

## Study and Characterization of PP-R/Polyolefin Elastomer and PP-R/EPDM Blend: Effect of Chlorinated Water on Blend Performance

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- ✓ Chlorinated water,
- ✓ polypropylene random copolymer,
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- ✓ degradation,
- ✓ Blend, Disinfectant.

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### Abstract

The chlorine present in water use as a disinfectant was reported to reduce the lifetime of polymeric material. Blends of Polypropylene random copolymer (PP-R), ethylene butene copolymer (EBC) and ethylene propylene diene terpolymer (EPDM) were prepared by melt mixing in a twin screw extruder. Mechanical, thermal, and morphological properties of the blend systems have been investigated as a function of two different elastomer, chlorine concentration and temperature of test condition. The prepared PP-R/EBC and PP-R/EPDM blend were exposed to chlorine with varying concentration of 50ppm, 500ppm and 5000ppm at different temperature. Mass changes was found for all composition was below statistical limit of 0.5%. The tensile strength of PP-R increases with increase in chlorine concentration with decrease in percent elongation and in PP-R/EBC and PP-R/EPDM blends no significant changes was found. Thermograms obtained from differential scanning calorimetric studies reveal that blends have lower percent crystallinity values compared to pure PP-R and after exposure also no increase in crystallinity was found, which confirms excellent resistant of blends to chlorinated water. Optical microscopic observations on surface indicate formation of black domain and increase in surface roughness in PP-R after exposed to 5000 ppm of chlorine and in PP-R/EBC and PP-R/EPDM no changed was observed indicates the better resistant of blends to hot and cold chlorinated water.

### 1. Introduction

Water chlorination is an acknowledged method and predominantly used method to kill the bacteria to render the water potable. It is necessary to add disinfectant such as chlorine dioxide  $\text{ClO}_2$  or Chlorine  $\text{Cl}_2$  [1-3]. Many polymers exposed to chlorinated water deteriorate faster that can influence on the properties of polymer and its application performance. Mostly polymeric materials application in handling of chlorinated water include cold and hot water pipe distribution system, membranes, pump parts, water purifier, etc. [4, 5]. However, disinfectant have the potential to initiate and accelerate the oxidation process. Long term contact with water containing chlorine is known to lead to degradation effects such as polyethylene embrittlement depends on the chlorine concentration, temperature, pH, and contact time and pressure [6, 7]. Already several studies have confirmed that this polymer embrittlement is due to oxidation induced by chlorine. This oxidation can be measured by mechanical properties, mass crystallinity, thermal properties, carbonyl group content and surface morphology [3, 8-11].

Polypropylene (PP) is one of the most widely used engineering polymers because of its low cost, good mechanical and thermal properties, wide chemical resistance, and easy processing [3, 12, 13]. However, its percent elongation at higher temperature and chemical stability in highly acidic environment often limits its industrial applications in water distribution system. To address this issue, numerous researches have been conducted in preparing highly chemical resistant material toughened PP blends over the last 10 years. To date, elastomer-toughened PP blends are one of the most successful systems for various kind of application. Elastomers can be ethylene-propylene diene monomer (EPDM), polychloroprene rubber, fluoro elastomer, silicon rubber etc. More recently, poly(ethyleneoctene) (POE) was used as the impact modifier for PP, and the results show that POE presented good toughening efficiency with better processability and good chemical resistant than neat PP-R.

As a new product of modified PP, polypropylene random copolymer (PP-R) has received a great deal of attention from academics and industry [14, 15]. By copolymerization with propylene, ethylene was occasionally

embedded into the long propylene sequences. Consequently, the crystallization of the propylene sequences is disrupted by the embedded ethylene units, leading to a decrease in total crystallinity, rigidity, and melting point of PP. As the copolymer is mainly composed of long propylene sequences and occasional ethylene units, PP-R has shown to have excellent thermal stability, aging resistance, and mechanical properties, making it attractive for piping systems for both domestic and industrial applications [16-18].

POE is characterized by a narrow molecular weight distribution and homogeneous octene distribution that exhibits the advantage of good processability and compatibility with PP [19-21]. When compared with conventional EPR or EPDM, POE exhibits the advantage of mechanical properties when blended with PP [22-25]. There are a wide variety of materials available to the water industry, ranging from nitriles (NBR), neoprenes, EPDMs, Polytetrafluoroethylene (PTFE), Polysulphone (PSU), Polypropylene (PP) and Polyvinyl chloride (PVC). Each elastomer has a unique reaction when exposed to free chlorine or chloramines; some have been observed to resist degradation, while others degrade rapidly [26, 27]. Polyolefin Elastomer (POE) Engage is a premier impact modifier for a wide variety of plastics and Thermoplastic elastomer (TPO) applications. Blends using ENGAGE resins exhibit significant improvements in impact strength and a better balance of properties with addition levels ranging from 5 to 30% [28, 29]. Several new EPDM-based products were reported that have been formulated specifically for chloramine resistance in aggressive water utility applications. EPDM rubber is ideal for outdoor applications because of its excellent resistance to ozone, oxidants, and severe weather conditions. Within the water industry, EPDM is widely used for O-rings, valve seats, flat gaskets, and pond liners. More recently, peroxide-cured EPDM is being used where chloramines resistance is important [27].

In this study, aim was to prepared chlorine resistant polymeric blend which offer the same properties in comparison with high cost PTFE, Polyether sulfone, Crosslinked Polymer etc. Here, we prepared the blend of PP-R/Polyolefin elastomer and PP-R/EPDM, which is low cost and easily processable material. The prepared of blend of PP-R/Polyolefin elastomer and PP-R/EPDM exposed to different concentration of chlorine like 50 ppm, 500 ppm, 5000ppm. Also the test was carried at higher temperatures in order to study the performance of blend in accelerated environment. After exposer to chlorine, the blend tested for its physico-mechanical properties, thermal properties, weight loss, surface hardness and morphological changes.

## 2. Experimental

### 2.1. Material

PP-R (MFI 12 gm/10min, Grade: REPOL SRM100NC) in form of pellets has been supplied by Reliance, Mumbai, India. Ethylene propylene diene terpolymer (EPDM) (pellet form, Mooney viscosity, ML1+4 at 125°C 45, NORDEL IP 3745, ethylene content = 70% with 0.5% of ENB, and density of 0.88 g/cc) and Ethylene-Butene copolymer (EBC) (pellet form, Mooney viscosity, ML1+4 at 121oC 13, Engage 7256, having Crystallinity 23% and density of 0.885 g/cc) is supplied by Dow chemical, Mumbai, India. Sodium Hypochlorite (NaOCl) was supplied by SD Fine Chemicals, Mumbai having 4% available chlorine. Also the NaOH and HCL was supplied by SD Fine Chemicals, Mumbai.

### 2.2 Preparation of Blend

Blend of PP-R/EBC and PP-R/EPDM were prepared in ratio 70:30. Firstly, the mix was melt blended in a twin screw co-rotating extruder (Lab Tech Engineering Co. Ltd., Germany) having L/D ratio of 32:1 and temperature profile from the hopper to the die as 185°C, 200°C, 215°C, 230°C, and 220°C respectively. Extruded strands were water cooled at 30°C and pelletized. Pellets obtained were used for injection molding after pre-drying at 80°C for 8 - 10 hrs. Injection molding (Boolani machineries India ltd, Mumbai, India) was done maintaining temperature profile as 190°C, 210°C and 230°C from the hopper to the ejection nozzle respectively. Standard ASTM based samples for tensile testing were obtained from injection molding. Formulation of PP-R/EBC and PP-R/EPDM was given below. The sample codes are provided in Table 1. In the sample code 'PP-R' stands for Polypropylene random copolymer, EBC stands for ethylene butene copolymer (Engage 7256) and 'EPDM' stands for Ethylene propylene diene terpolymer (Nordel 3745).

**Table 1:** Formulation of Blends.

Sr. No	Sample Name	Polymer (Wt %)	Elastomer (Wt %)
1	PP-R	100	0
2	PP-R/EBC	70	30
3	PP-R/EPDM	70	30

### 2.3 Accelerated ageing methods

Ageing solutions were prepared according to ASTM D6284a with reagent water from a 4% sodium hypochlorite. Water pH was adjusted using NaOH and HCl. The first method (referred to as the 50 ppm method) involved adding 4% NaOCl directly to reagent water to achieve 50 ppm as Cl<sub>2</sub> free available chlorine concentration. Same procedure was followed for the preparation 500 ppm and 5000 ppm chlorinated solution [11]. Several die-cut dog-bone shaped PP-R, PP-R/EBC and PP-R/EPDM samples were placed in separate 1 L glass bottles as shown in figure 1. Chlorine solution was added and sealed bottles were stored vertically in a 25°C and 80°C oven in the dark. On Day 21 (500 h), the samples were removed from chlorinated solution and placed in reagent water and stored in the dark at room temperature. After 24 h of soaking in reagent water, all remaining samples were removed and dried in an oven at 60°C for 24 hr. Tensile properties after ageing were measured according to ASTM D638. Physical properties also measured after specified interval of time e.g hardness, melting point, percent crystallinity, surface structure, and percent mass change. Test specimens were routinely inspected visually.



**Figure 1.** Glass Bottle with Cap for Immersion of sample.

### 2.4 Characterization of Blends

#### 2.4.1 % Mass Change

Aged sample were dried in an oven for 24h at 80°C before weight measurement. Mass variation was calculated by the equation:  $\Delta M = \{[(M_f - M_i) / M_i] \times 100\}$ , where  $M_f$  is the final mass and  $M_i$  is the initial mass.

#### 2.4.2 Surface Hardness

Polymer hardness was measured with a shore D hardness test according to ASTM D2240 using a Zwick 7206 Hardness Tester. Three measurements were taken for each sample and then averaged to ensure a uniform hardness value representative of the sample as a whole.

#### 2.4.3. Mechanical tests

Dumbbell-shaped samples were subjected to tensile test to determine tensile strength, % elongation as well as Young modulus using LLOYED UTM with 50 kN load. Cross head speed was set to 50 mm/min. Sample dimension was 50 mm × 5 mm × 2 mm. Numbers were derived from three replicas of the same samples producing close results.

#### 2.3.4. Differential scanning calorimetry (DSC)

To analyze the melting and crystallization behaviors of neat polymers and their blends, differential scanning calorimetry (TA Q100, USA) was used. The samples were heated from room temperature to 200°C at 10°C min<sup>-1</sup> and kept for 2 min at this temperature to erase thermal history. Then the crystallization process of the blends was cooled to 0°C at a controlled rate of 10°C min<sup>-1</sup>. After holding the samples at 0°C for 2 min, the melting tests were scanned at a heating rate of 10°C min<sup>-1</sup> from 0 to 200°C. The second melting curve was recorded to calculate the crystallinity. Weight of each sample was about 5 mg. Crystalline content ( $W_c = \Delta H_m [\text{Experimental}] / \Delta H_m [100\% \text{ Theroetical PP}]$ ) was calculated by using the melting peak ( $\Delta H_m$ ) on the first heating where  $\Delta H_m [100\% \text{ Theroetical PP}]$  is 293J/g [23].

#### 2.3.5. FTIR analysis

The FTIR spectra of both sample before and after exposed to chlorinated water (2mm thick) have been recorded on a Bruker-Alpha's Platinum ATR model. Sample are characterized on Attenuated total reflection (ATR) mode in wave number ranging from 500-4000 cm<sup>-1</sup>

### 2.3.6 Surface morphology by Optical Microscope

All Blend Photographs were taken through a microscope with x20 magnification on Olympus BX41 (Melville, NY – Olympus) optical microscope.

## 3. Results and discussion

Experiments were performed using two different polymeric blend, PP-R/EBC and PP-R/EPDM with 70:30 ratio. A key criteria in selecting the latter material was our expressed goal of working with a PP-R blend and its performance against chlorine as a disinfectant.

### 3.1. % Mass Changes

In Table 2 and 3, the changes in weight of pure PP-R and its blend was mentioned before and after exposed to chlorine at different temperature for 500 hr. It was observed that as the concentration of chlorine increases, the weight gained also increasing due to the oxidation of material. Normally at higher temperature the chlorine deposited on the contact material which lead to increase in the weight of material because the effect being measured is a chemical reaction, it is assumed that the rate of the reaction increases with increasing temperature based on the exponential law for chemical reaction. Mass variation remain lower than 0.5% of the initial mass of all sample which is statistically significant. Its shows PP-R/EBC 73 and PP-R/EPDM 73 blend were resist the chlorinated water at higher concentration of chlorine at higher temperature.

**Table 2.** Mass change (%) of PP-R, PP-R/EBC 73 and PP-R/EPDM 73 after 500 hr of exposure to chlorinate water at 25°C

Sr.No	Sample Name	0 ppm	50 ppm	500 ppm	5000 ppm
1	PP-R	0.01	0.02	0.01	0.09
2	PP-R/EBC 73	0.02	0.01	0.03	0.10
3	PP-R/EPDM 73	-0.02	-0.01	0.01	0.09

*Note : Weight Changes within  $\pm 0.6\%$  were not statistically significant[30]*

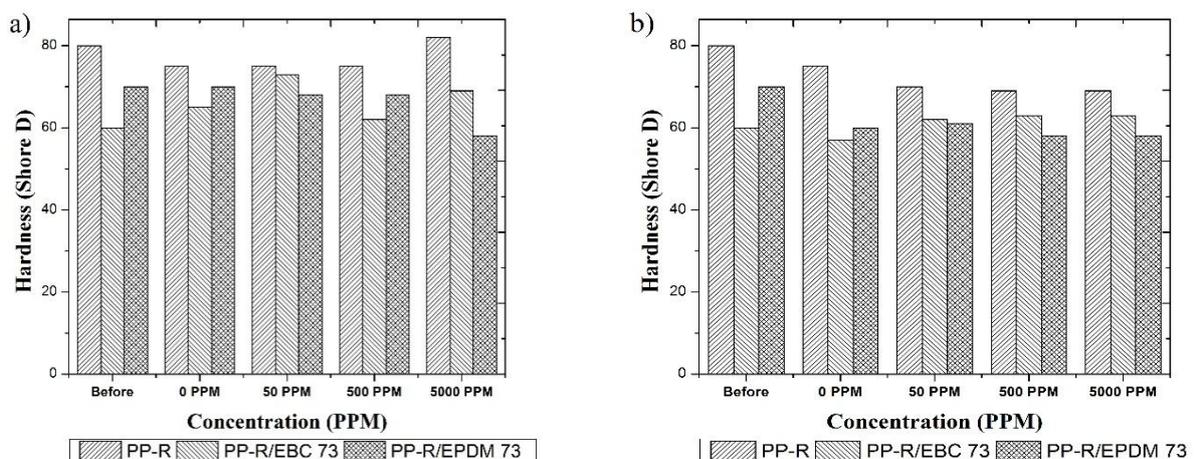
**Table 3.** Mass change (%) of PP-R, PP-R/EBC 73 and PP-R/EPDM 73 after 500 hr of exposure to chlorinate water at 80°C

Sr.No	Sample Name	0 ppm	50 ppm	500 ppm	5000 ppm
1	PP-R	0.01	0.02	0.01	0.18
2	PP-R/EBC 73	0.00	0.01	0.01	0.20
3	PP-R/EPDM 73	0.01	0.09	-0.03	0.14

*Note : Weight Changes within  $\pm 0.6\%$  were not statistically significant.*

### 3.2. Surface Hardness

Figure 2 depicts the shore D hardness value of PP-R, PP-R/EBC 73 and PP-R/EPDM 73 at a) 25°C and b) 80°C for 500 hr of exposer to chlorine. In applications where long-term elastomer surface hardness is critical, it is important to select a material that will have limited loss of hardness over time.



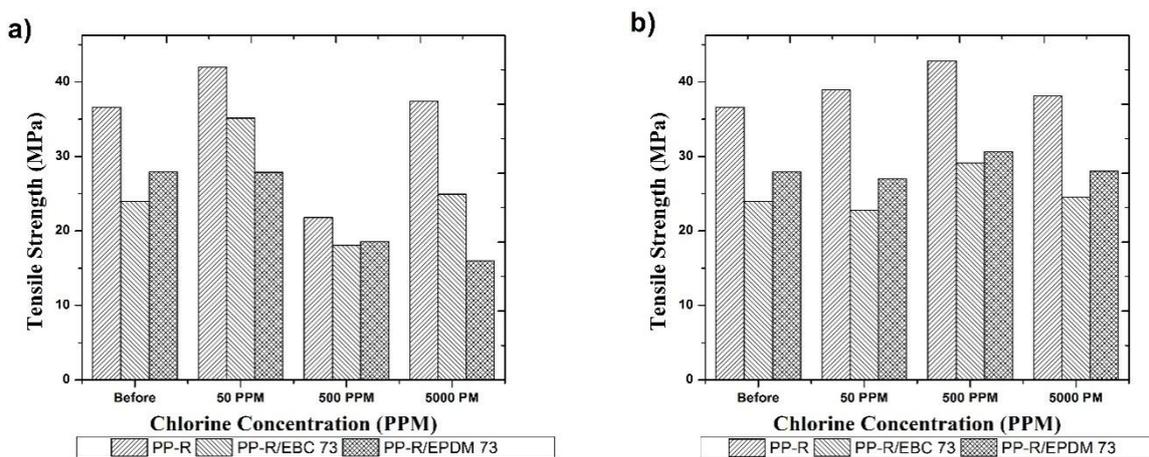
**Figure 2:** (a) Shore D Hardness value of PP-R, PP-R/EBC 73 and PP-R/EPDM 73 at 25°C temperature; (b) Shore D Hardness value of PP-R, PP-R/EBC 73 and PP-R/EPDM 73 at 80°C temperature for various concentration of chlorine.

An application of this in the water utility industry would be in cases where when considering wear resistance of an elastomer part. However, in water utility applications where hardness is not a critical factor, material that exhibit a loss of hardness with time may be suitable, provided they meet other critical performance requirements. As observed from Figure 2, the hardness value in case of pure PP-R is increased after exposed to higher concentration of chlorine, while in case of blend of PP-R/EBC and PP-R/EPDM was decreased. As observed from above hardness graphs, there was seen not significant change in value before and after exposed material. Hence it was concluded that the blend prepared was stable to change in hardness at concentration of chlorine at higher temperature.

### 3.2. Effect of chlorinated water on mechanical properties of PP-R, PP-R/EBC and PP-R/EPDM Blend

The change in breaking strain often is considered in material selection because it correlates to the integrity of the material molecular backbone structure. In applications where long term elongation or strength is critical, such as diaphragms, it is important to select a material that will have limited loss of strain over time. The influence of temperature on material degradation was assessed by systematically blocking other exposure variables so that degradation parameters were only influenced by temperature. A summary of the tensile strength test results was shown in Figure 3a & 3b for 50 ppm, 500 ppm and 5000 ppm chlorine concentration exposure at two different temperature conditions. It is noted that the summary figure present the total change of the measured performance parameter, at the 21-day (500 hr) test point.

From Figure 3, it observed that there was no much difference in tensile strength of PP-R before and after expose to chlorine. The changed was observed in case of PP-R at 500 ppm (80°C) and at 500ppm (25°C) tensile strength found to be slight decrease for all sample. This slight drop in the tensile strength was likely due to the thermal ageing and chlorine attack and the similar results of tensile strength after chlorine expose of 5000ppm at 25°C for PP-R, PP-R/EBC 73 and PP-R/EPDM 73 was observed.



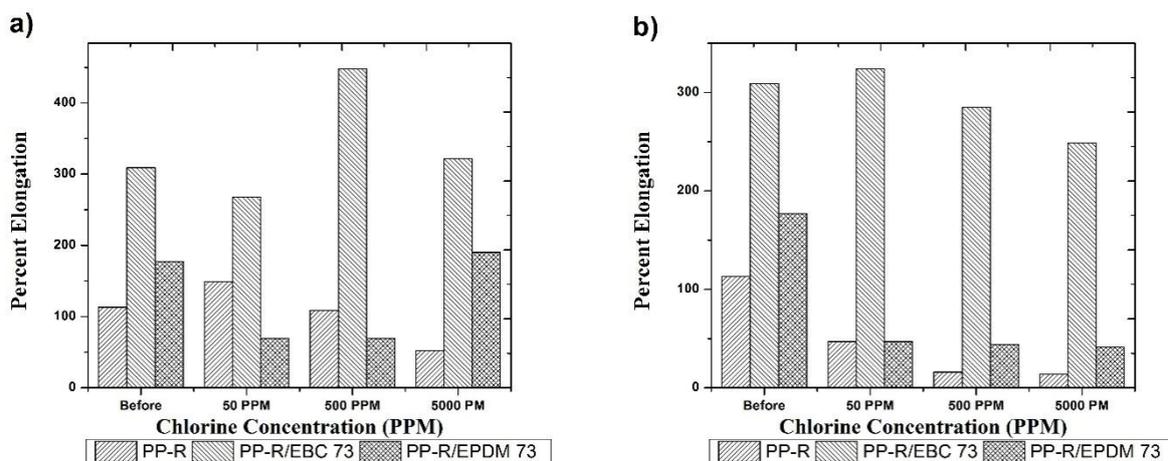
**Figure 3:** (a) Tensile Strength value of PP-R, PP-R/EBC 73 and PP-R/EPDM 73 at 25°C temperature; (b) Tensile Strength value of PP-R, PP-R/EBC 73 and PP-R/EPDM 73 at 80°C temperature for various concentration of chlorine.

As shown in the Figure 4a and 4b, PP-R having very less percent elongation at break originally and as the concentration of chlorine increase along with the temperature it seems to be lowered largely (5000 ppm chlorine at 80°C). Hence it is concluded that the PP-R having less resistant to chlorine and it get tend to be brittle after exposed to higher concentration of chlorine. The percent elongation was decreased in case of PP-R at 5000ppm at 25°C and 80°C from 110% to 50 % and 30 % respectively. There was no much change in percent elongation found for PP-R/EBC at all conditions. Little changed was found in case of PP-R/EPDM at 5000ppm 80°C as shown in figure 4a and 4b. There was, however, great variability in elongation at break results and a clear brittle failure mode for 5000ppm 80°C samples in comparison to ductile fracture for before exposed sample. Ductile failure can be attributed to chain fracture as well as chain disentanglement which were caused by chlorinated water induced oxidation at higher temperature.

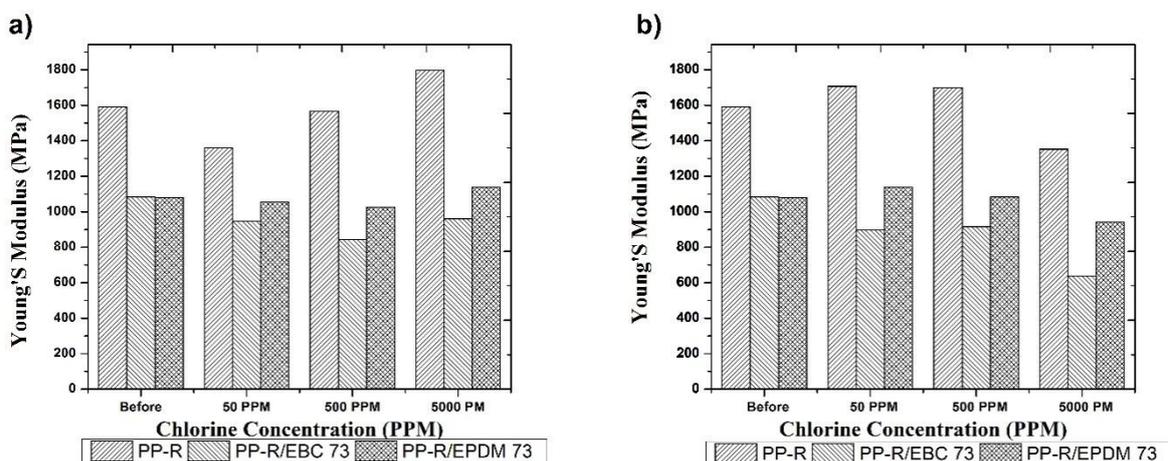
From Figure 5, it was observed that there was slight decrease in modulus at 5000ppm chlorine concentration and after that at higher temperature much difference found for all sample. PP-R/EBC and PP-R/EPDM showing stable modulus value at 25°C as compared to PP-R.

Of the materials evaluated, PP-R/EPDM blend compounds showed the least amount of performance change due to heat aging when exposed to the chlorine for varying concentration. The PP-R/EBC materials exhibited moderate changes in performance. As can be seen from Figure 3, 4 and 5 under all test conditions and with all

of the materials, performance change with respect to temperature, concentration tended to decrease more rapidly i.e., the rate of change of degradation tended to increase as time, temperature and concentration progressed in the 500hr tests.



**Figure 4:** (a) Percent Elongation at Break value of PP-R, PP-R/EBC 73 and PP-R/EPDM 73 at 25°C temperature; (b) Percent Elongation at Break value of PP-R, PP-R/EBC 73 and PP-R/EPDM 73 at 80°C temperature for various concentration of chlorine.



**Figure 5:** (a) Young's Modulus value of PP-R, PP-R/EBC 73 and PP-R/EPDM 73 at 25°C temperature; (b) Young's Modulus value of PPRC, PPRCEN 73 and PPRCEP 73 at 80°C temperature for various concentration of chlorine.

### 3.4. Differential Scanning Calorimetry (DSC)

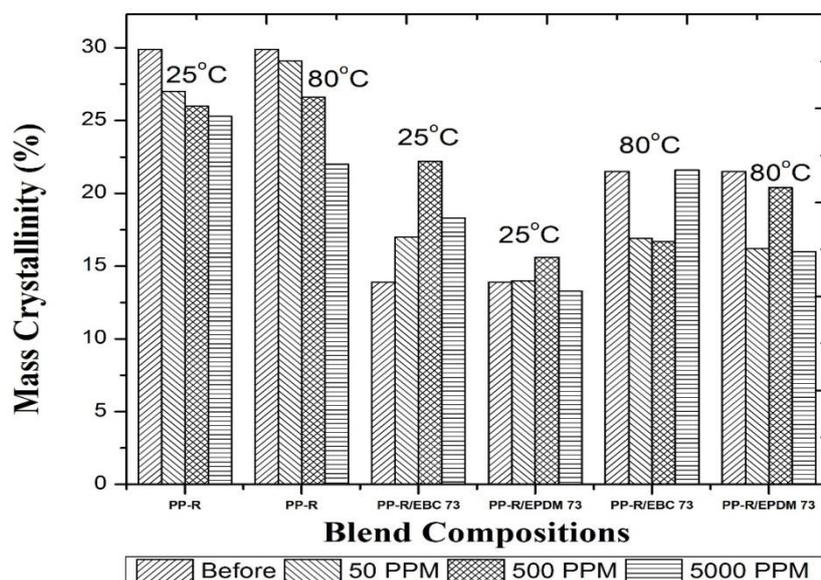
Figure 6, shows the mass Crystallinity profile of PP-R, PP-R/EBC and PP-R/EPDM. It depicts that crystallinity found to decrease in PP-R as concentration of chlorine and temperature increases. Reversed case found in case of PP-R/EBC and PP-R/EPDM the slight crystallinity found to increase with increase in the chlorine concentration and temperature. The melting temperature, crystallization temperature, enthalpy of melting and crystallization data of PP-R, PP-R/EBC and PP-R/EPDM are shown in Table 4, 5 and 6. Exposure for 5000ppm at 80°C in PP-R/EBC and PP-R/EPDM had major influence on the crystallinity profile. There was no influence of chlorine on melting peak temperature of PP-R, PP-R/EBC and PP-R/EPDM blends was observed.

DSC is typically used as a quick screening tool to check any structural changes in the material when heating up the sample. For semi-crystalline materials, this is used to measure the amount of energy needed to crystallize. No changes are seen for the materials whereas a slight shift in crystallization temperature is seen after ageing. This is an indication that the crystalline structure from the material is somewhat changed.

### 3.5. FTIR Spectroscopy

The FTIR spectrum of PP-R, PP-R/EBC and PP-EPDM before and exposed to various concentration of chlorine is shown in Figure 7, 8 and 9. Changes in the chemical structure of the polymer can be observed by infrared spectroscopy. Polymer oxidation is shown by the appearance of hydroxyl (~3400cm<sup>-1</sup>) and carbonyl (~1700cm<sup>-1</sup>)

1) peaks shown in figure 7, 8, and 9 [31-33]. In particular, Colin et al. [32], mainly for pipe sample exposed to water containing chlorine dioxide, had already reported an increase in hydroxyl absorption and as well as an increase in carbonyl absorption in agreement with our data. The OH group increased found significant for ageing at 500 ppm and 5000 ppm as shown in figure 7, 8 and 9.



**Figure 6:** Mass Crystallinity profile of PP-R and its blend at various concentration of chlorine and temperature.

**Table 4:** Thermal Properties of PP-R by DSC for 50 ppm, 500ppm and 5000 ppm exposed sample at 25°C and 80°C temperature for 500 Hr.

Sample name	Tm	Enthalpy of Melting [J/g]	Tc	Enthalpy of Crystallization	% Crystallinity
PP-R Before ageing	149	71.46	115	73.91	29.90
PP-R 50 PPM @ 25°C	147	62.57	114	72.91	26.18
PP-R 50 PPM @ 80°C	148	69.78	115	69.05	29.20
PP-R 500 PPM @ 25°C	149	72.63	113	73.88	30.39
PP-R 500 ppm @ 80°C	150	63.71	113	68.92	26.66
PP-R 5000 PPM @ 25°C	150	60.7	114	73.98	25.40
PP-R 5000 PPM @ 80°C	146	52.67	114	64.68	22.04

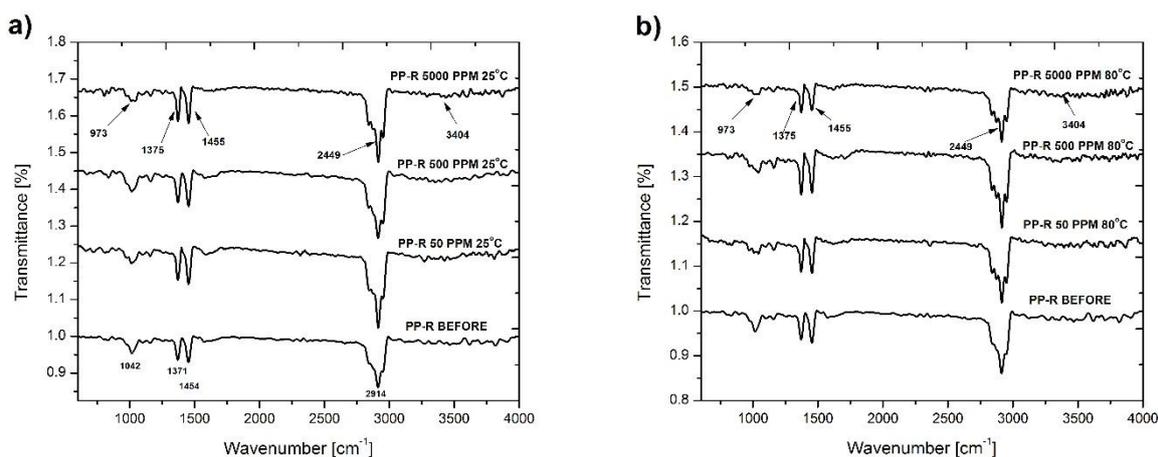
**Table 5:** Thermal Properties of PP-R/EBC 73 by DSC for 50 ppm, 500ppm and 5000 ppm exposed sample at 25°C and 80°C temperature for 500 Hr..

Sample name	Tm	Enthalpy of Melting [J/g]	Tc	Enthalpy of Crystallization	% Crystallinity
PP-R/EBC 73 Before ageing	147	33.25	115	38.91	13.91
PP-R/EBC 73 50 ppm @ 25°C	148	40.73	115	49.96	17.04
PP-R/EBC 73 50 PPM @ 80°C	150	22.97	112	38.27	9.61
PP-R/EBC 73 500 PPM @ 25°C	143	53.2	115	53.3	22.26
PP-R/EBC 73 500 ppm @ 80°C	147	37.34	115	45.62	15.62
PP-R/EBC 73 5000 PPM @ 25°C	148	43.84	118	50.29	18.34
PP-R/EBC 73 5000 ppm @ 80°C	147	31.97	118	37.07	13.38

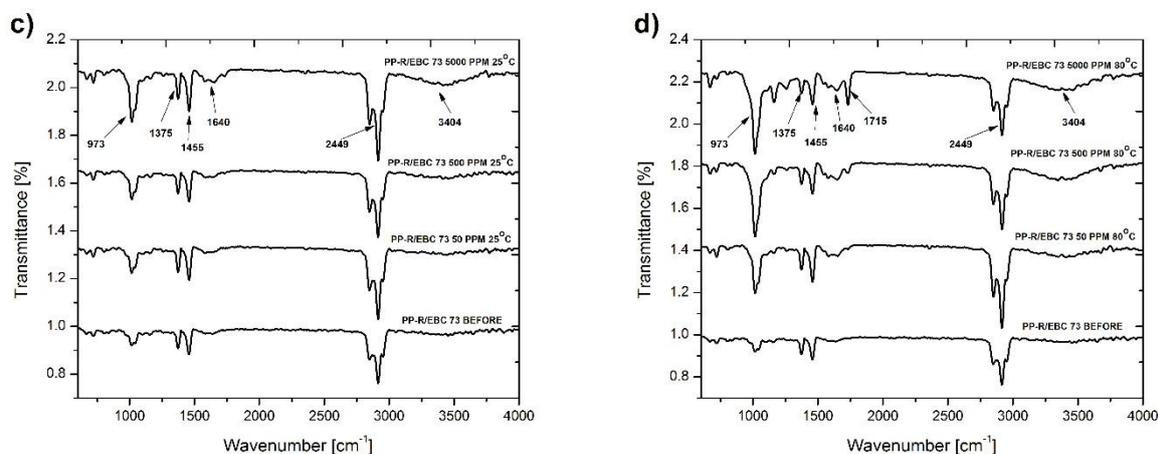
**Table 6:** Thermal Properties of PP-R/EPDM 73 by DSC for 50 ppm, 500ppm and 5000 ppm exposed sample at 25°C and 80°C temperature for 500 Hr.

Sample name	Tm	Enthalpy of Melting [J/g]	Tc	Enthalpy of Crystallization	% Crystallinity
PP-R/EPDM 73 Before ageing	147	51.43	115	58.78	21.52
PP-R/EPDM 73 50 ppm @ 25 <sup>0</sup> C	146	40.46	113	51.88	16.93
PP-R/EPDM 73 50 PPM @ 80 <sup>0</sup> C	147	38.83	114	46.95	16.25
PP-R/EPDM 73 500 PPM @ 25 <sup>0</sup> C	147	40.09	114	50.64	16.77
PP-R/EPDM 73 500 ppm @ 80 <sup>0</sup> C	145	48.99	115	56.12	20.50
PP-R/EPDM 73 5000 PPM @ 25 <sup>0</sup> C	147	51.85	114	63.44	21.69
PP-R/EPDM 73 5000 ppm @ 80 <sup>0</sup> C	150	38.29	118	61.14	16.02

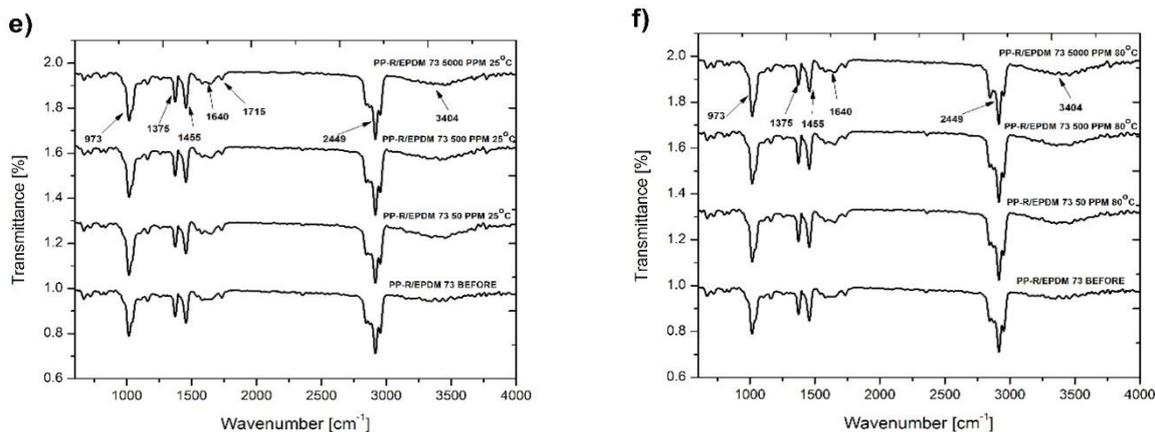
It is well known that failures in polyolefins which occur through oxidative degradation of the polymer create carbonyl groups (carbon – oxygen double bond) in the polymer that do not exist initially. These carbonyl groups absorb infrared radiation in the range from 1900 to 1550 cm<sup>-1</sup> [34]. Figure 7, 8 and 9 compare the inside surfaces of unexposed and exposed sample PP-R, PP-R/EBC and PP-EPDM. The spectra of the PP-R, PP-R/EBC and PP-EPDM blend exposed sample contain peaks of carbonyl species, none of which were present in the unexposed sample. The most intense of these peaks is at 1713 cm<sup>-1</sup> and is associated with the formation of ketone species in polypropylene oxidation. The ketone carbonyl peak is usually the most prominent of the carbonyl peaks that appear in oxidized polypropylene. These ketone groups were found in only PP-R/EBC 73 at 5000 ppm for 80°C. Also the appearance of this ketone peak was observed in PP-R but the peak was not prominent that much.



**Figure 7:** FTIR of PP-R for 50 ppm, 500 ppm, and 5000 ppm concentration of chlorine a) at 25°C and b) 80°C before and after exposed.



**Figure 8:** FTIR of PP-R/EBC 73 for 50 ppm, 500 ppm, and 5000 ppm concentration of chlorine c) at 25°C and d) 80°C before and after exposed.

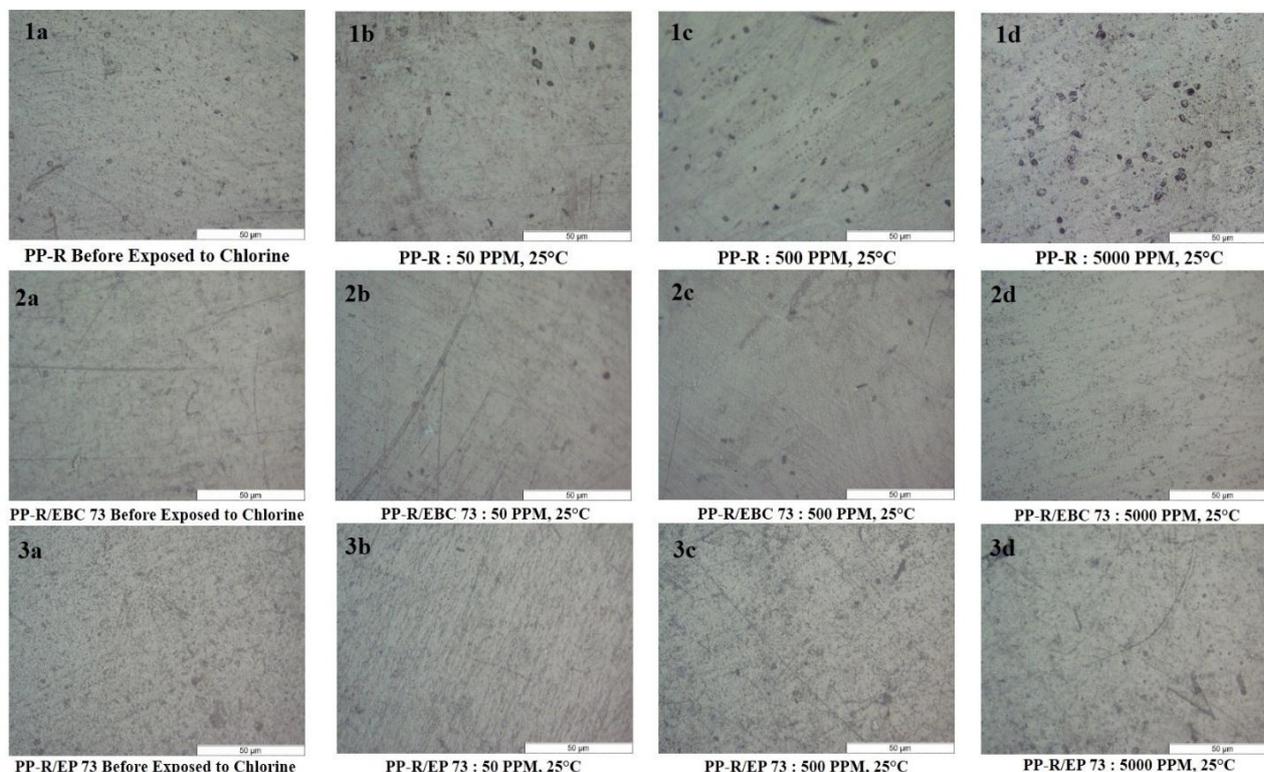


**Figure 9:** FTIR of PP-R/EPDM 73 for 50 ppm, 500 ppm, and 5000 ppm concentration of chlorine e) at 25°C and f) 80°C before and after exposed.

FT-IR is used to evaluate potential chemical organic changes in a material. There are some major changes visible for PP-R/EBC at higher concentration and temperature around 1,700  $\text{cm}^{-1}$ , which is an indication of oxidation. The correlation shows it to be a carbonyl absorption peak, and it should not occur at all. It has been formed by oxidation, which may occur by several possible mechanisms, but especially by processing at too high a temperature and/or exposure to chlorine induced oxidation.

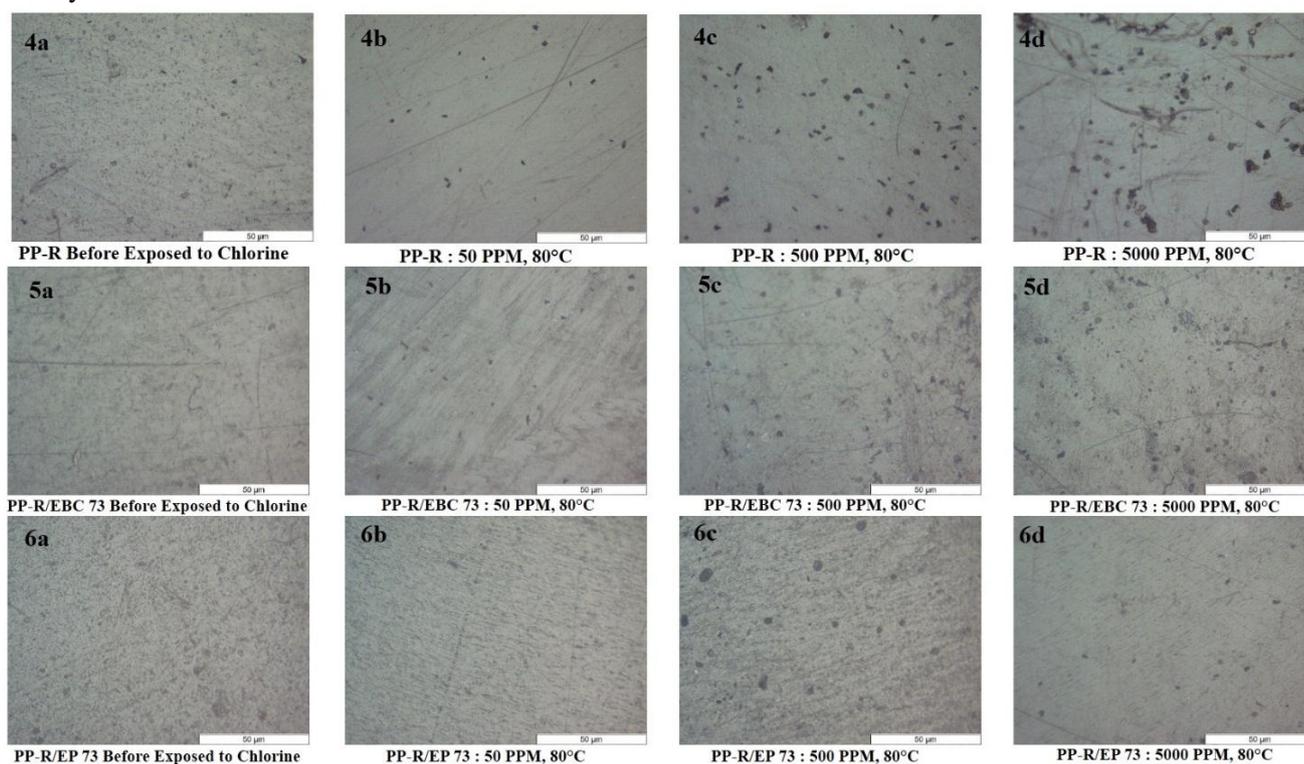
### 3.6 Optical Microscope

Visual microscopic inspection via optical microscope indicate the sample immersed in water for 500 hr showed no micro cracks at 20x magnification as shown in Figure 10 and 11. However major black domain seems on the PP-R surface which may be due to local molecular degradation at the surface of sample. This black domain is more apparent in only PP-R case while in case of PP-R/EBC and PP-R/EPDM it was not prominent. At higher concentration of chlorine and temperature (5000 ppm and 80°C) this domain size is increased and increased in intensity also found.



**Figure 10:** Optical Microscope images of PP-R (1a, 1b, 1c and 1d), PP-R/EBC (2a, 2b, 2c and 2d) and PP-R/EPDM (3a, 3b, 3c and 3d) before and after exposed at 50 ppm, 500 ppm and 5000 ppm of chlorine at 25°C temperature for 500 hr (Photographs were taken through a microscope with x20 magnification).

In case of PP-R/EBC and PP-R/EPDM, the surface looks become clear and smooth showing no sign of cracks and surface roughness which indicate the no degradation on surface of sample. It also indicate the good resistant stability of PP-R/EBC and PP-R/EPDM blend to hot chlorinated water.



**Figure 11:** Optical Microscope images of PP-R (4a, 4b, 4c and 4d), PP-R/EBC (5a, 5b, 5c and 5d) and PP-R/EPDM (6a, 6b, 6c and 6d) before and after exposed at 50 ppm, 500 ppm and 5000 ppm of chlorine at 25°C temperature for 500 hr (Photographs were taken through a microscope with x20 magnification).

## Conclusions

This paper includes weight loss, surface hardness, mechanical properties, FT-IR, DSC and Optical Microscope data for PP-R, PP-R/EBC and PP-R/EPDM that immersed in hot chlorinated water. For exposure time up to 500 hr in hot chlorinated water, PP-R/EBC and PP-R/EPDM showed no desirable changes in mechanical properties and no evidence of degradation of these materials was found in optical microscope. PP-R showed a loss in percent elongation and increase in surface degradation by optical microscope when immersed in hot chlorinated water. The results show that at the highest concentration (5000 ppm), large reductions in performance due to temperature and chlorine effects were measured in PP-R across all performance parameters. While temperature effects appeared to be amplified at high concentrations, PP-R exhibited the least degradation, particularly with respect to percent elongation and change in hardness. At 80°C and at 5000 ppm concentration, all performance parameters were greatly reduced, with bulk parameters changing over 10 percent, and tensile strength and modulus was dropping over 10 percent. For example, PP-R/EBC and PP-R/EPDM at high concentration experienced relatively small changes in performance as temperature increased from 25°C to 80°C. From all the observations it was revealed that, the prepared blends of PP-R/EBC and PP-R/EPDM had excellent resistance to hot and cold chlorinated water.

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