



## Journal of Advanced Research in Applied Mechanics

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ISSN: 2289-7895



# Water Absorption Effect on Tensile Properties of Linear Low-Density Polyethylene (LLDPE) Blend with Recycle Acrylonitrile Butadiene Rubber Gloves (NBRr) in Saline Water

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### ARTICLE INFO

#### Article history:

Received 15 April 2024  
Received in revised form 10 June 2024  
Accepted 23 June 2024  
Available online 30 July 2024

#### Keywords:

Hydrothermal; linear low-density polyethylene; recycle acrylonitrile butadiene rubber gloves; tensile properties

### ABSTRACT

Nowadays, waste acrylonitrile butadiene rubber glove (NBRr) has been studied for use in building materials. The primary limitation of using rubber in construction was its low water absorption capacity. The goal of this research is to investigate the effect of Linear Low-Density Polyethylene (LLDPE) on water absorption and the temperature differential (20 and 30 °C) of NBRr blender composite in distilled water (DW) and saline water (SW). The rubber glove has been blended with heated two-rolled mills at 120 °C. The substance had been compressed using a hot press. Five samples had already been created. The sample was formed like a dumbbell. The five samples were immersed in DS and SW for 30 days at temperatures of 25°C and 35°C, respectively. The result shown the tensile strength, elongation at break  $E_b$  and Young's modulus of LLDPE/NBRr blend decrease. The tensile properties of saline water lower compare to distilled water due to corrosion and degradation. Saline water contains dissolved salts, which can contribute to corrosion and degradation of the materials. The presence of salts can accelerate chemical reactions, leading to the degradation of the polymer matrix and the rubber phase. This degradation can weaken the material and reduce its tensile strength. Moreover, as the temperature increases, the thermal energy also increases, causing the polymer chains to gain more kinetic energy. This increased energy disrupts the intermolecular forces and reduces the overall molecular interactions within the material. Weaker intermolecular interactions lead to a decrease in tensile strength. As conclusion, hydrothermal effect tensile properties when temperature increase tensile properties decrease. distilled water has better diffusion than saltwater. LLDPE/NBRr blend was discovered that both distilled and salt-water absorption resulted in a decrease in tensile properties.

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<https://doi.org/10.37934/aram.121.1.107116>

## 1. Introduction

The Rubber gloves are used in a variety of industries, including industrial, automobile manufacturing, engineering, medical, and household items. Rubber waste gloves are harmful to the environment since they are used and then [1,2] Recycling waste materials is an excellent way to address environmental challenges. Therefore, an expensive method for the disposal of rubber waste is required [3,4]. Thermoplastic Elastomers (TPE) is a physical combination of polymers, often rubber and plastic. Thermoplastic Elastomers (TPE) have the benefit of being able to stretch to mild elongation and then return to their original form. They also have a greater physical range and a longer life than other materials [5-7] The methyl group in polypropylene increases thermal and mechanical qualities while decreasing chemical resistance [8]. The tensile modulus of Linear Low-Density Polyethylene (LLDPE) resins is quite high. The mechanical characteristics are outstanding. Acrylonitrile Butadiene Rubber (NBR) is an oil-resistant synthetic rubber. NBR in polymers enhances tensile strength and flexibility [9-11].

The global expansion of the healthcare business, particularly with the COVID-19 pandemic. According to Malaysian Rubber Glove Manufacturers Association (MARGMA), rubber glove exports were 18.8 billion Malaysian Ringgit in 2018 [12]. Malaysia supplies 60 to 65 percent of the market's natural and nitrile gloves, accounting for nearly half of global demand [13,14]. Polymer mixes will be partially or entirely submerged in salty water. The influence of moisture and temperature on the polymer and its change in properties are critical factors. The saline water (SW) absorption characteristics and mechanical properties at 25 °C and 35 °C are examined in this work. Projects such as construction are extremely popular in our current construction technology business. As a result, seawater-affected concrete buildings require specific treatment [15]. Nearshore structures are continually in touch with saltwater, resulting in a range of physicochemical and biological failure mechanisms. When concrete is exposed to seawater, it can deteriorate due to chemical and physical causes such as Sulphate attack, Leaching of Lime, Salt Crystallization from Alternate Wetting and Drying [16]. Seawater penetrates into porosity of concrete and enters the reinforcement, causing corrosion. Leaching also took away the lime content of the concrete. Temperature has an impact on chemical assaults as well. The more serious the assault, the greater the fever [17]. Greater leaching will occur when both calcium hydroxide and calcium sulphate are permeable in salt water.

When a concrete building is built in seawater, the most damaged component of the structure is well beyond the rising water level. This is because when saltwater gets in touch with the region above the good point due to wave impact, seawater is produced in the pore spaces. In cold climates, water in concrete pores freezes, expanding the concrete and reducing its durability. In cold climates, water in concrete pores freezes, expanding the concrete and reducing its durability [18]. Chemical interactions of saltwater elements with cement hydrates, lime expansion, crystal growth strain of salts beneath concrete, and freezing effect in cold climes can all cause concrete to degrade in a marine environment [15]. Corrosion of iron bars produced by sodium chloride, sulphur attack on cementitious material, and swelling disturbance of concrete if oxidizing agent impurities are present in the concrete have all been variables that impact the properties of concrete in coastal settings [18]

According to Anwar and Roushdi [19] using environmental by-products like fly ash and silica fume in concrete has increased the material's capacity to tolerate seawater. Rubber bearings are employed as a vibration dampener and an isolator between the bottom of a structure for earthquake protection foundation sustainability of laminated rubber-metal spring [20]. It shows that there are many studies that were held to improve the negative impact of bridges in the construction industries.

## 2. Methodology

### 2.1 Materials Preparation

Juara One Resources Sdn Bhd provided the NBRr. The characteristics of Acrylonitrile Butadiene Rubber (NBRr) produced from Juara One Resources Sdn Bhd were moderate nitrile with 33.3 percent ACN. Using Rotor Mills, the gloves were sliced and masticated many times to obtain minute powder. The NBRr grains were then sieved into sizes in the range from 150  $\mu\text{m}$  to 300  $\mu\text{m}$ . Lotte Chemical Titan (M) Sdn Bhd supplied the Linear Low Density (LLDPE), which was also utilized as a polymer composite.

### 2.2 Compounding and Mixing

LLDPE and NBRr both weighed and manufactured in accordance with the formulations. Table 1 shows how the weight percent of LLDPE and NBRr were modified to attain a total of 100 percent. The components were mixed together for 7 minutes at 120 °C using a heated two roll mill with a rotor speed of 15 rpm. LLDPE was melted for 4 minutes, then NBRr was added and left for 3 minutes. The mix was revealed at the 7<sup>th</sup> minute. The blending schedule of the procedure with time is shown in Table 2. After blending, the compound was vacuum-dried for 24 hours at 80 °C.

**Table 1**

Formulation for LLDPE and NBRr Blend

Material	Amount (*wt%)						
LLDPE	100	90	80	70	60	50	40
NBRr	0	10	20	30	40	50	60

\*wt (weight percent)

**Table 2**

Timing of Mixing

Material	Time (min)
LLDPE	0
NBRr	4
Discharge	7

After drying, an electrical heated hydraulic press model GT-7014-A300 C was used to compress the compounds into a 1 mm thin sheet with a pressure of 15 KPa at 120 °C. 7 minutes for preheating, 2 minutes for compression, and the next 2 minutes for cooling press. Then, all the 1 mm thin sheet samples were cut into dumb bell shapes by using a Wallace die cutter model S6/1/6. The samples were ready to be tested.

### 2.3 Samples Testing

The dumbbell samples been soaked in distilled water (DW) and saline water (SW) for 30 days at different temperature (25 °C and 35 °C). After 30 days, tensile testing was carried out using an Instron 3366 universal testing machine (UTM). Tensile strength, elongation at break ( $E_b$ ), and Young's modulus were measured using an ASTM D 638 tensile test at a cross head speed of 5 mm  $\text{min}^{-1}$ .

### 3. Results

#### 3.1 Mechanical Properties Before Soaking

According to the data Table 3 before the original (before the water absorption test, the tensile strength of LLDPE/NBRr ranged from 9.8 MPa to 3.7 MPa. However, the greatest and lowest Young's modulus of LLDPE/NBRr are 282 MPa and 46.2 MP. Next, LLDPE/NBRr have the highest and lowest elongation at break values, respectively, of 71.9% and 29.7%. As the loading of NBRr increases, the blends' tensile strength, Young's modulus, and elongation at break before water absorption decrease. This is because there is little interaction between LLDPE and NBRr, and the filler cannot withstand the stress transmitted from the LLDPE matrix. The LLDPE and NBRr have low interfacial adhesion, which increases the stress concentration area and decreases the blend's tensile strength [9,21].

The interphase that forms between the matrix and filler gives blends their fragile structure. The presence of the NBRr limits the mobility of the matrix and recycled chains, are to blame for the decrease in elongation at break as the loading of NBRr increases [22].

**Table 3**  
LLDPE/NBRr blend before water absorption test

LLDPE/NBRr	Tensile Strength, (MPa)	Elongation at break, $E_b$ (%)	Young's Modulus, (MPa)
100/0	9.8	71.9	46.2
90/10	8.1	64.3	75.8
80/20	7.6	50.8	102.1
70/30	6.4	41.4	148.8
60/40	5.3	37.2	222.4
50/50	4.9	34.4	245.8
40/60	3.7	29.7	282.0

#### 3.2 Effect Hydrothermal on Tensile Strength

Moreover, as loading of NBRr increases after water absorption, tensile strength, Young's modulus, and elongation at break all drop. In comparison to mechanical qualities prior to water absorption, all blends' mechanical properties decrease under all conditions. Pure LLDPE, on the other hand, have extremely little water absorption. Therefore, the results of tensile strength elongation at break and Young's modulus do not differ much. It may therefore be disregarded.

Table 4 and Figure 1 shown the data when submerged in distilled water at temperatures of 25°C and 35 °C, LLDPE/NBRr blends' tensile strengths ranged from 8.8 MPa to 2.5 MPa and 7.8 MPa to 1.2 MPa respectively. The LLDPE/NBRr blends' tensile strengths range from 8.1 MPa to 1.8 and 6.9 MPa to 0.8 MPa when submerged in seawater at temperatures of 25 °C and 35 °C, respectively. Finally, the LLDPE/NBRr mix had tensile strengths between 8.8 MPa and 0.8 MPa respectively, when submerged in distilled water and seawater at temperatures of 25 °C and 35 °C. The tensile strength LLDPE/NBRr of saline water lower the distilled water. This may due to corrosion and degradation. Saline water contains dissolved salts, which can contribute to corrosion and degradation of the materials. The presence of salts can accelerate chemical reactions, leading to the degradation of the polymer matrix and the rubber phase. This degradation can weaken the material and reduce its tensile strength [23,24].

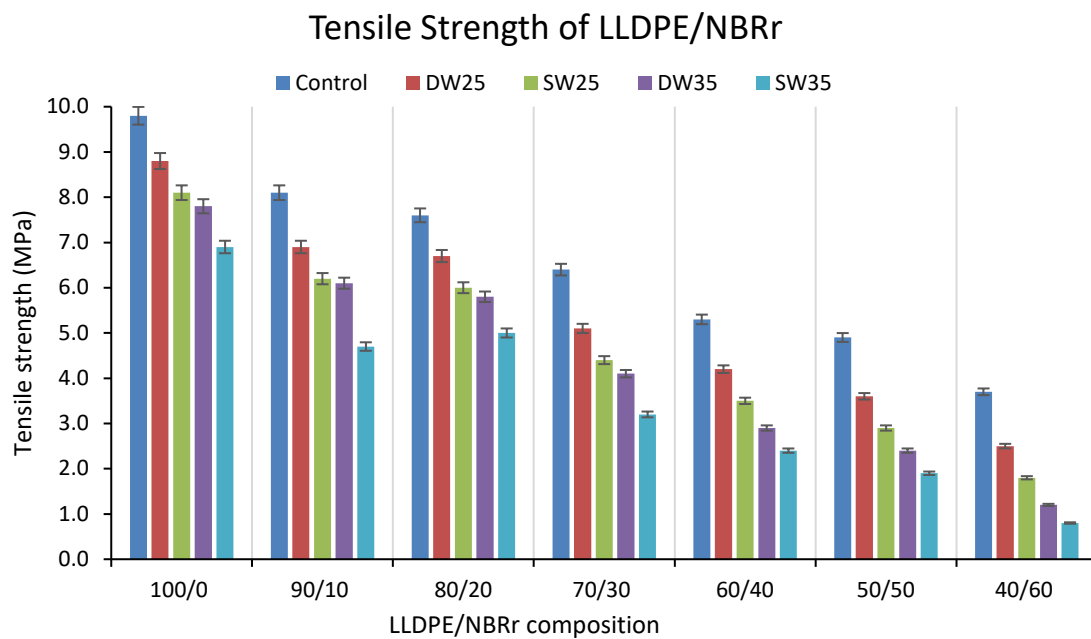
Moreover, the tensile strength both of LLDPE at distilled water and saline water at 35°C lower compared at 25°C due to decreased molecular interaction. As the temperature increases, the thermal energy also increases, causing the polymer chains to gain more kinetic energy. This increased energy

disrupts the intermolecular forces and reduces the overall molecular interactions within the material. Weaker intermolecular interactions lead to a decrease in tensile strength [25]. At lower temperatures, LLDPE polymer chains tend to have more entanglements, which provide resistance against deformation [26]. As the temperature increases, the chains gain more mobility and can slide past each other more easily. This reduced chain entanglement weakens the material's resistance to deformation and results in a lower tensile strength.

**Table 4**  
 Tensile Strength (MPa) of LLDPE/NBRr in Distilled Water and Saline Water at Different Water Temperatures 25°C and 35°C

LLDPE/NBRr	Tensile Strength, (MPa)			
	*DW25	*SW25	*DW35	*SW35
100/0	8.8	8.1	7.8	6.9
90/10	6.9	6.2	6.1	4.7
80/20	6.7	6.0	6.7	5.0
70/30	5.1	4.4	4.1	3.2
60/40	4.2	3.5	2.9	2.4
50/50	3.6	2.9	2.4	1.9
40/60	2.5	1.8	1.2	0.8

\* DW (distilled water) \* SW (saline water)



**Fig. 1.** Tensile Strength of LLDPE/NBRr

Table 5 and Figure 2 show the elongation at break, ( $E_b$ ) of LLDPE and NBRr in distilled and saline water at various temperatures (25°C and 35°C). The elongation at break ranged from 69.9% to 28.6% and 68.7% to 27.6%, respectively. At temperatures of 25°C and 35°C, the elongation at break of the LLDPE/NBRr blends immersed in saltwater varies between 69.2% and 27.9% and 68% and 26.9%, respectively. According to the findings, the elongation at break,  $E_b$  of LLDPE/NBRr in saline water is lower than distilled water. This may be due to osmotic effects. Saline water with a higher salt concentration can create osmotic effects on the LLDPE. Osmotic pressure can induce water movement into the polymer, resulting in increased internal stresses and reduced elongation at break.

[27,28]. Distilled water with lower salt concentration does not induce significant osmotic effects, allowing the LLDPE to exhibit higher elongation at break.

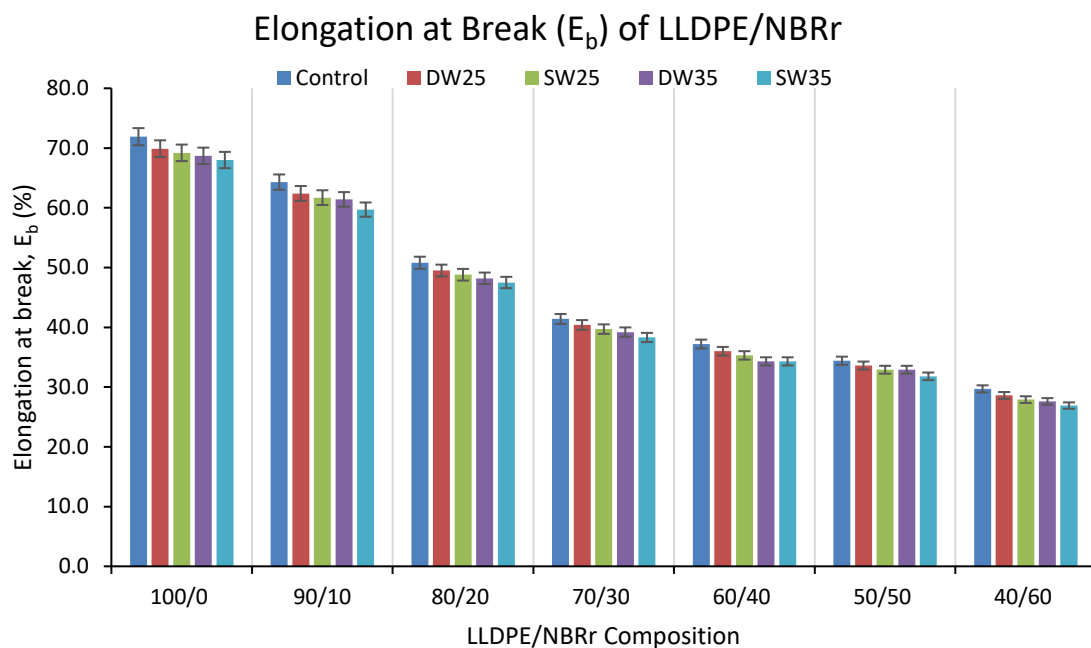
Other hand, The  $E_b$  LLDPE/NBRr decrease when temperature increase due to the Thermal degradation. High temperatures can induce thermal degradation in polymers, including LLDPE. The increased temperature can accelerate chemical reactions within the material, leading to chain scission and the formation of weak points [29]. Thermal degradation weakens the material's structure and reduces its overall elongation at break. Saline water typically has a higher water content compared to distilled water. The increased water content can result in greater water absorption and swelling of the LLDPE. Swelling causes the polymer chains to separate, reducing the intermolecular forces and limiting the material's ability to elongate before breaking [30]. As the temperature increases, the swelling effect becomes more pronounced, leading to a decrease in elongation at break.

**Table 5**

Elongation at Break (%) of LLDPE/NBRr in Distilled Water and Saline Water at Different Water Temperatures 25°C and 35°C

LLDPE/NBRr	Elongation at Break, $E_b$ (%)			
	*DW25	*SW25	*DW35	*SW35
100/0	69.9	69.2	68.7	68.0
90/10	62.4	61.7	61.4	59.7
80/20	49.5	48.8	48.2	47.5
70/30	40.4	39.7	39.2	38.3
60/40	36.0	35.3	34.3	34.3
50/50	33.6	32.9	32.9	31.8
40/60	28.6	27.9	27.6	26.9

\* DW (distilled water) \* SW (saline water)



**Fig. 2.** Elongation at Break ( $E_b$ ) of LLDPE/NBRr

### 3.3 Effect Hydrothermal on Young's Modulu

At temperatures of 25 °C and 35 °C, the Young's modulus of LLDPE/NBRr blends immersed in distilled water at different temperatures 25°C and 35°C from 44.8 MPa to 280.6 MPa and 43.5 MPa to 279.6 MPa, respectively. The LLDPE /NBRr blends' tensile strengths range from 44.1 MPa to 279.9 MPa and 42.9 MPa to 278.9 MPa when submerged in seawater at temperatures of 25 °C and 35 °C, respectively in Table 6 and Figure 3. However, when immersed in distilled water and seawater at different temperatures of 25 °C and 35 °C, the highest Young's modulus is 280.6 MPa while for the lowest is 42.9 MPa.

The blends that are submerged in seawater at a temperature of 25 °C have higher mechanical qualities, as can be seen in every composition. The blends with the least mechanical qualities are those that are submerged in distilled water at 35 °C. This is the result of how quickly water is absorbed. The mechanical qualities deteriorate more quickly when the water absorption rate is high. This is due to capacity of water to absorb into the tiny spaces between polymer chains, capillary transit of water molecules between LLDPE and NBRr, and the transport of water molecules in the tiny cracks of blends of LLDPE/NBRr as opposed to pure LLDPE. Thus, the addition of water molecules tends to alter the structure of the matrix and the interface between them, resulting in cracked matrix and damaged [31,32] a result, the blend's mechanical qualities are further diminished.

Young's modulus of LLDPE/NBRr decrease when temperature increase in saline water due to weakened intermolecular forces. The presence of salts and ions in saline water can weaken the intermolecular forces between the polymer chains. The electrostatic interactions between the ions and the polymer chains can disrupt the polymer's network structure, reducing the overall strength and stiffness of the material [33]. This weakening of intermolecular forces contributes to the decrease in Young's modulus as the temperature increases in saline water.

**Table 6**  
 Young's modulus (MPa) of LLDPE/NBRr in Distilled Water and Saline Water at Different Water Temperatures 25°C and 35°C

LLDPE/NBRr	Young's Modulus (MPa)			
	*DW25	*SW25	*DW35	*SW35
100/0	44.8	43.5	44.1	42.9
90/10	74.3	73.1	73.6	72.6
80/20	100.5	99.0	99.8	98.4
70/30	147.1	145.9	146.4	146.0
60/40	220.9	218.9	220.2	219.2
50/50	244.6	243.0	243.9	242.4
40/60	280.6	279.6	279.9	278.9

\* DW (distilled water) \* SW (saline water)

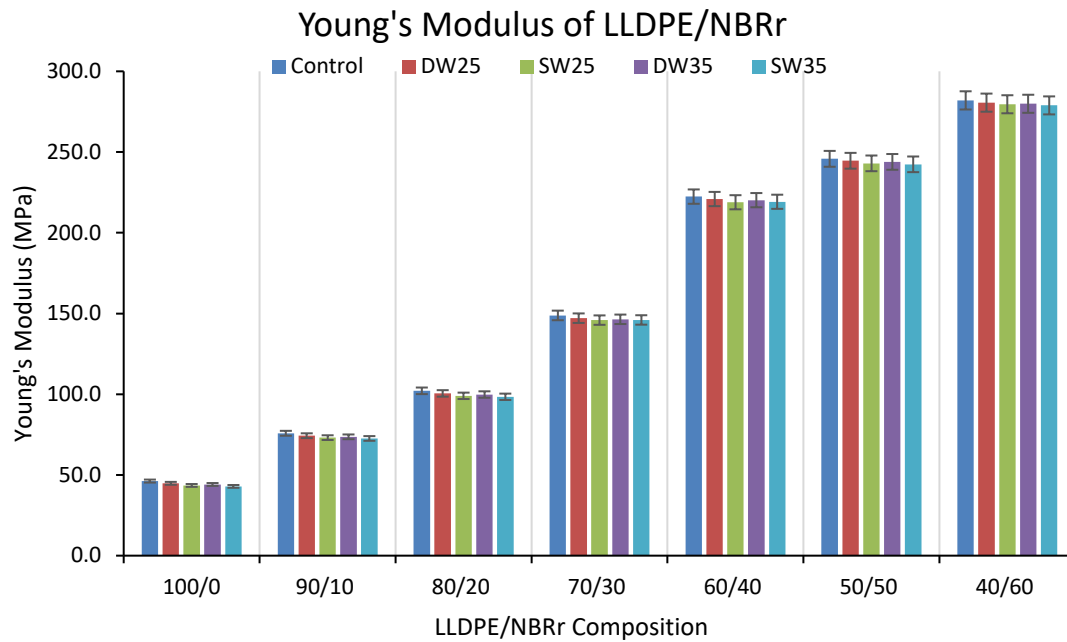


Fig. 3. Young's Modulus of LLDPE/NBRr

#### 4. Conclusions

As conclusion, tensile properties of LLDPE/NBRr blends such as tensile strength, Young's modulus, and elongation at break before water absorption decrease as NBRr loading increases. The blend with the lower rubber loading absorbs less water than the blend with the higher rubber loading. Saline water absorbs water at a slower pace than distilled water. The higher the temperature, the faster the water absorbs. Apart from that, at higher temperatures, the mixtures reach equilibrium in a shorter amount of time. Distilled water has better diffusion than saltwater. LLDPE/NBRr blend was discovered that both distilled and salt-water absorption resulted in a decrease in stiffness, yield stress, and hardness but had only a minimal impact on the sensitivity of the reaction to the imposed strain rate and the tensile ductility.

#### Acknowledgement

This research was funded by a grant from Ministry of Higher Education of Malaysia (FRGS/1/2020/TK0/UNIMAP/02/67).

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