

## Study of the Effect of the Variation Effect of Water Temperatures on Shore (D) Hardness for Some Polymers

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### Abstract

The current investigation was carried to study and determine the value of shore [D] hardness for different kinds of polymers [Epoxy [Ep], unsaturated polyester [UPE] and unplasticised PVC. After the preparation our samples Shore [D] hardness values were measured for the samples at 25 °C. Then the samples were immersed in water bath of two types of water [distilled and tap water] at different temperatures [40,50 & 60] °C for different times [1,2,3 & 4] hour. Other samples immersed in cooled water at 10 °C for the same previous periods for comparing the obtained results from samples under test, it was found that the shore hardness value decreases after the immersion of samples in both types of water at 25 °C for [1,2,3 & 4] hours, the hardness value decreased after immersing these samples in water bath at higher temperature as, while increases when the samples immersed in two types of water at 10 °C at the same period. The obtained results showed that the rate of decreasing or increasing of hardness value depends on the period of the immersion and the type of the solution used as well as the nature of water and it's temperature.

Keywords: Polymers, Epoxy, Unsaturated polyester, PVC, Shore hardness.

### Introduction

Synthetic polymers are mainly used by scientist because of their outstanding mechanical properties. All their industrial importance as fibers, plastics, rubbers, adhesives and coating is ultimately based on strength, high elongation, high modulus, toughness, abrasion resistance, thermal & mechanical durability [1]. Since the formation of earth over 4 billion years ago, in its giant "laboratory", elements like carbon, hydrogen, oxygen and nitrogen have been combined to form complex molecules [2]. Hardness can be defined as a material's resistance to permanent indentation and durometer in one of several scales used to measure hardness. Hardness has been well established in characterizing metallic materials and ceramics for many years, but only recently has it been widely employed for characterizing polymers [3].

The importance of hardness test:

1. It is non-destructive test [NDT], which is mean that no change in properties or the nature of materials after making the test especially for the micro hardness test, and it depend on the application of the sample under investigation, [4].
2. Easy and Simple.
3. Ability of obtains information about the effect of mechanical& thermal treatment on material, [4].

Due to all the reasons above and in addition to increasing the importance which was occurred in the last year for using polymeric materials in especial different advanced industrial applications, so this research come to explained the important mechanical properties and the effect of aggressive chemical solutions on polymeric materials.

Brown studied the effect of gaseous environments on polymers. He studied the effect of H<sub>2</sub>, He, and vacuum on stress-strain curve of polycarbonate at 90 K. The conclusion of this study is that the effect of inter gases on the mechanical properties of polymers is unnoticed in general, [5].

Hazim Studied mechanical properties of Novolac and it's composites after immersed in tap water for [2,4,6,8,10] weeks at (25 °C). He noticed that the hardness of this material decreases as the time of immersion increased compared with the same value of the hardness before the immersion, as well as he found that when the composite reinforced with particles the variation was so obvious in which the powder contained pores especially ceramic material so the water will interpenetrated easily the material through diffusion action lead to breaking the bond between the molecules, [6].

Raghad studied the effect of weathering (radiation and Chemical solutions) on some properties of epoxy composites. She had been prepared (4) samples of epoxy reinforced with Al, SiO<sub>2</sub>, G.F and Al. These samples immersed on chemical solutions (NaOH, HCL) and H<sub>2</sub>O for (2,4,6) weeks. Hybrid composite (epoxy reinforced with G.F and Si<sub>2</sub>O,G.F and Al) showed best mechanical properties with all the weathering conditions. NaOH with (1N) was more effective on samples as compared with other solution, [7].

Althawale & Alhousami investigated the hardness of epoxy resin modified urea-formaldehyde/silicon blends, the hardness was found to be high valued in the case of modified epoxy resin as compared to blank epoxy. The results of the modified epoxy resins showed remarkable high thermal stability as well as a higher degree of solvent resistance as compared with blank epoxy resin, [8].

Wurood M. Hammed [9] studied the effect of Acidic solutions in Epoxy resin (EP-223) as a matrix reinforcement with iron on the form of wires iron powder, the research subject take place in (Natural condition & Chemical solutions), all the samples immersed in (HCL,HNO<sub>3</sub>) as the chemical solution for (1,2,3) months in the room temperature. All the samples showed decreases in the hardness values after the immersion on the solution. The aim of this work is to study the effect of changing the immersion temperatures during a period of time on prepared polymeric samples. Our samples contained (Epoxy (Ep), unsaturated polyester (UPE) & Unplasticised PVC) were immersed in to (tap & distilled water).

## Experimental Part

### 1-Technique of samples preparation:

Three types of the resins were used in the current study as follows.

#### 1-Epoxy resin (EP):

Epoxy resin (type Conbextra EP 10) was used in this research, it is a liquid with moderate viscosity and capable to be converted to solid state by adding the solution (Meta phenylene diamine, MPDA) as hardener, this hardener is a light liquid with yellowish color, the ratio of this hardener to the epoxy is about (1:3), after manual mixing

process in order to achieve a homogenous solution. The solidification process is done and our sample is ready to take in to the iron mold with dimensions (25,25,0.5) cm, after the curing process which take place in an oven with (60 °C) for 2 hours. Finally the samples were cutting in slandered dimension according to ISO (9001).

#### 2-Unsaturated polyester resin (UPE):

It is a liquid with moderate viscosity which can be cured to the solid state by adding (Methyle Ethyle Keton Peroxid, MEKP). As hardener, while cobiltoctoate acts as a catalyst to accelerate the solidification process. The percentage of the hardener to the resin is (2%) while it is (0.5%) for the accelerator. After mixing process for each resin(Ep & UPE) apart, these mixtures were cast in a metal mould with dimensions (12, 10&3) cm<sup>3</sup> at 25 C<sup>0</sup>.After solidification process the casting block were released from the mould and placed in an oven with (Temp=50 °C)for 1 hour to post cure the castings.

#### 3- Polyvinyl chloride:

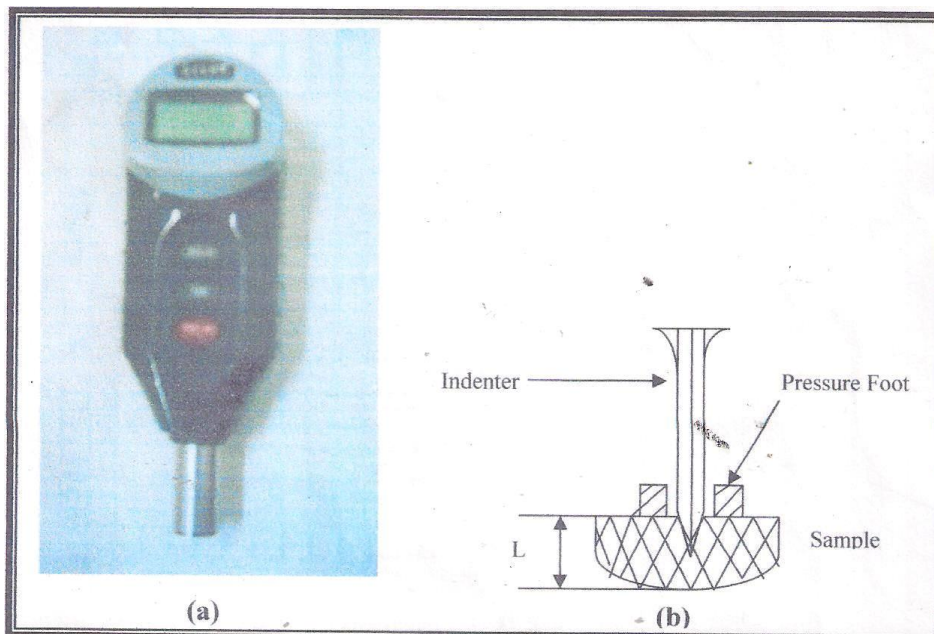
According to the standard specification (ASTM D570) the samples were cut in rectangular shapes of certain dimension (10, 10)mm<sup>2</sup>from (UPVC) pipes, made in K.S.A by the national factory for plastic industries in Jeddah city.

### 2-Hardness Test:

Shore durometer hardness test apparatus (digital, Italy, type TH210) was used to measure the hardness values of the samples under study. This test was carried out by fixing penetration tool of the Shore D apparatus on surface of samples, the number value of hardness exhibits on the electronic screen of the instrument as shown in Fig.(1). This test was performed on three different (polymeric materials). These samples were tested under the influence of these conditions (Dry & immersed into the water at room temperature (at 25 °C), two types of water were used for this study that included; (tap water, distilled water) and after immersed the samples in both types of water each hour at higher temperatures (40,50 &60 °C) for (1,2,3,4) hours. In the other hand, we cooled both type of water mentioned above till (10 °C) for 4 hours also Shore hardness test was performed

on the samples each hour for the following samples:

1. Each of the dry samples (Polyester, Epoxy & PVC) before the immersion process.
2. Previous samples after the immersion for (4hours) at room temperature (25 °C).
3. The samples after the immersion for (4 hours) in both type of water at (40, 50 and 60 °C).
4. The samples after the immersion for (4 hours) in both type of water at (10 °C).



*Fig.(1) Digital Shore D Hardness apparatus.*

### Result and Discussion

According to the Figs. (2 & 3) it is obvious that the hardness value decreases for all the samples when the period of immersion to the water increases for both kinds of water mentioned above at (25 °C) in approximate value as indicated in Table (1 & 2). It is noticed that the major effects of the water lead to swell & plasticize of the resin which causes drop of hardness of the samples. The reason behind this plasticizing is that water molecules are relatively small and they could cluster at the polar centers or in micro cavities that exist in the polymer resin, [10].

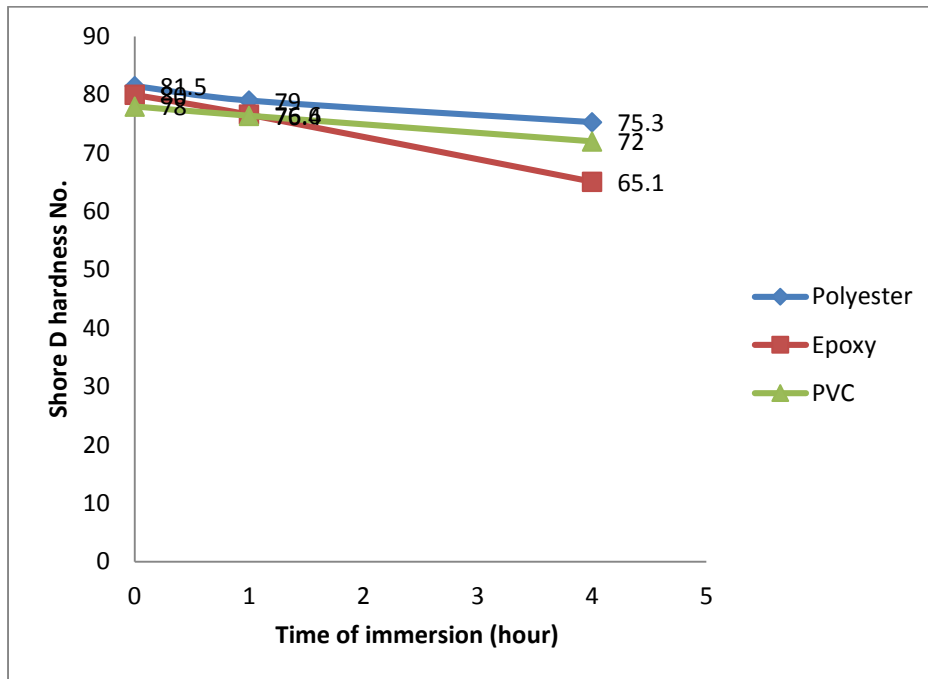
Also water inter the resin by diffusion, The surface damages and cracks produced as a result of weathering further facilitate the entry of water. This research refer to the effect of water on the resin is to cause swelling and plasticization-hydrolysis of resin is not considered to be an important process under the conditions encountered outdoors, [11].

*Table (1)  
Value of Shore (D) hardness at (25 °C) for  
4hours of immersion in tap water.*

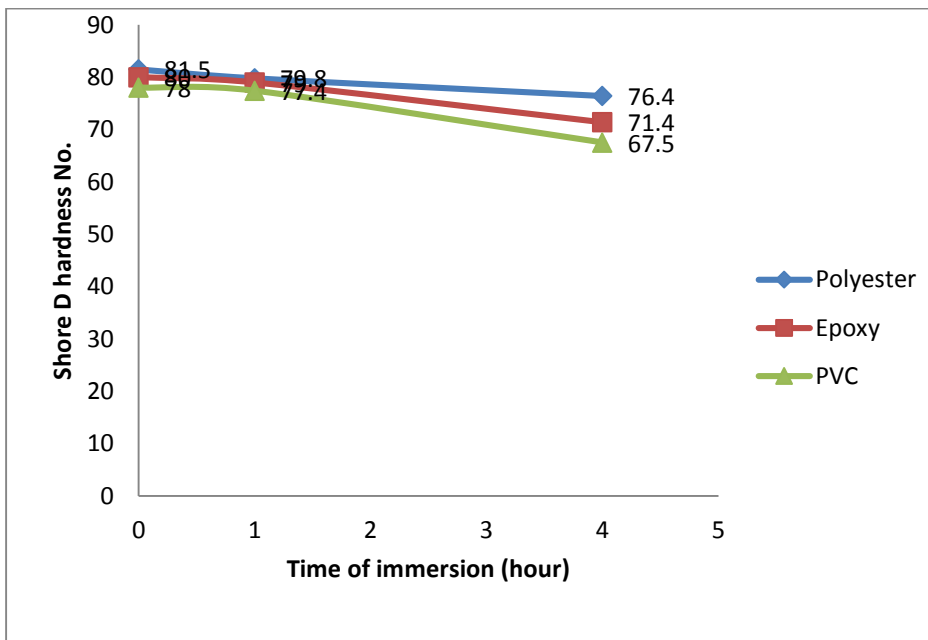
Hour	Polyester	Epoxy	PVC
0	81.5	80	78
1	79.8	79	77.4
4	76.4	71.4	67.5

*Table (2)  
Value of Shore (D) hardness at (25 °C) for  
4hours of immersion in distilled water.*

Hour	Polyester	Epoxy	PVC
0	81.5	80	78
1	79	76.6	76.4
4	75.3	65.1	72



**Fig.(2) Influence of tap water at (25 °C) on Shore (D) hardness after 4 hours of immersion.**



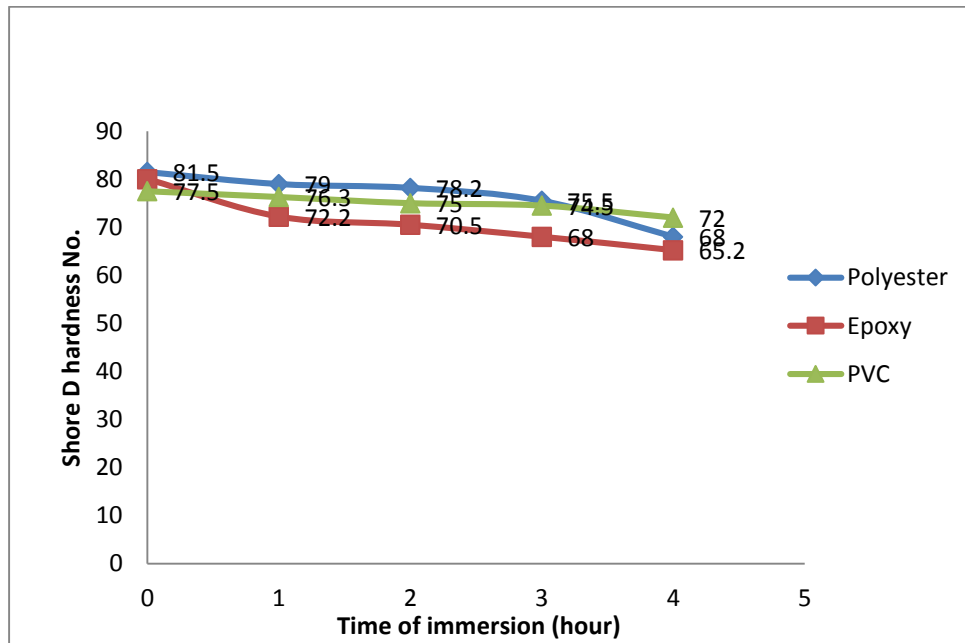
**Fig.(3) Influence of Distilled water at (25 °C) on Shore (D) hardness after 4 hours of immersion.**

The result of increasing the temperature of water on the hardness value of the samples under investigation, after (1,2,3 & 4) hours of immersion in (tap & distilled water) are shown in Figs. (4,5,6) & (7,8,9) respectively. In which Figs.(4,5,6) represent the effect of raising the temperature (40, 50 & 60 °C) respectively on the hardness value after immersion of samples in tap water. It is noticed that all the samples undergo decreasing in hardness value for all kinds of

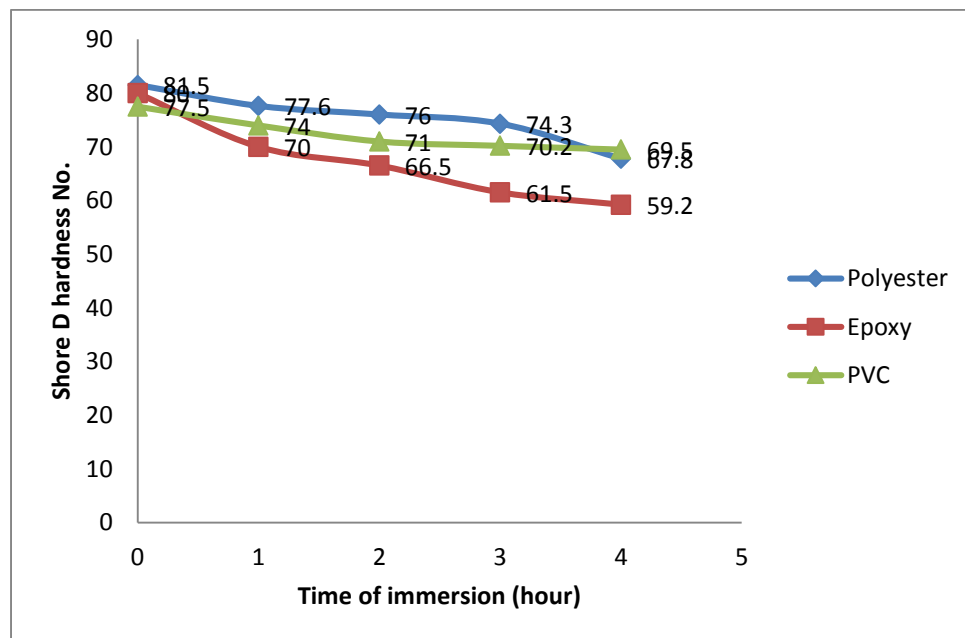
water. As the temperature increased the hardness value decreased at the same period (i.e for example at (60 °C) Epoxy resin hardness value (57) while at (40 °C) the hardness value was (65.2) for the same period). It is also noticed from these three figures that the results are nearly approximated. During the temperature increase there is a drop in the hardness values for all samples, where the hardness value is a measure of the plastic deformation of the

samples under the outside stress load. Therefore increasing of temperature lead to increasing the material flexibility because of the primary units motion and bound loosen

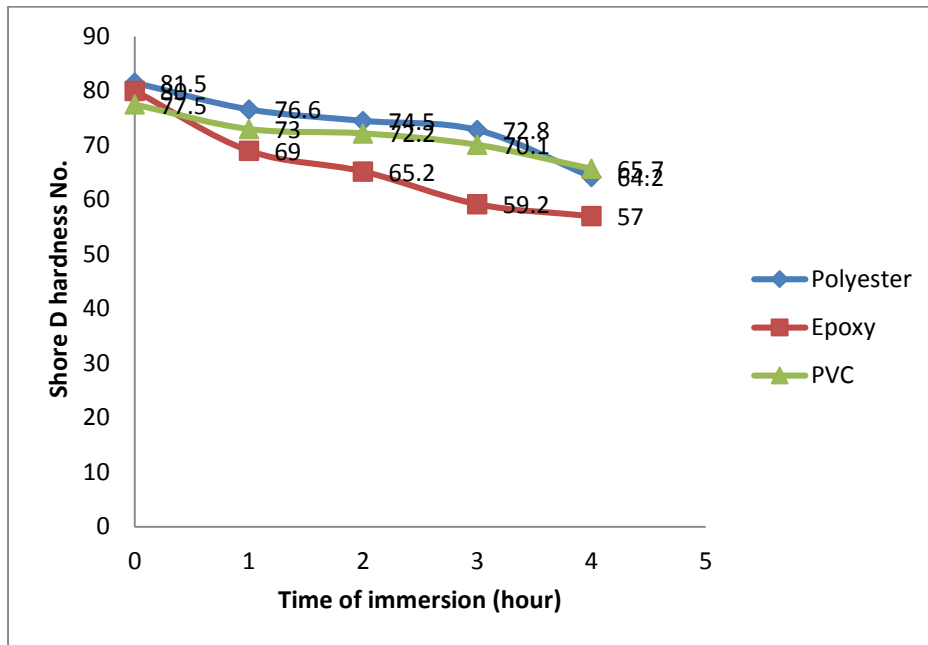
between them which causes reduction in material resistance of permanent and scratching, [12].



*Fig.(4) Influence of tap water on Shore (D) hardness No. of Samples at 40 °C after 4 hours of immersion.*



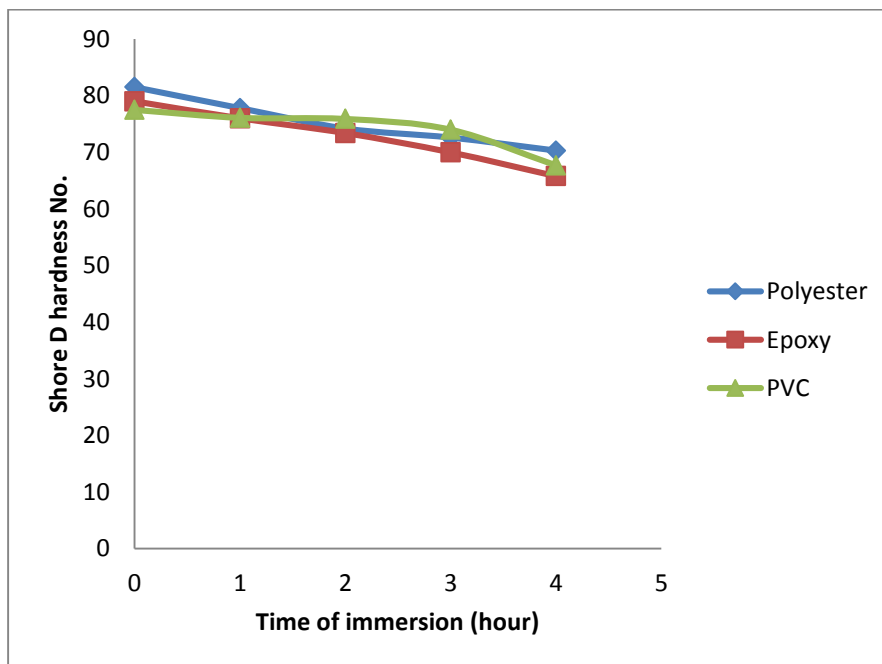
*Fig.(5) Influence of tap water on Shore (D) hardness No. of Samples at 50 °C after 4 hours of immersion.*



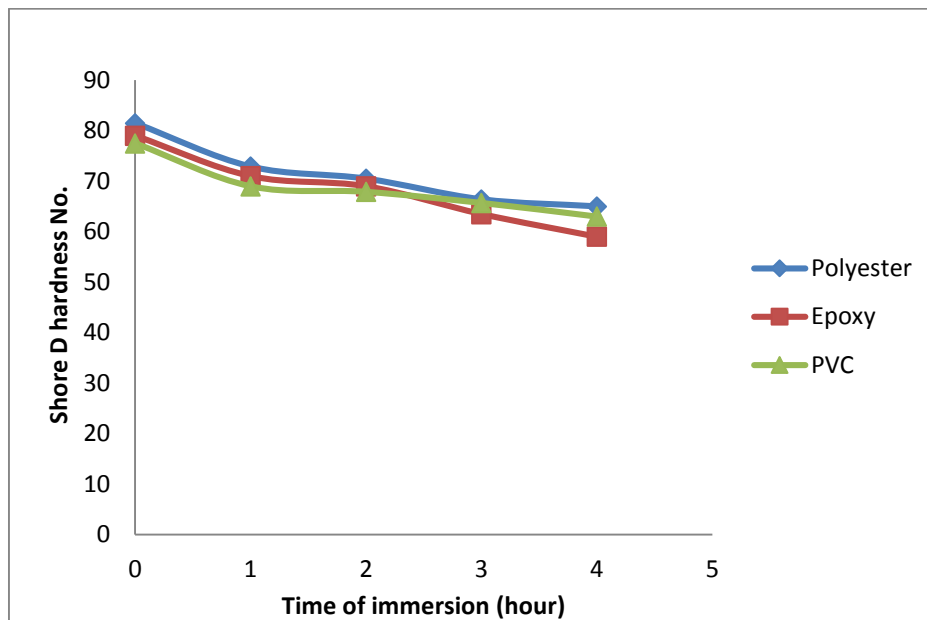
**Fig.(6) Influence of tap water on Shore (D) hardness No. of Samples at 60 after 4 hours of immersion.**

Also one can notice by the Figs. (7, 8, 9) that distilled water has the higher effect on the samples than the tap water. This phenomenon may be related to the nature of water (PH & Total dissolved salts), (Epoxy hardness value on the tap water after 4 hours at 60 °C) was only (57) while on the distilled water shore hardness value was (50) for the same temperature & period). This could possible concerned with the fact that the fracture toughness appears to decrease with immersion

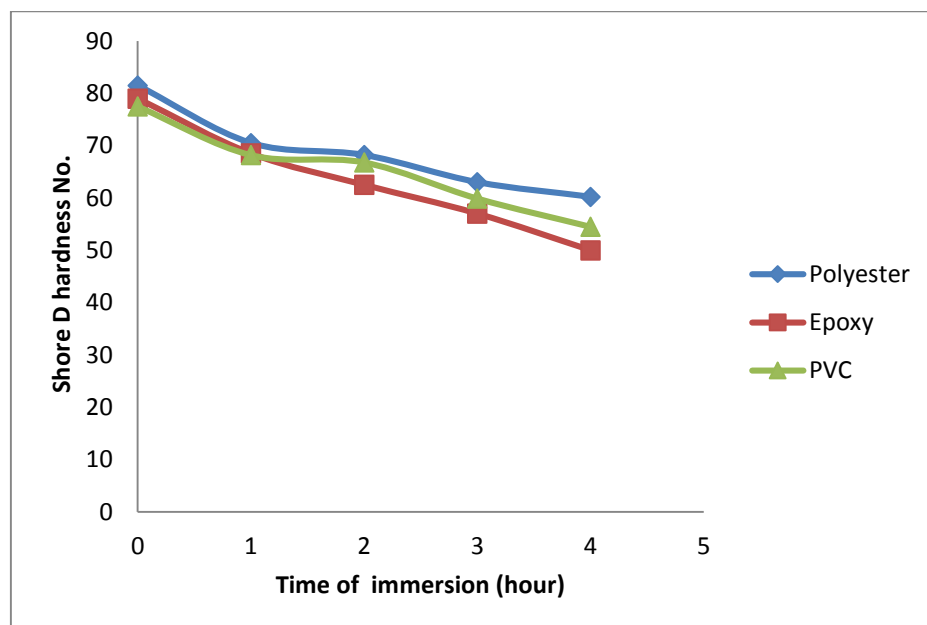
time for distilled water whereas it is interesting to note that it increase for the salt water environment, this could be explained. If NaCl molecules act as an interphase between the materials particles and causes the reduction in interfacial shear. This will increase the energy absorption capability at the interface resulting in the increase of the fracture toughness inside the materials which causes the increase in the hardness value, [13].



**Fig.(7) Influence of distilled water on Shore (D) hardness No. of Samples at 40 °C after 4 hours of immersion.**



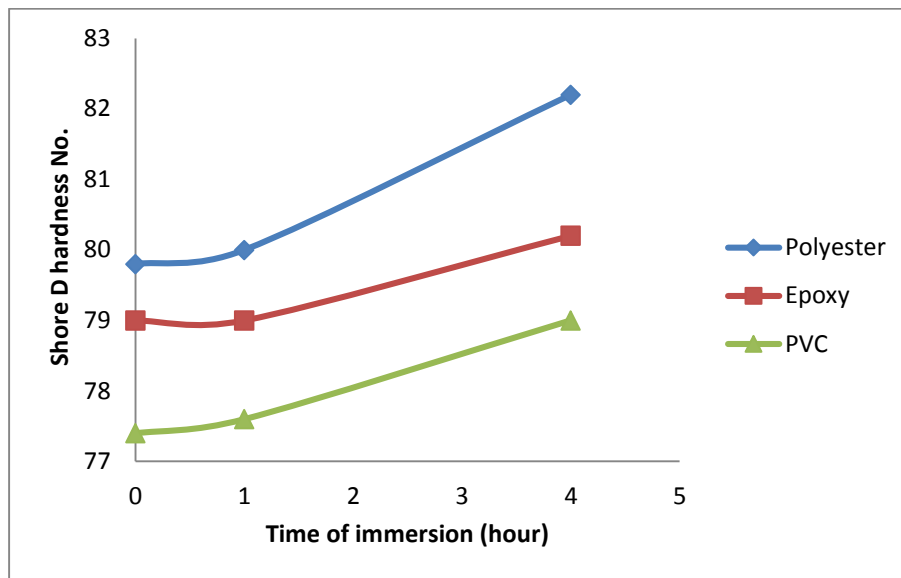
*Fig.(8) Influence of distilled water on Shore (D) hardness No. of Samples at 50 °C after 4 hours of immersion.*



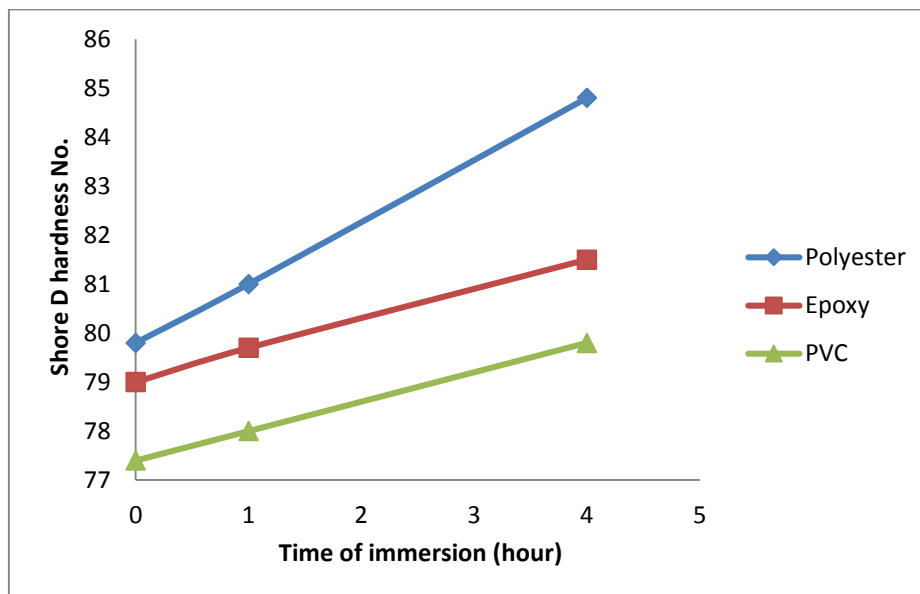
*Fig.(9) Influence of distilled water on Shore (D) hardness No. of Samples at 60 °C after 4 hours of immersion.*

Figs. (10 & 11) illustrate that the hardness value increases after immersion all the samples in both types of water at (10 °C) for (1, 2,3 & 4) hours, even more than the value of the hardness for the dry condition. In this case our measurement was in 1 & 4 hours only, because the effect of this degree on the samples is so slowly. It is noticed that (UPE) possess the highest value of Shore (D) hardness & all the samples were affected by distilled water more

than tap water in this state. When the temperature was decreased then the motion of polymer molecules decreased that the hardness value becomes greater, [14].



*Fig.(10) Influence of tap water on Shore (D) hardness No. of Samples at 10 °C after 4 hours of immersion.*



*Fig.(11) Influence of distilled water on Shore (D) hardness No. of Samples at 10 °C after 4 hours of immersion.*

### Conclusion

The effect of variation of water temperatures on shore (D) hardness for some polymers were investigated. The following conclusion could be drawn.

1. The hardness value of all the polymeric samples in this research were decreased after the immersion in both (tap & distilled water) at (25 °C) compared with there values at the dry state and this decreasing continues as the period of the immersion increases for both kinds of water used with slight change between their values.
2. During increasing the immersion temperatures, all the samples showed fast decreasing in the hardness value and the decrease continues as the period of immersion increases.
3. It was noticed that the epoxy resin has the maximum affection at higher temperature immersion, while PVC has the minimum.
4. The hardness value for all the samples increases when reducing the immersion temperature even more than their values at the dry state. Cooling the immersed samples causes increasing in the binding



- force between the particles which in turn causes more hardness for the samples.
- At higher temperature of immersion it was noticed that the samples affected and change their behavior faster and more noticeable, while reducing the immersion temperature, means on need more time to effect on the same polymeric samples.
  - There are no effects observed on the shapes, dimension or color of the samples after the immersion water under all conditions.

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## الخلاصة

أجري البحث الحالي لدراسة وتحديد قيم صلادة شور (D) لمواد بوليميرية مختلفة (ايبوكسي E<sub>p</sub> والبولي استر غير المشبع UPE والبولي فاينيل كلورايد PVC غير المشبع. بعد تحضير نماذج البحث وتحديد قيم صلادة شور لجميع النماذج عند درجة حرارة الغرفة (٢٥ درجة مئوية) و يتم غمر النماذج في نوعين من المياه (ماء الحنفية و الماء المقطر) وباستعمال حمام مائي يسخن بدرجات حرارية (٤٠ و ٥٠ و ٦٠) مئوية ولفترات زمنية (1,2,3,4) ساعة. تم غمر نماذج اخرى بعد خفض درجة الحرارة الى (١٠) درجة مئوية باستخدام انواع المياه المستخدمة سابقا ولفس الفترة الزمنية لغرض المقارنة بين جميع النتائج المستحصلة. لقد وجد ان قيم صلادة شور تقل بعد غمر النماذج الثلاثة في جميع انواع المياه المستعملة عند درجة حرارة الغرفة للفترات الزمنية التي اجري فيها الاختبار وهذه القيم تستمر بالنقصان عند غمر النماذج بحوض مائي وبزيادة درجة حرارة الماء لكلا نوعي المياه المستعمل، بينما نجد ان قيم صلادة شور تزداد لجميع العينات عند الغمر بدرجات حرارية منخفضة تصل الى (١٠) مئوية لنفس الفترات الزمنية. وقد لوحظ من خلال النتائج المستحصلة ان معدل الانخفاض او الزيادة لقيم الصلادة للعينات المستخدمة تعتمد على فترة الغمر ونوع المحلول او طبيعة الماء المستخدم للغمر ودرجة حرارته.