentage of weight gain. The diffusion coefficient was calculated by Fickian law,

$$D = 2\pi \left(\frac{Kb}{M_\infty} \right) \quad (2)$$

Where: D is the diffusion coefficient of the solution (m^2/min)

K : the slope of the curve between gain in mass and root time.

M_∞ : maximum profitability after immersion.

b : the thickness of the sample

3. RESULTS AND DISCUSSION

In this part, the results were obtained as a result of immersing the composite material with chemical solutions (diluted HCl, NaOH, and distilled water). Closest study comparison to this research ([Awham& Raghad, 2013](#)).

Fig. 1 shows the relation of weight gain % of composite material and the square root of time in diluted HCl. The composite material's weight gain increases with increasing immersion time of the sample in dilute hydrochloric acid. The highest weight gain values were at 0% clay because of the breakdown of intermolecular bonds due to the penetration of hydrochloric acid into the (epoxy/NBR), which leads to increased porosity and, thus, increased solution absorption (Bin et al., 2021; Salma et al., 2014). When the reinforcement ratio is increased by 1%, 1.5%, 3%, and 5% of clay, the composite material's weight gain decreases for the same immersion time because of an increase in bonding in the composite material, which improves its properties and increases in its density, which prevents the penetration of acid into the composite material (Ana et al., 2013), the lowest values of the weight gain were at 5% clay.

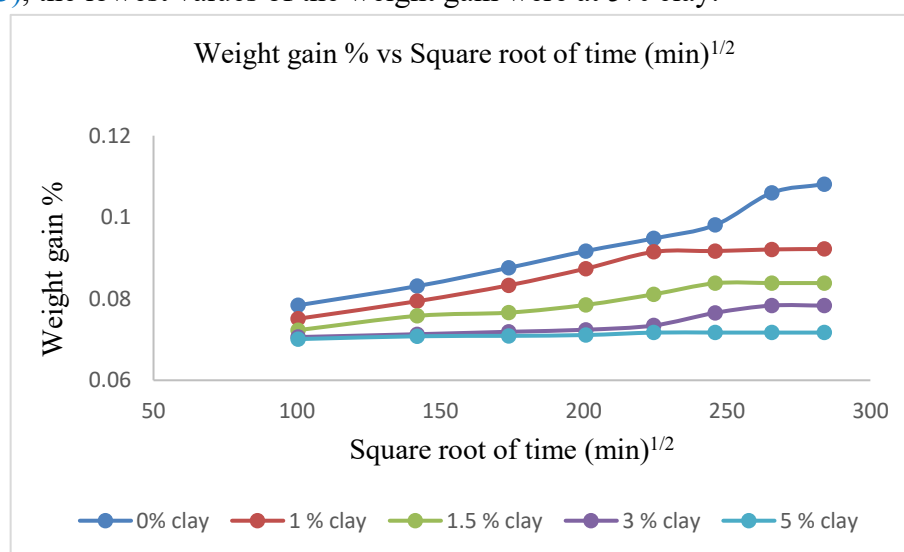


Fig. 1. Weight gain % of composite material vs square root of time in diluted HCl

Fig. 2 shows the relation of weight gain % of composite material and the square root of time in NaOH. When the composite material is immersed in the NaOH solution, weight gain values increase with increasing immersion time. The highest values of weight gain were at 0% clay compared with diluted acid because of the ability of the alkali to penetrate the epoxy resin is low due to the presence of rubber, which is considered a reinforcing agent for epoxy (Tassawuth et al., 2011). Weight gain of Epoxy/NBR/bentonite composite closely decreased with the increase of reinforced ratio for the same immersion time. The lowest values were at 5% clay because the bentonite particles increase the bonding between the epoxy particles, which increases the viscosity and hardness of the composite material and prevents the penetration of the alkali solution through it (Tezara et al., 2022).

Fig. 3 shows the relation of weight gain % of composite material and the square root of time in distilled water. The results showed stable behavior of composite material compared to immersion in acid and alkali, where the values of weight gain increase with an increase of

immersion time but decrease with the increase of reinforcement ratio for the same immersion time. At 0% clay, the highest weight gain values were obtained because of the ability of water to penetrate (epoxy/NBR) and break the chemical bonds of the material. While the lowest values were at 5% clay because of the increase in the polymer molecules bonding, in addition, rubber is also a catalyst to protect and reinforce epoxy from corrosion (Luca et al., 2011).

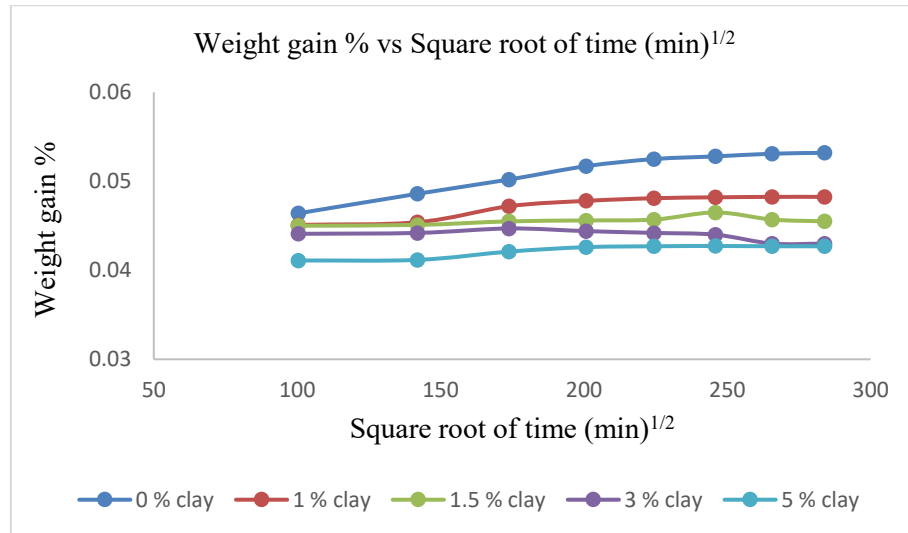


Fig. 2. Weight gain % of composite material vs square root of time in NaOH

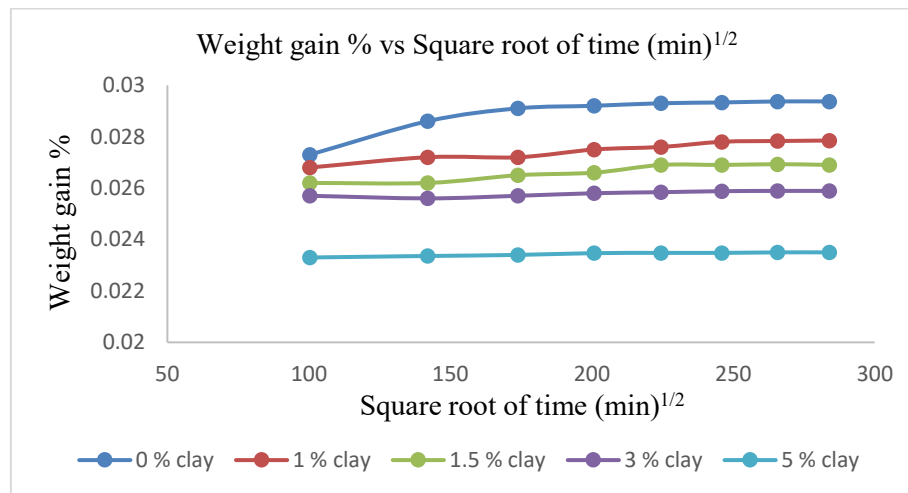


Fig.3. Weight gain % of composite material vs square root of time in distilled water

Fig. 4 shows the relation of diffusion coefficient $E-11$ (m^2/min) of the composite material immersed in the acid, alkali, and distilled water and the amount of clay%. The results show that the highest values of the diffusion coefficient were obtained when the composite material was immersed in the acidic solution and penetrated it, causing corrosion and chemical decomposition, compared to the alkali solution and distilled water (Raghad, 2022). The diffusion coefficient decreased with increasing amounts of bentonite, 0%, 1%, 1.5%, 3%, and 5%, lowest values at 5% clay because of increases in local stress on the composite material, the permeability solutions were decreased (Najat & May, 2013).

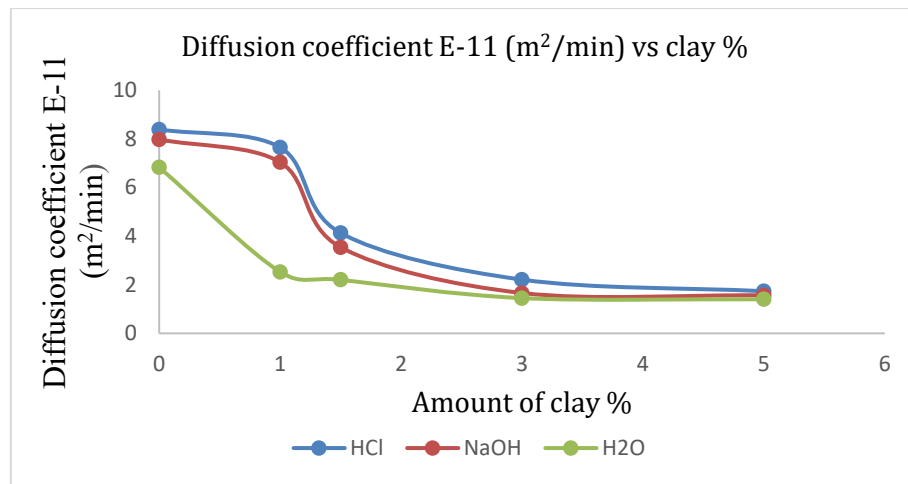


Fig.4. Diffusion coefficient E-11 (m²/min) in solutions vs amount of clay%

3.1. CHARACTERIZATION OF (EPOXY/NBR/ BENTONITE) AT DIFFERENT AMOUNTS OF CLAY

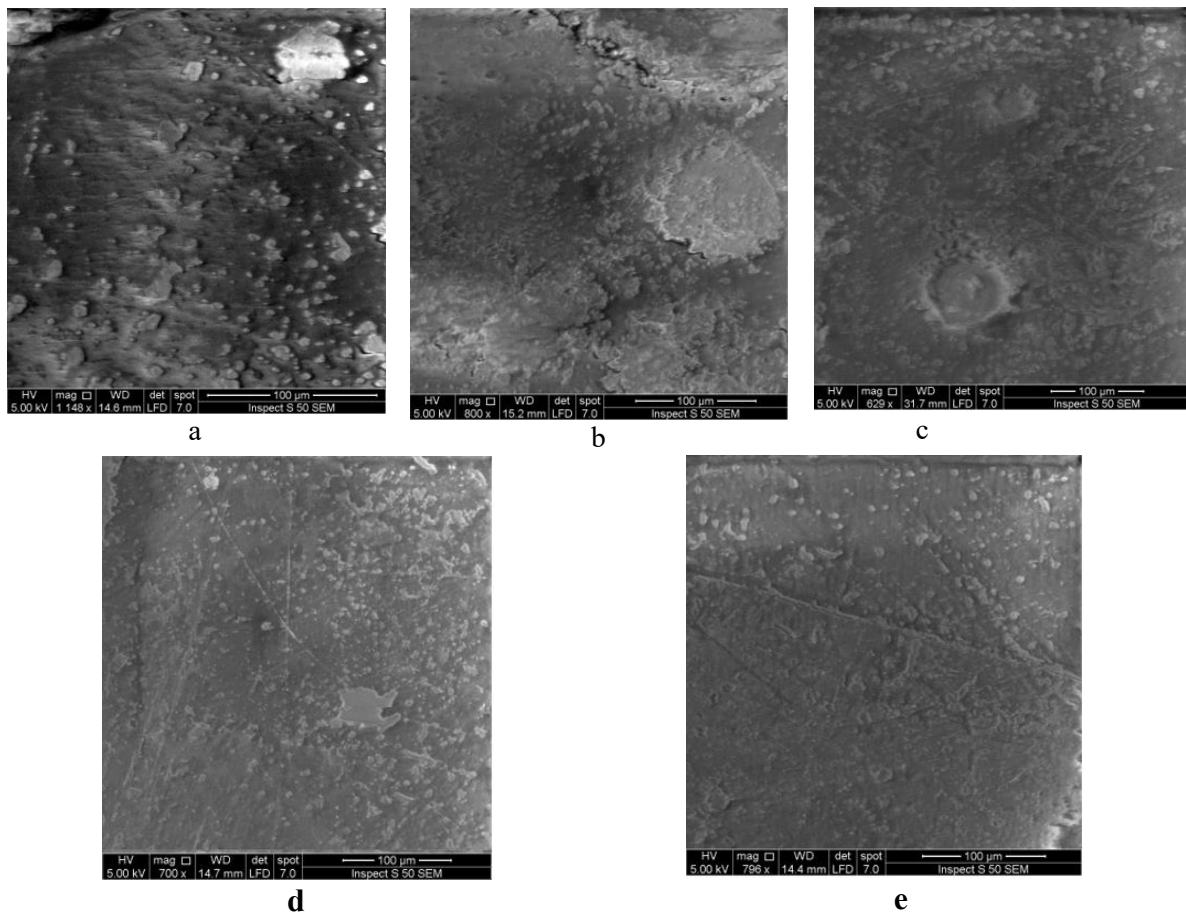


Fig.5. SEM images of composite material after immersion in distilled water at (a) 0% bentonite, (b) 1% bentonite, (c) 1.5 % bentonite, (d) 3% bentonite, (e) 5% bentonite

Fig.5 shows that the surface morphology of the composite material was analyzed using scanning electron microscopy (SEM). Fig. 5a 0% bentonite shows dark holes resulting from the beginning of corrosion on the sample's surface. Fig. 5b at 1% bentonite shows a large-size swelling. Fig. 5c at 1.5% bentonite shows small swellings of different sizes and small holes

distributed in different areas of the sample surface. Increasing bentonite helps the composite material reduce the penetration and diffusing of solution through it; Fig. 5d at 3% bentonite shows different sizes of holes. Fig. 5e at 5% bentonite shows small holes and no swellings on the surface.

4. CONCLUSIONS

The diffusion coefficient of epoxy /NBR was increased with immersion time in chemical solutions, where the highest values were (8.389, 7.98, and 6.832) E-11m²/min to diluted HCl, NaOH, and distilled water, respectively. The composite material epoxy/ NRB/bentonite was better at preventing solutions penetration, so the diffusion coefficient decreased with an increase in bentonite ratio at the same immersion time; the lowest values at 5% bentonite were (1.73, 1.56, and 1.401) E-11m²/min to diluted HCl, NaOH, and distilled water respectively. In distilled water, the weight gain of composite material at 5% is nearly stable; thus, it is not dependent on the immersion time. Also, the weight gain of the composite material has the highest value in the acid solution, followed by the alkali solution, and then distilled water.

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