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# Study on synthesis, morphology, composition and thermal behaviour of different IPNs of soybean oil and cardanol based dyes by FTIR, TG, DSC, SEM and biodegradability test

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## Abstract

*Phenolic lipids from plant material are new raw materials from renewable resources and are essential in the preparation of biopolymers , i.e., Cardanol, a meta-substituted alkyl phenol derived from cashew nut shell liquid (CNSL), a by-product of cashew industry, holds a place of biomaterial for the manufacture of many industrial products. Another renewable resource like soybean oil poly-urethane and cardanol based semiliquid amino dyes have been used to synthesize IPNs along with BPO an EGDM which have been highly cross-linked structure with both amorphous and crystalline character. Morphology, composition and thermal behaviour of these samples have been characterised and compared with different NCO/OH ratio and with different amino dyes by FTIR, TG, DSC, SEM and Elemental analysis.*

**Keywords:** Cardanol, CNSL, Polyurethane amino dyes. BPO, EGDM.

## Introduction

Over the past decades a number of attempts have been made to substitute partially or some cases totally renewable resources, analogs for petroleum based polymers[1-3]. But recently cardanol and soybean oil have been used as renewable resources for the preparation of synthetic biopolymers[4-5]. Both of them are excellent monomers for preparation of highly cross linked interpenetrating polymer networks (IPNs). Soybean oil has side chain with unsaturation which helps for polymerisation and its derivatives are hydrolytically stable. Cardanol, m-stabilised phenols also have side chains with unsaturation is also a good monomer forms dye with amino benzoic acid. This paper presents a comparison of IPNs in different NCO/OH ratio and different amino acid dyes of Cardanol by FTIR, TG, DSC, WAXRD, SEM[6-12].

## Materials and methods

**Materials:** i. Refined soybean oil obtained from market. ii. Cardanol was obtained from fractional distillation of CNSL liquid, a by-product of sathya cashew chemical pvt. Ltd., Chennai. iii. NaOH, MEK, EGDM, $NaNO_2$, HCl, PbO, etc. Received from M/S BDH. Ltd. (INDIA), iv. TDI, DPMDI, 3-amino benzoic acid and 4- amino benzoic acid from E merk (Germany).

All chemicals were used as received.

**Method:** i. Spectroscopic analysis- FTIR (fourier transform infrared), ii. FTIR spectra of the prepared IPNs samples have been recorded on FTIR Spectrometer by Thermo Electric Corporation, USA, and Model: Nicolet 670 FT-IR using KBr palette in the wavelength range of 500cm-1 to 4000cm-1. iii. Thermal Analysis-DSC and TGA: of all IPNs have been performed by use of a Universal $v_4$.5A.TA instrument (Model SDT Q 600 V20.9 Build 20) at a rate of $10^0$c/minute. iv. Morphology study (SEM) Morphology of samples have been studied by JOEL scanning electron microscope (SEM) Model JSM 500. For this the fractured samples have been coated with a thin layer of gold- platinum alloy by sputtering to provide conductive surface. v. Element detection: IPNs are heated for 30 seconds in different scale count and the percentage of carbon, Nitrogen and oxygen atoms are given in graph. vi. Study of Crystallinity- wide angle X-ray diffraction study (WAXRD): X-ray diffraction pattern of polymer samples have been collected using a panalytical x'pert pro Θ/Θ goniometer with Cu - Kα radiation. vii. Test for biodegradability- The enviornmental resistance of the IPNs samples was carried out using soil burial test.

**Experimental:** Preparation of dye monomer- 6.85gm of 4-amino benzoic acid was dissolved in 25ml of conc. HCl acid and 25ml of water was added to it. The solution was cooled$0^0$-$5^0$C, and then a cold solution of sodium nitrite (4gm in 20ml of water) was added to it slowly with stirring for 3-4 minutes. A cold solution of cardanol (15g in 45ml) of 10% NaOH solution was prepared. Then cold diazonium solution was added slowly to the alkaline cardanol solution with stirring. A brown colour semi liquid dye was formed. The dye was separated by a separating funnel. Similarly the dye monomer with 3-aminobenzoic acid was prepared.

**Preparation of Mixed Ester Polyol (MEP) from Soybean Oil(SO)**: Refined soybean oil (350ml) was heated at $250^0$ C in an inert Nitrogen atmosphere taken in three naked flask fitted with a thermometer reflux condensers and a stirrer. At this temperature litherage (0.168g) and glycol (80ml) were added to the reaction mixture with constant stirring. The temperature was maintained at $210^0$C until one volume of reaction mixture gave a clear solution in same volume methanol. At this stage the contents were cooled to obtain MEP.

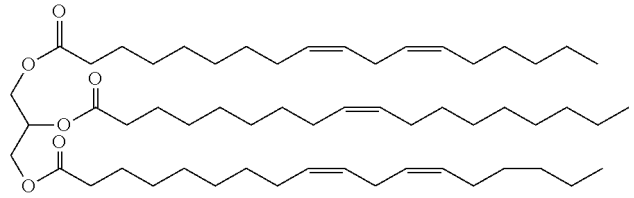
**Synthesis of Polyurethane (PU):** 1 mole of MEP was added to1.6 mole of TDI to maintain NCO/OH ratio at 1.6.The reaction was carried out at$75^0$C with continuous stirring for one hour until a pale yellow colour PU is separated out. The same process was repeated with different NCO/OH ratio (1.2, 1.6, and 2.0) and with other diisocyanate DPMDI PUs was produced.

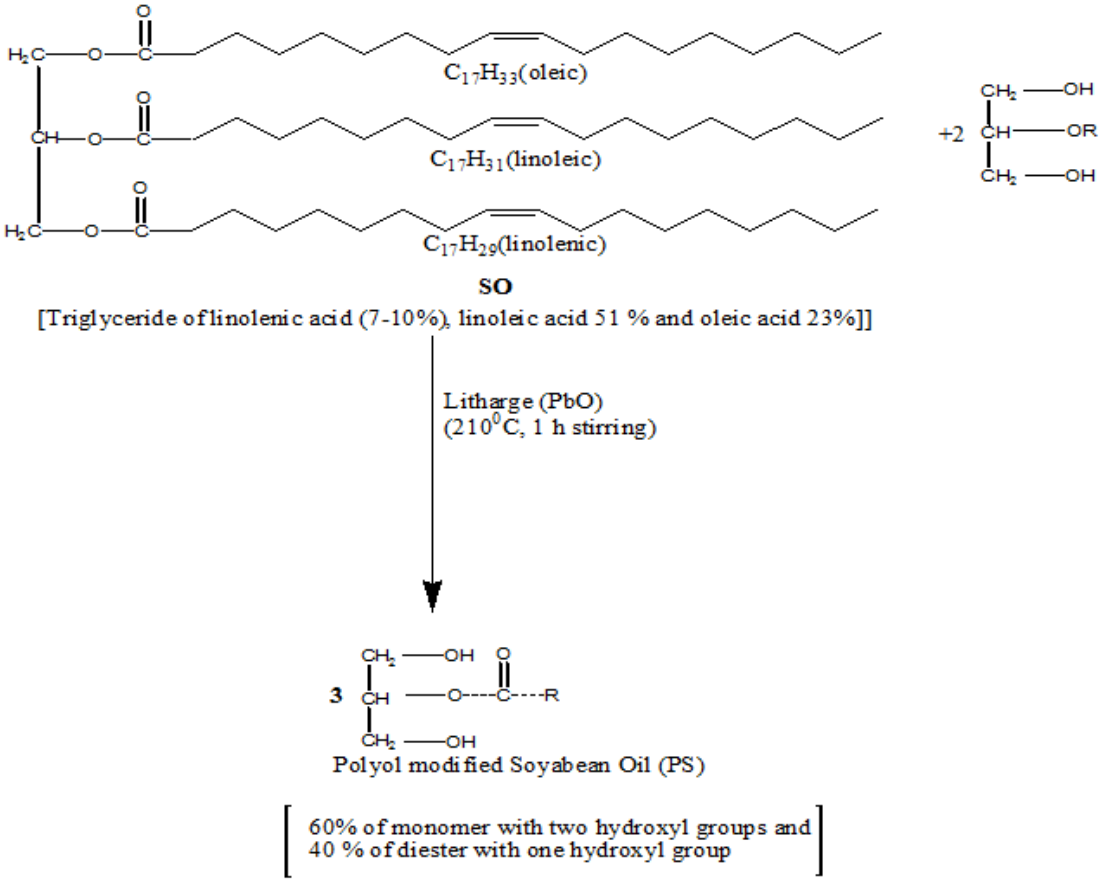
**Synthesis of IPNs:** The mixture of PU and diazotised cardanol (with different PU/monomer ratio i.e., (75:25, 50:50, 65:35) and solvent (MEK) were taken in small beaker. Then 5ml of 10% EGDM along with 20mg of Benzoyl peroxide (BPO) were added to each mixture. The total mixture was stirred for 15 minutes with magnetic stirrer in cold to obtain a homogenous solution .Then the temperature was raised to $75^0$C and stirred until a thick solution was formed. Then the viscous mass was poured into a petridish in hot condition and kept in an oven at $75^0$C for 24 hour.

The thin film thus obtained was cooled and removed from the petridish with a sharp blade and sent for characterisation to the Central Instrumentation Facility Pondicherry University, Puducherry, pin- 605014.

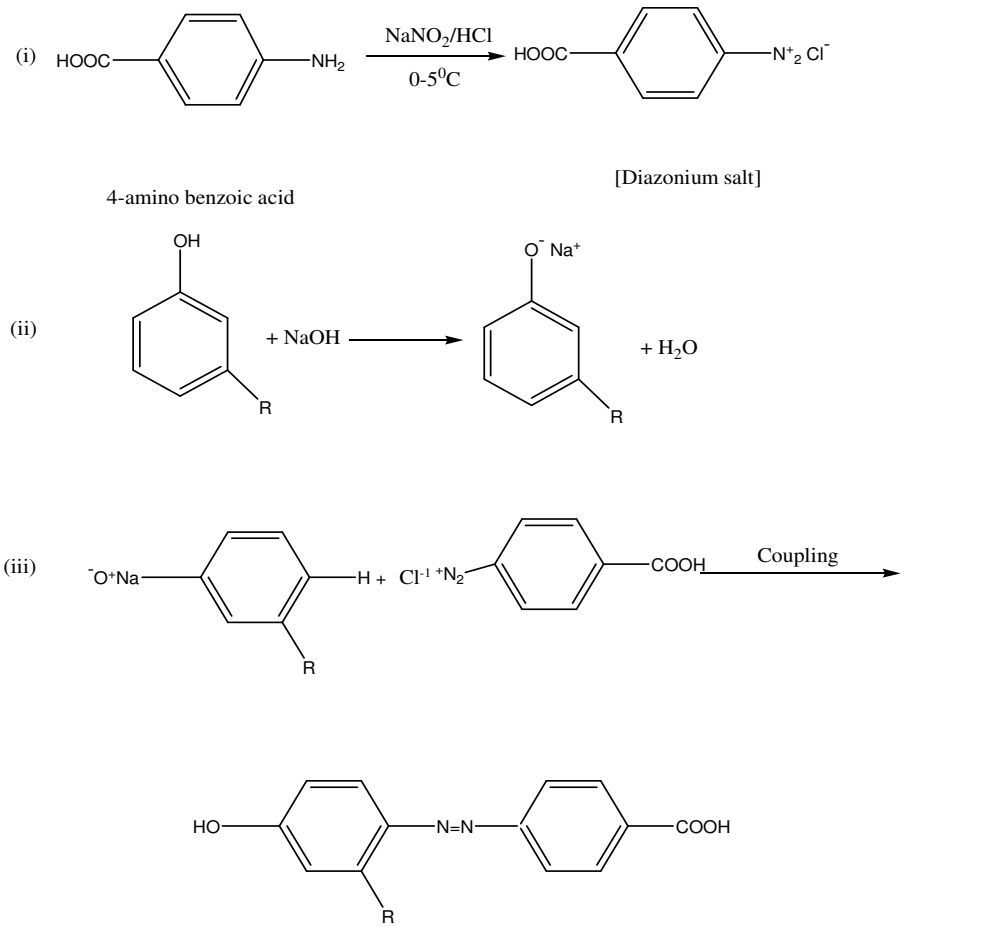
**Soybean oil (SO):** Triglyceride of linoleic (53%), oleic acid (18%) and linoleic acid (15%).

(II)



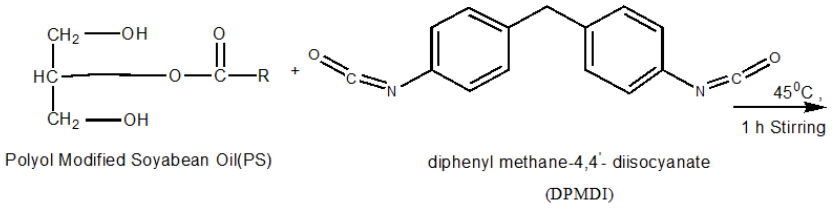



**Scheme-1:** Preparation of polyol modified soyabean oil (PS).



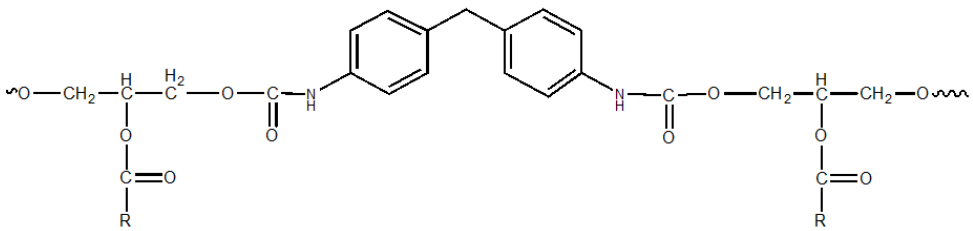

Cardanol based Dye (CD) with 4-aminobenzoic acid

**Scheme-2:** Preparation of based dye (CD) with 4-aminobenzoic acid.

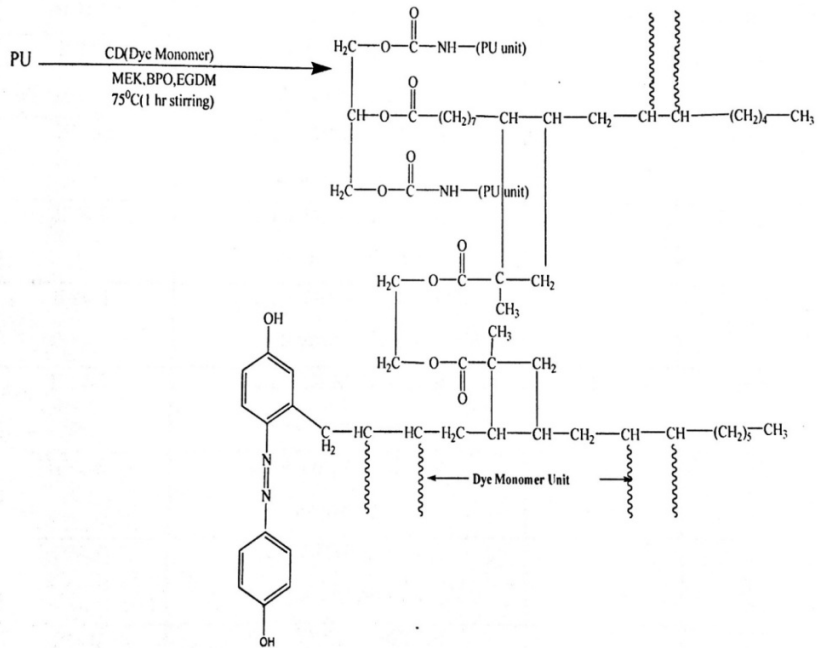



Polyol Modified Soyabean Oil(PS)

diphenyl methane-4,4'- diisocyanate (DPMDI)




**Scheme–3:** Polyurathane (PU).




**Scheme–4:** Interpenetrating polymer network from natural resources.

## Analysis of the Sample

FTIR spectrum is the fingerprint of the entire molecule of the polymer. Hence peak by peak correlation of the unknown IPNs with known authentic compound helps to identify the new IPNs. Functional groups or groups of atoms give rise bands at or near the same frequency regardless of the complete structure of the rest of the compound.

FTIR – The FTIR spectra of the IPNs 10, 12, 14, 24 and 27 are presented in Figures-1-a to 1-e.

**FTIR of IPN 10:** The characteristic absorption of IPN-10 corresponding to IPN-10 to -OH stretching of >OH groups shifted to lower value by hydrogen bonding at 3837.7 $cm^{-1}$. The characteristic absorption of IPN-10 corresponding to IPN-10 to N-H stretching of >NH group at 3441.2 $cm^{-1}$, C-H stretching (ss/as) of $>CH_2$ and $> CH_3$ groups at 2855.4 $cm^{-1}$ and 2924.7 $cm^{-1}$, N≡C stretching of -N=C=O group for the isocyanate terminating PU unit at 2334.8 $cm^{-1}$ , C=O stretching of urethane linkage at 1665.0 $cm^{-1}$ , N=N stretching of azo group at 1589.8 $cm^{-1}$, C-O bending at 1055.2 $cm^{-1}$, C=C stretching at 1390.3 $cm^{-1}$, C-C stretching at 1342.8 $cm^{-1}$, out of plane C-H bending at 723.3 $cm^{-1}$ and out of plane C-C bending at 450.5 $cm^{-1}$ were observed.

**FTIR of IPN 12:** The characteristic absorption of IPN-12 corresponding to IPN-12 to -OH stretching of >OH groups shifted to lower value by hydrogen bonding at 3834.8 $cm^{-1}$. The characteristic absorption of IPN-12 corresponding to IPN-12 to N-H stretching of >NH group at 3402.4 $cm^{-1}$, C-H stretching (ss/as) of $>CH_2$ and $>CH_3$ groups at 2926.5 $cm^{-1}$ and 2857.2 $cm^{-1}$, -N≡C stretching of -N=C=O group for the isocyanate terminating PU unit at 2374.3 $cm^{-1}$ , C=O stretching of urethane linkage at 1727.6 $cm^{-1}$ , -N=N stretching of azo group at 1604.0 $cm^{-1}$, -N=N stretching of aromatic rings at 1542.4 $cm^{-1}$, C-O bending at 1164.2 $cm^{-1}$, C=C stretching at 1531.2 $cm^{-1}$, C=C stretching of aromatic rings at 1232.2 $cm^{-1}$, C-O stretching of ester at 1160.7 $cm^{-1}$, out of plane C-H bending at 869.6 $cm^{-1}$ and out of plane C-C bending at 713.8 $cm^{-1}$ were observed.

**FTIR of IPN 14:** The characteristic absorption of IPN-14 corresponding to IPN-14 to N-H stretching of >NH group at 3456.9 $cm^{-1}$, C-H stretching (ss/as) of $>CH_2$ and $>CH_3$ groups at 2925.4 $cm^{-1}$ and 2856.5 $cm^{-1}$, -N≡C stretching of -N=C=O group for the isocyanates at 2354.0 $cm^{-1}$ and 2546.0 $cm^{-1}$, C=O stretching of urethane linkage at 1691.5 $cm^{-1}$, -N=N stretching of azo group at 1596.3 $cm^{-1}$, -N=N stretching of aromatic rings at 1542.4 $cm^{-1}$, C=C stretching at 1393.2 $cm^{-1}$, C=C stretching of aromatic rings at 1244.8 $cm^{-1}$, C-O stretching of ester at 1166.6$cm^{-1}$, out of plane C-H bending at 784.4$cm^{-1}$ and out of plane C-C bending of p-substituted benzene ring at 695.2 $cm^{-1}$ and 543.1$cm^{-1}$ were observed.

**FTIR of IPN 24:** The characteristic absorption of IPN-24 corresponding to IPN-24 to -OH stretching of >OH groups shifted to lower value by hydrogen bonding at 3590.8 and 3452.4 $cm^{-1}$. The characteristic absorption of IPN-12 corresponding to IPN-12 to N-H stretching of >NH group at 3349.2 $cm^{-1}$, C-H stretching (ss/as) of $>CH_2$ and $>CH_3$ groups at 2921.1 $cm^{-1}$ and 2861.8 $cm^{-1}$, -N≡C stretching of -N=C=O group for the isocyanides at 2771.5 $cm^{-1}$, 2619.9 $cm^{-1}$, 2365.4 $cm^{-1}$, C=O stretching of urethane linkage at 1984.0 $cm^{-1}$ ,-OH bending due to –COOH group at 1306.7 $cm^{-1}$ , -N=N stretching

of azo group at 1605.5 $cm^{-1}$, C-O bending at 1154.8 $cm^{-1}$, C-C stretching of aromatic rings at 1399.7 $cm^{-1}$, C=C stretching of aromatic rings at 1518.6 $cm^{-1}$, C-O stretching of ester at 1160.7 $cm^{-1}$, out of plane C-H bending at 811 $cm^{-1}$ and out of plane C-C bending of p-substituted benzene ring at 634 $cm^{-1}$ and 481$cm^{-1}$ were observed.

**FTIR of IPN 27:** The presence of component materials in the macromolecules was confirmed by the study of FT-IR spectra if the prepared samples. The characteristic absorption of IPN-27 corresponding to IPN-27 to O-H stretching of >OH groups shifted to lower value by hydrogen bonding at 3858.6 $cm^{-1}$. The characteristic absorption of IPN-27 corresponding to IPN-27 to N-H stretching of >NH group at 3444.5 $cm^{-1}$, C-H stretching (ss/as) of $>CH_2$ and $>CH_3$ groups at 2861.9 $cm^{-1}$ and 2747.9 $cm^{-1}$, N≡C stretching of -N=C=O group for the isocyanate terminating PU unit at 2319.9 $cm^{-1}$ , C=O stretching of urethane linkage at 1660.3bcm$^{-1}$ , N=N stretching of azo group at 1547.6 $cm^{-1}$, C-O bending at 1029.3 $cm^{-1}$, C-C stretching of aromatic rings at 1398.8 $cm^{-1}$, out of plane C-H bending at 806.6 $cm^{-1}$ and out of plane C-C bending at 691.8 $cm^{-1}$ and 551.6 $cm^{-1}$ were observed.

**Findings:** From the Figure-1a to 1e correlation with the peak of the authentic compound helps to identify the structure of polymer sample. Thus it is concluded that the polymer sample is an azo based compound which contain –COOH, -OH, $-CH_2$ , $-CH_3$ , -C-O-C stretching of $–OCH_3$ group and benzene rings.

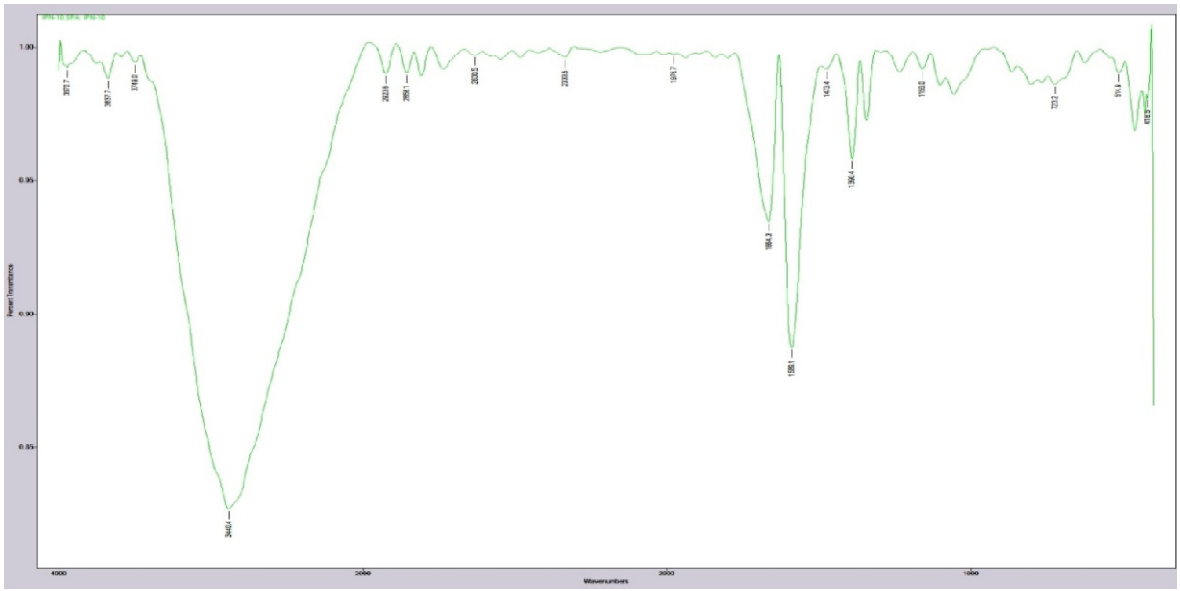


**Figure-1a:** FTIR of IPN-10.

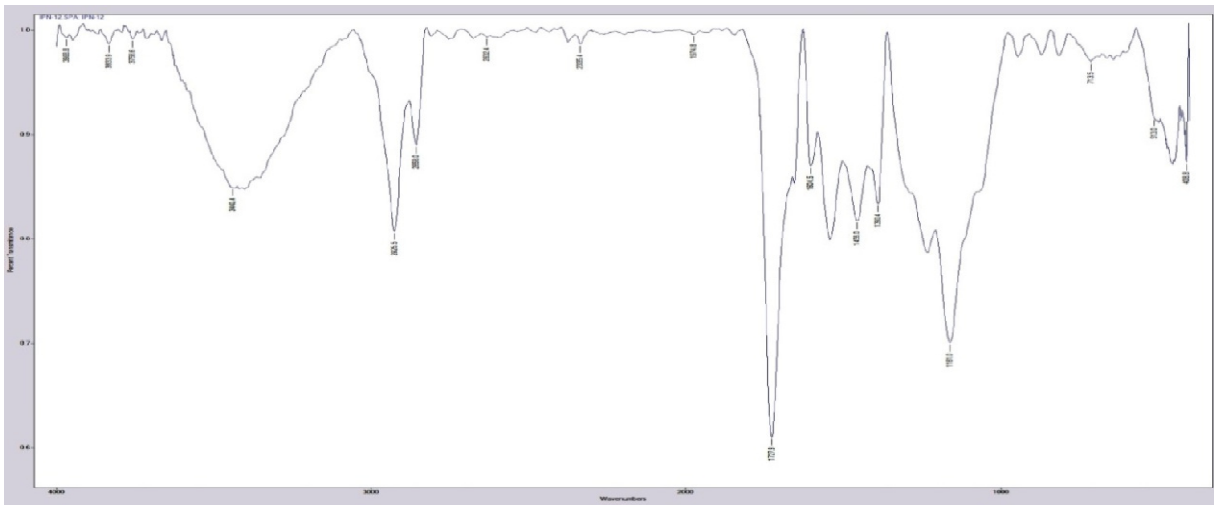


**Figure-1b:** FTIR of IPN 12.

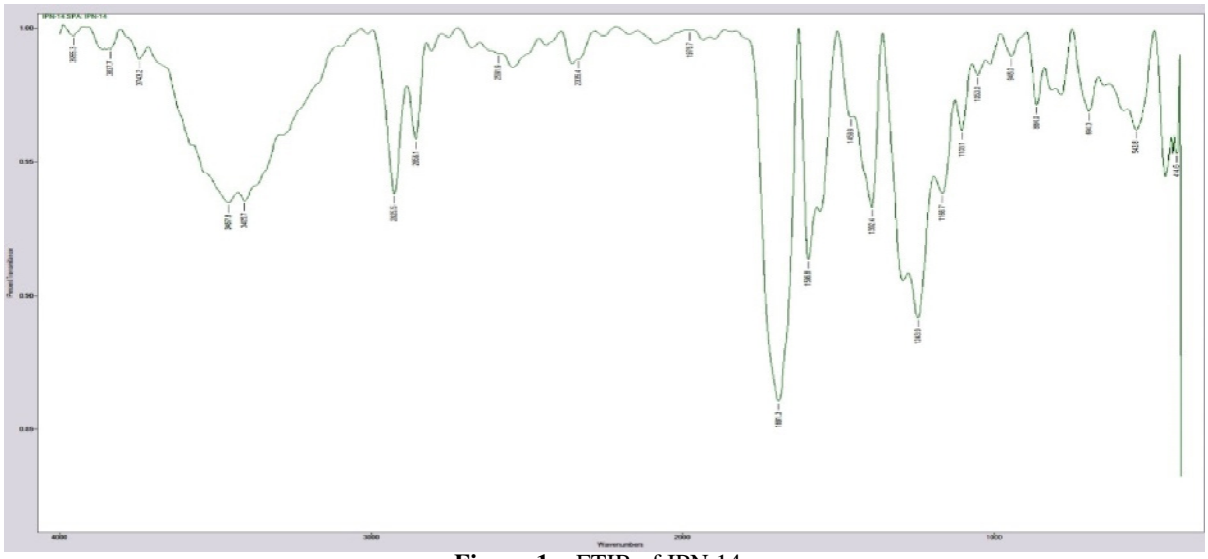


**Figure-1c:** FTIR of IPN 14.

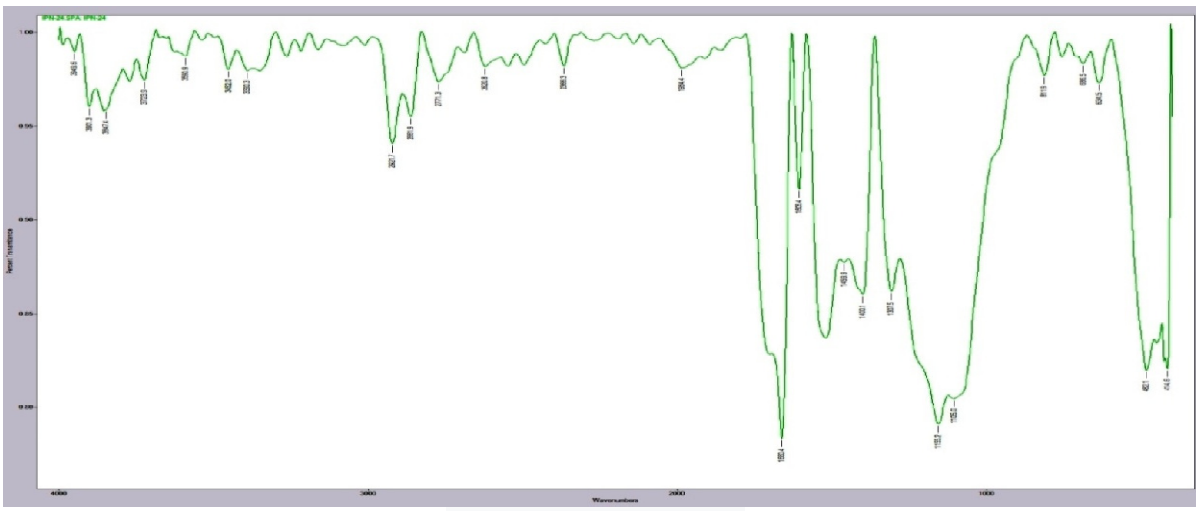


**Figure-1d:** FTIR of IPN-24.

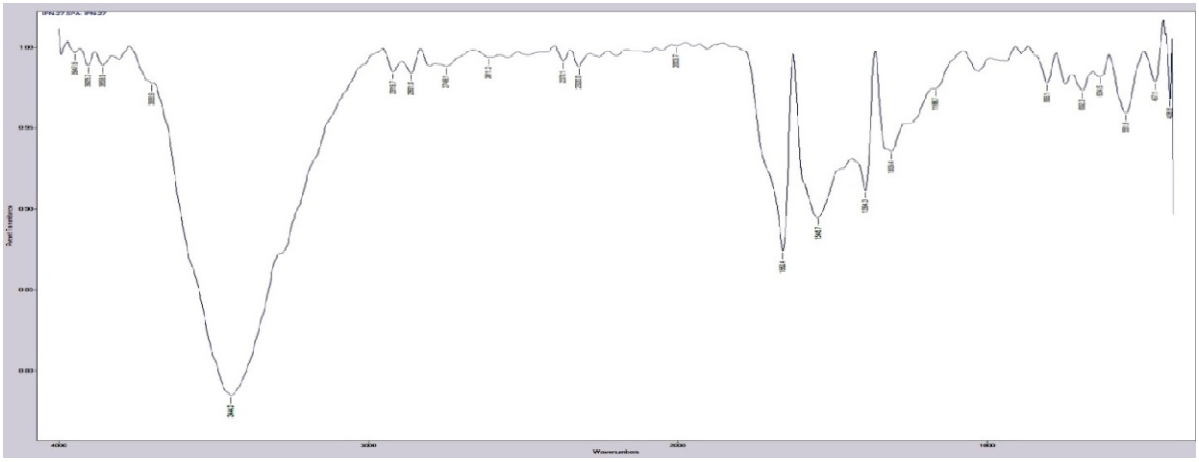


**Figure-1e:** FTIR of IPN-27.

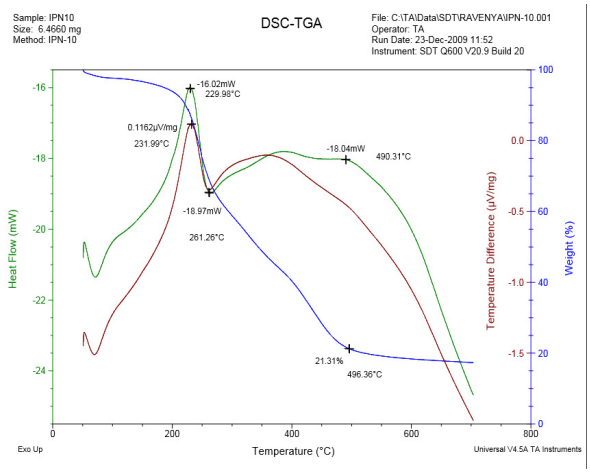



**Figure-2a:** DSC-TGA OF IPN-10.

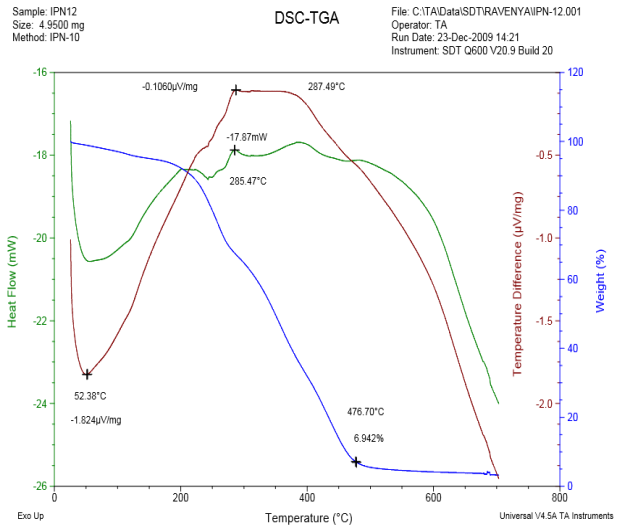



**Figure-2b:** DSC-TGA OF IPN-12.

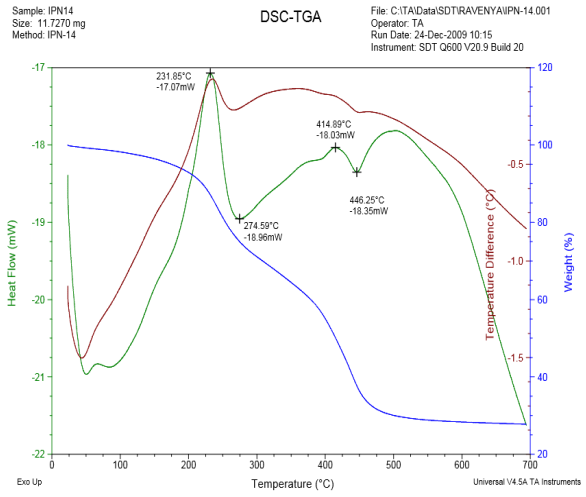



**Figure-2c:** DSC-TGA OF IPN-14.

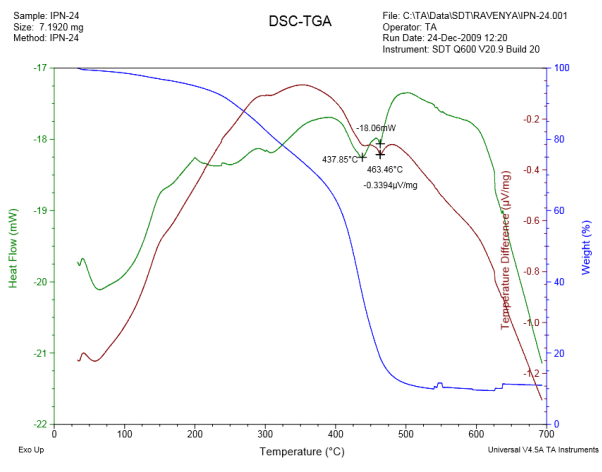



**Figure-2d:** DSC-TGA OF IPN 24.

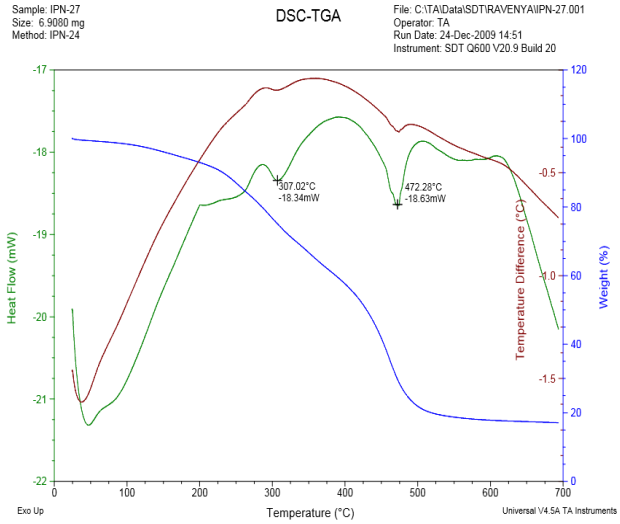



**Figure-2e:** DSC-TGA OF IPN-27.

**Thermogravimetric Analysis:** Thermal stability of IPNs was determined by the use of Universal $V_4$ 5ATA instrument at a rate of $10^0$C/min from room temperature to $700^0$C, again it is cooled from$700^0$C to room temperature. The percentage of mass left with temperature was recorded in Table-2. In this paper we have compared the thermal stability of different IPNs with varied NCO/OH ratio and different amino acid compounds as shown in Table–5.

Kinetics of IPNs is determined by Freeman Anderson method as per the following equation

$$\Delta \log\left(-\frac{dw}{dt}\right) = n\Delta \log w - \frac{Ea}{2.303R}\Delta\left(\frac{1}{T}\right)$$

Where: n= order of reaction, $E_a$= Activation Energy.

These values are determined from the plot of $\Delta \log\left(-\frac{dw}{dt}\right)$ vs $\Delta \log w$. The slope gives us order of reaction n and intercept is

related to activation energy (Ea) which is given by Ea which is given by

$$Ea = \frac{-Intercept\ X\ 2.303\ R}{\Delta(\frac{1}{T})}$$

**Findings:** IPN 14 is more stable than IPN 10, IPN 12, IPN 24 and IPN 27 having 0.35/0.65 PU/CD ratio. IPN 12 is less stable than 10, 24 and 27. IPNs are stable up to $180^0$C after which they decompose. In general it is observed that IPNs undergo degradation in three steps. In the first step, there is an initial weight loss which is attributed to the loss of moisture retained in the samples and elimination of smaller groups. In the second step, there is a gradual weight loss which is due to the decomposition of the chain. Small groups are removed from the IPN. Thus, the strained macro molecule suffered depolymerisation and released different larger groups leaving a charred residue and a small mass is left. From Activation energy values, IPN 14 is the most stable.

**D.S.C. (Differential scanning calorimetry):** In this instrument heat capacity of a sample is measured as the function of differential heat flow rate between the sample and reference material. The instrument directly gives a recording of heat flow rate against temperature.

Heat flow rate undergoes a change during transition. $T_g$, $T_c$ and $T_m$ values can be computed from the Table-3.

**Findings:** IPN 24 has more Tg, Tc and Tm value than IPN14 because it contains more amount of PU and more crystalline.

**Element Detection:** IPNs are heated for 30 seconds in different scale count and the percentages of Carbon, Nitrogen and Oxygen atoms were found which are given in graphs named as Figures-4a and 4b and Table-7b and 7c respectively.

Findings: This IPN contains C, N and O as shown in Table-7a to 7c and Figure-4a to 4c.

**WAXRD:** In this present investigation we have tried to focus on the morphology of IPNs by wide angle x-ray diffraction study. This IPN 27 show a broad peak at around 2Θ which indicates crystalline structure.

The average crystallite size of the sample has been determined by line broadening method using Scherer's equation

$$D = \frac{10 \times \wedge}{\beta \cos \theta}$$

Where: D is average crystallite size in nm. ∧ is the wave length of x-ray in nm. β is full width at half maximum (FWHM) of peak in radian. $\theta$ is half of diffraction angle in degree sample length = 10 [mm]

Findings: In this paper we review that IPN 27 has more crystalline structure than amorphous nature.

*Hence this IPN can be used as paints, lamination and abrasive.

**SEM Study:** This technique has been used to study the morphology of polymer samples. The photos of IPN 27 clearly shows the two distinct phases of the sample.

Findings: A binary (Crystalline and amouphous) morphology is clearly indicated in the Figure-5a to 5d. This SEM Study helps to know extent of the interpenetration, phase mixing and morphology quality of the IPNs.

**Biodegradability:** The IPN samples synthesized were tested for environmental resistance by use of soil burial test. The samples were buried in soil for sixty days. The samples were removed from the soil once in fifteen days to access the changes in their weight loss, mechanical strength and surface damage if any and is shown in Table-6.

**Findings**: From this observation (table-6) it is seen that these samples are not biodegradable, only a small amount of it decomposes with the bacteria and virus present in the soil which is very negligible.

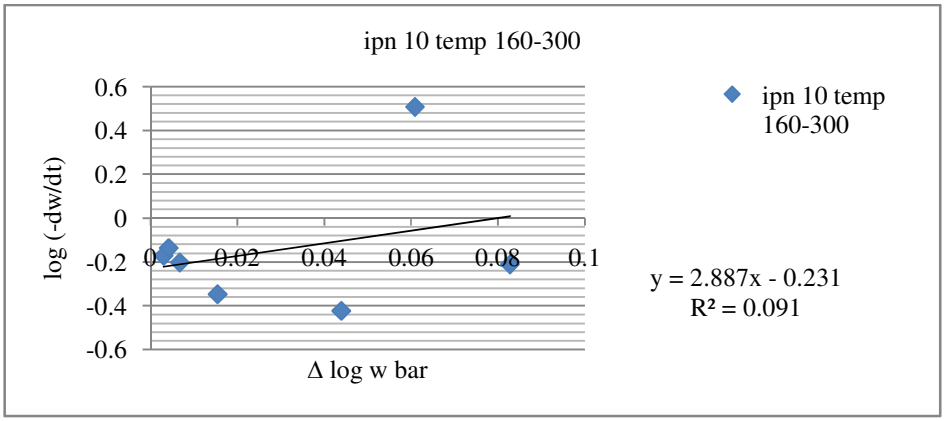



**Figure-2a-i:** Freeman-Anderson Plot of IPN 10.

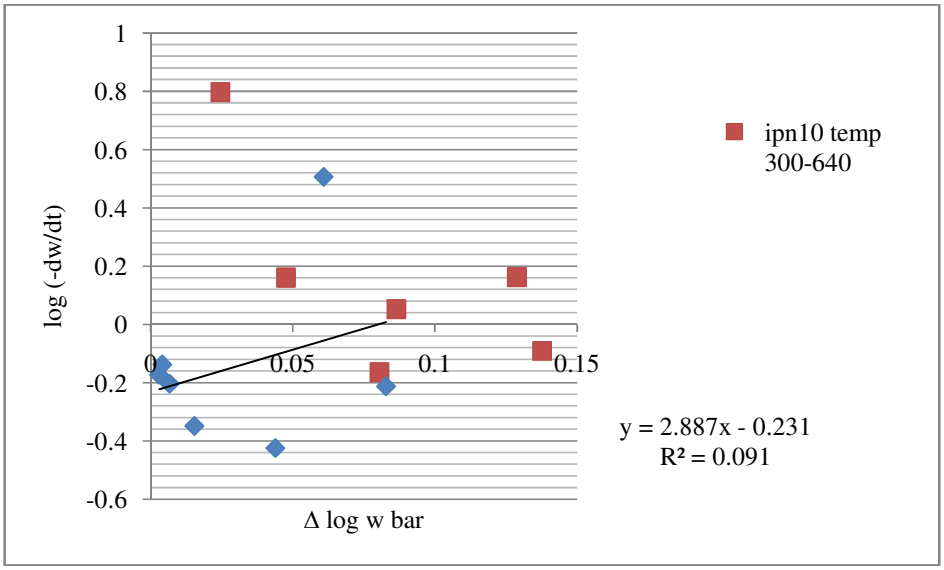



**Figure-2a-ii:** Freeman-Anderson Plot of IPN 10.

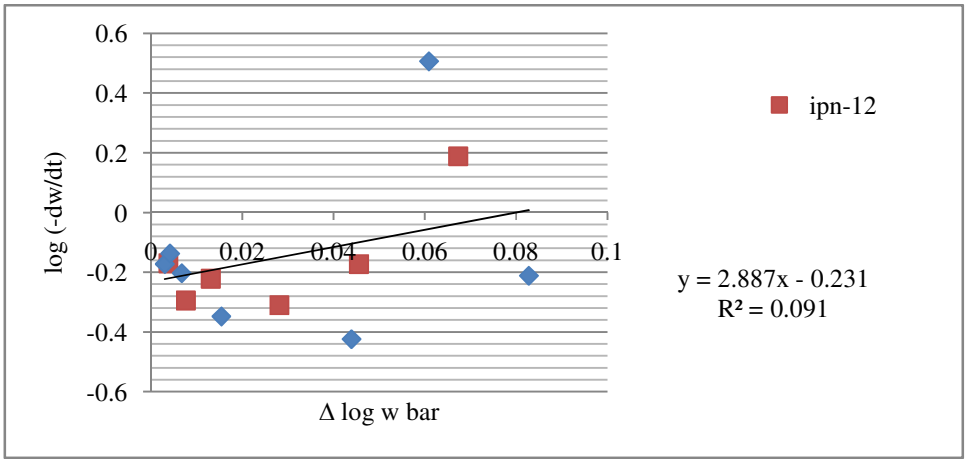



**Figure-2b-i:** Freeman-Anderson Plot of IPN 12.

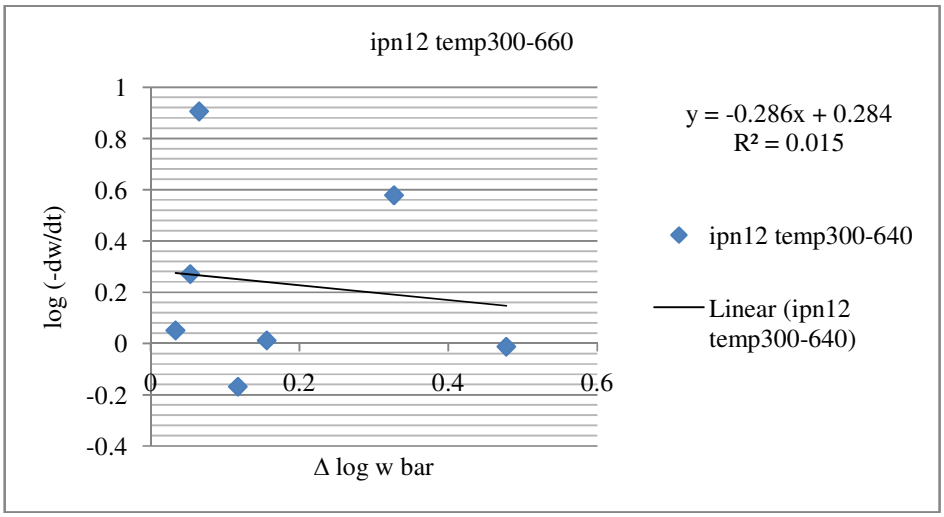



**Figure-2b-ii:** Freeman-Anderson Plot of IPN 12.

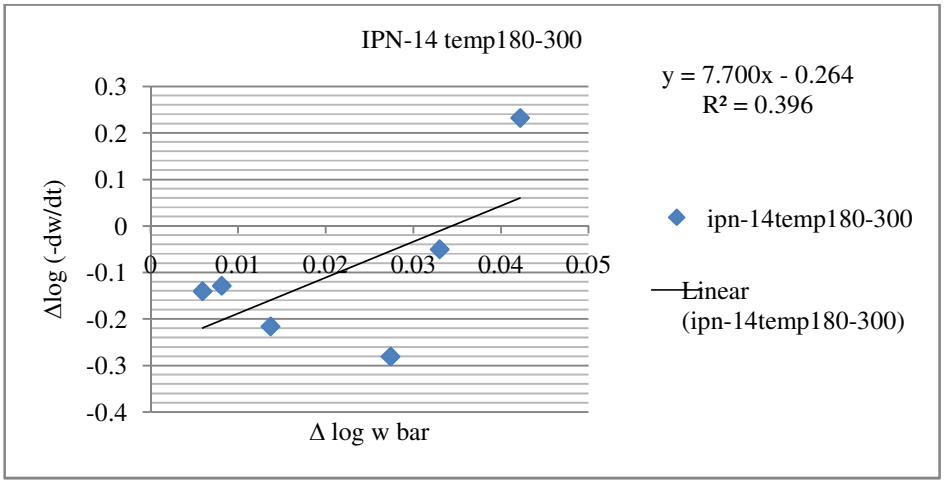



**Figure-2c-i:** Freeman-Anderson Plot of IPN 14.

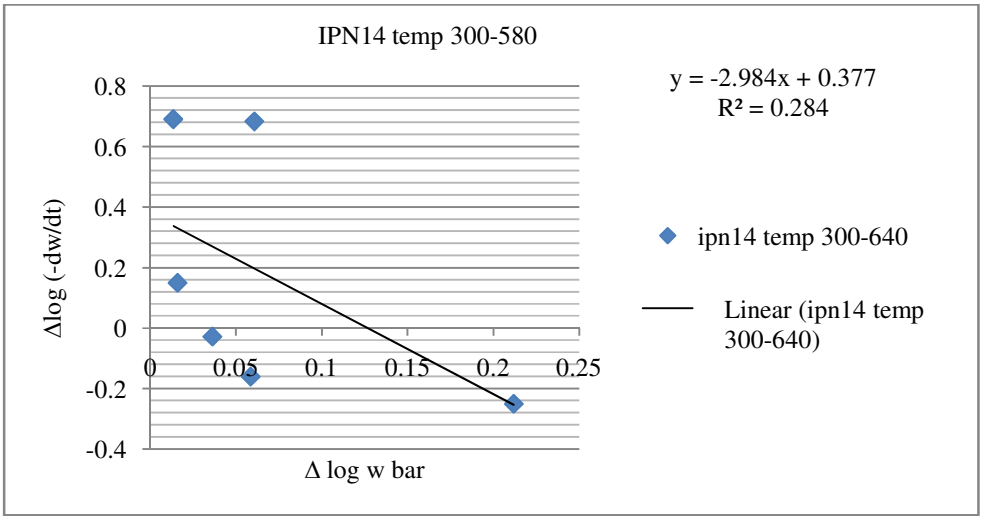



**Figure-2c-ii:** Freeman-Anderson Plot of IPN 14.

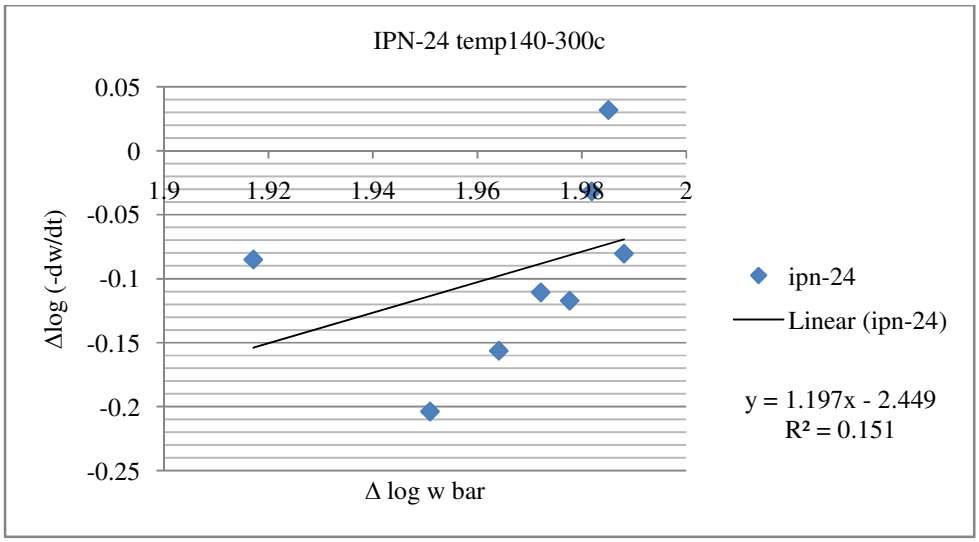



**Figure-2d-i:** Freeman-Anderson Plot of IPN 24.

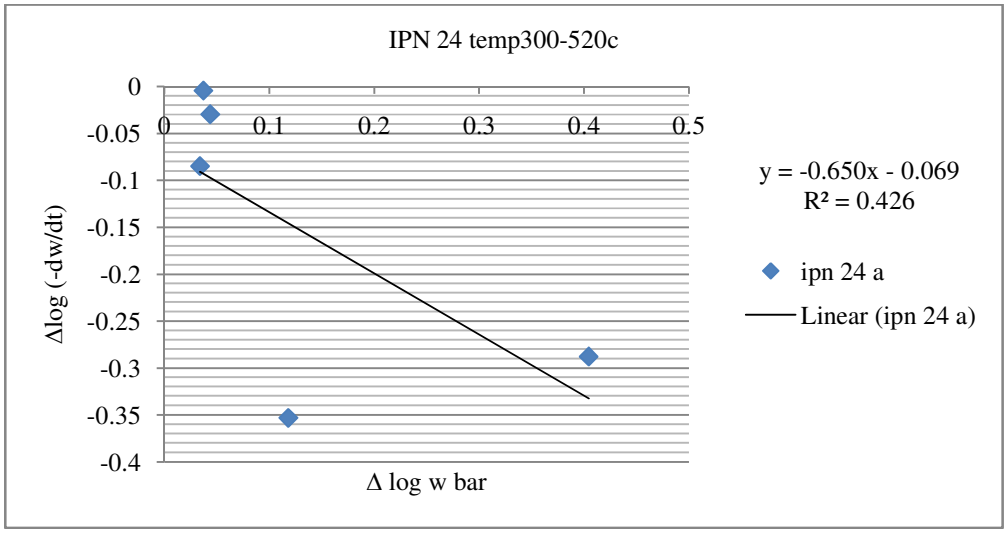



**Figure-2d-ii:** Freeman-Anderson Plot of IPN 24

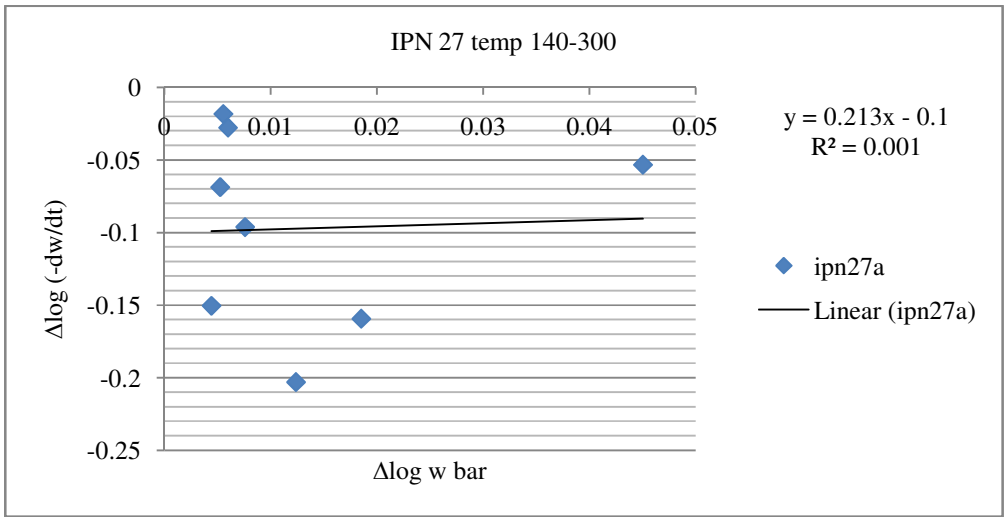



**Figure-2e-i:** Freeman-Anderson Plot of IPN 27.

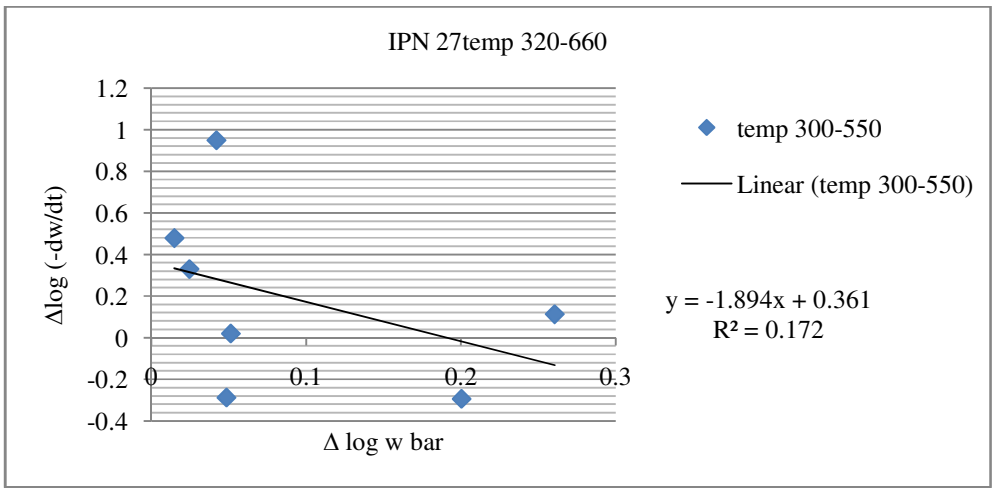



**Figure-2e-ii:** Freeman-Anderson Plot of IPN 27.

**Table-1:** Feed Composition Data

| Sample Code | DI used | Name of the oil used | NCO/OH ratio | CBD(cardanol based dye) | Contents of P.U. | Contents of dye monometer wt% |
|---|---|---|---|---|---|---|
| IPN 10 | TDI | Soybean Oil | 1.2(2.08/3.54) | 4-amino benzoic acid | 0.25 | 0.75 |
| IPN12 | TDI | Soybean Oil | 1.2(2.78/3.54) | 4-amino benzoic acid | 0.50 | 0.50 |
| IPN 14 | TDI | Soybean Oil | 1.6(2.78/3.54) | 4-amino benzoic acid | 0.35 | 0.65 |
| IPN 24 | DPMDI | Soybean Oil | 2.0(3.48/3.54) | 3-amino benzoic acid | 0.50 | 0.50 |
| IPN 27 | DPMDI | Soybean Oil | 2.0(3.48/3.54) | 4-amino benzoic acid | 0.50 | 0.50 |

**Table-2:** Percentage of residual mass left with temperature

| Sl No. | Sample code | $100^0$C | $200^0$C | $300^0$C | $400^0$C | $500^0$C | $600^0$C | $700^0$C |
|---|---|---|---|---|---|---|---|---|
| 1 | IPN10 | 97.66 | 93.92 | 58.84 | 4.9 | 20.99 | 18.37 | 17.36 |
| 2 | IPN12 | 97.04 | 92.29 | 64.73 | 31.91 | 5.48 | 4.16 | 3.27 |
| 3 | IPN14 | 98.18 | 92.88 | 70.94 | 54.78 | 30.05 | 28.34 | 27.76 |
| 4 | IPN 24 | 98.58 | 94.48 | 82.6 | 63.09 | 11.44 | 9.61 | 9.12 |
| 5 | IPN27 | 98.4 | 93 | 76.4 | 57.6 | 21.9 | 17.8 | 17.8 |

**Table-3:** DSC Parameter.

| Sl. No. | Sample Code | Composition | NCO/OH | PU/CD | Tg | Tc | Tm |
|---|---|---|---|---|---|---|---|
| 1 | IPN10 | 4-A.B.A + TDI | 1.2 | 25:75 | 200.11 | 231.1 | 490.31 |
| 2 | IPN12 | 4-A.B.A + TDI | 1.6 | 50:50 | 172.91 | 285.47 | 496.11 |
| 3 | IPN14 | 4-A.B.A + TDI | 1.6 | 35:65 | 172.1 | 231.85<br>414.89 | 446.25 |
| 4 | IPN24 | 3-A.B.A + TDI | 1.6 | 50:50 | 195.02 | 310.05<br>437.03 | 472.25 |
| 5 | IPN 27 | 3-A.B.A + DPMDI | 2.0 | 50:50 | 175.5 | 307.02 | 472.3 |

$T_g$: Glass transition temperature, $T_c$: Curie temperature or crystallization temperature, $T_m$: The temperature at which change of state occurs, $T_f$: The flow point, $T_g$= (Pre transition temperature+Post transition temperature)/2

**Table-4:** TG Traces of IPNs

| Sample Code | $T_o$ | $T_{max}$ | $T_f$ | % of CY |
|---|---|---|---|---|
| IPN 10 | 50.2 | 260.1 | 496.36 | 21.31 |
| IPN12 | 50.5 | 265.5 | 476.7 | 6.94 |
| IPN14 | 49.2 | 250.42 | 453.2 | 9.01 |
| IPN24 | 62.1 | 275.3 | 465.1 | 12.2 |
| IPN 27 | 57.9 | 272.1 | 464.2 | 17.8 |

$T_O$-Onset temperature of degradation, $T_m$-Temperature of maximum rate of mass loss, $T_f$-Extrapolated final decomposition temperature, $C_y$-Char yield.

**Table-5:** Kinetic Parameters of different IPNs.

| Sample Code | Temperature Range ($^0$C) | Order of reaction (n) | Intercept | Activation Energy (Ea) J/mol |
|---|---|---|---|---|
| IPN-10 | 160-300 | 2.8877 | -0.2314 | 442.31 |
| | 300-600 | 5.1696 | -0.5886 | 1125.10 |
| IPN-12 | 180-300 | 5.654 | -0.3203 | 612.25 |
| | 300-600 | 0.2861 | -0.2845 | 543.81 |
| IPN-14 | 180-300 | 7.7004 | -0.2649 | 506.35 |
| | 300-580 | 2.9846 | -0.3778 | 722.16 |
| IPN-24 | 140-300 | 1.1974 | -2.4496 | 4682.38 |
| | 300-520 | 0.6507 | -0.0692 | 132.27 |
| IPN-27 | 140-300 | 0.2134 | -0.1 | 191.14 |
| | 320-660 | 1.8942 | -0.3616 | 691.19 |

**Table-6:** Biodegradability Study (Decomposition by bacteria and virus).

| Sample Code | Initial Mass in mg | Mass after 15 days in mg | Mass after 30 days in mg | Mass after 45 days in mg | Mass after 60 days in mg |
|---|---|---|---|---|---|
| IPN-10 | 10.31 | 10.26 | 10.21 | 10.10 | 10.09 |
| IPN-12 | 9.52 | 9.47 | 9.41 | 9.39 | 9.29 |
| IPN-14 | 9.98 | 9.89 | 9.57 | 9.43 | 9.40 |
| IPN-24 | 9.76 | 9.64 | 9.56 | 9.41 | 9.32 |
| IPN-27 | 10.42 | 10.36 | 10.23 | 10.11 | 10.01 |

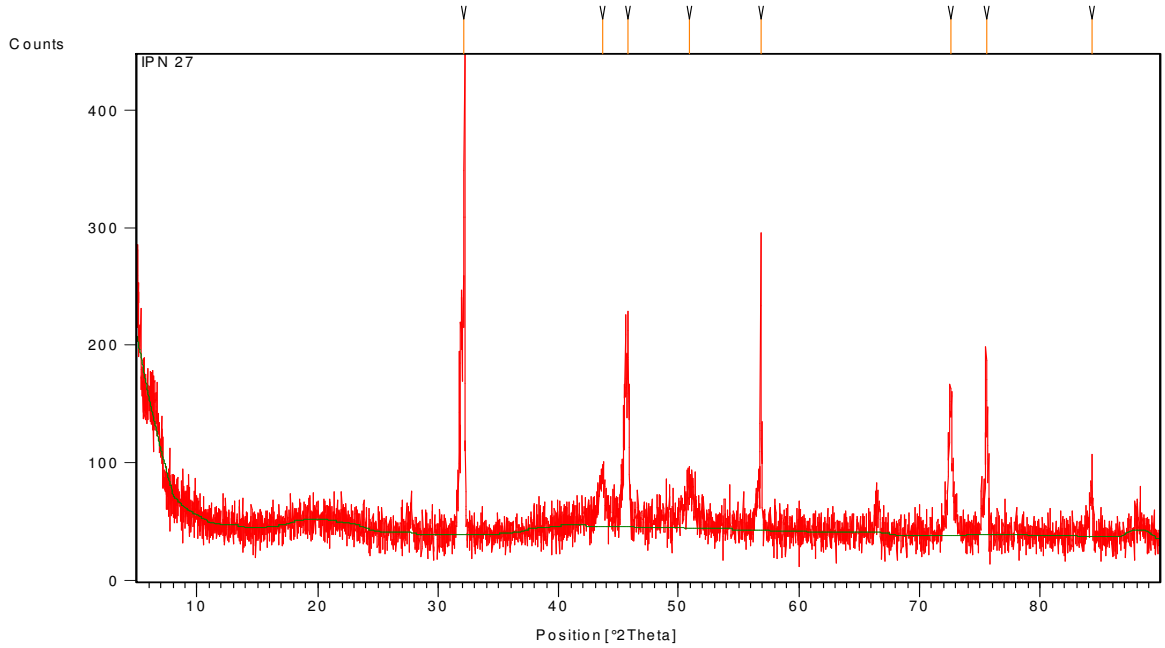
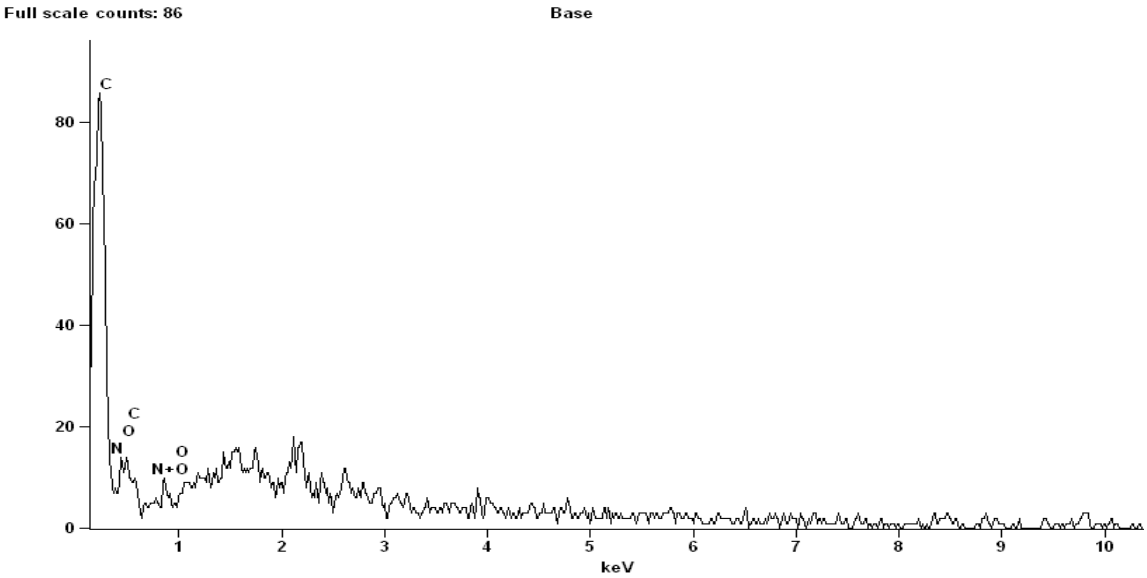



**Figure-3:** WA XRD of IPN 27

**Table-7a:** Peak list of WAXRD of IPN-27

| Pos. [°2Th.] | Height [cts] | FWHM [°2Th.] | d-spacing [Å] | Rel. Int. [%] |
|---|---|---|---|---|
| 32.1472 | 296.40 | 0.1440 | 2.78215 | 100.00 |
| 43.6773 | 39.96 | 0.5760 | 2.07073 | 13.48 |
| 45.8599 | 152.13 | 0.1920 | 1.97713 | 51.33 |
| 50.9136 | 31.27 | 1.1520 | 1.79210 | 10.55 |
| 56.8643 | 145.80 | 0.1920 | 1.61787 | 49.19 |
| 72.5808 | 112.13 | 0.2880 | 1.30145 | 37.83 |
| 75.5410 | 139.77 | 0.1920 | 1.25763 | 47.15 |
| 84.2679 | 39.83 | 0.2880 | 1.14822 | 13.44 |

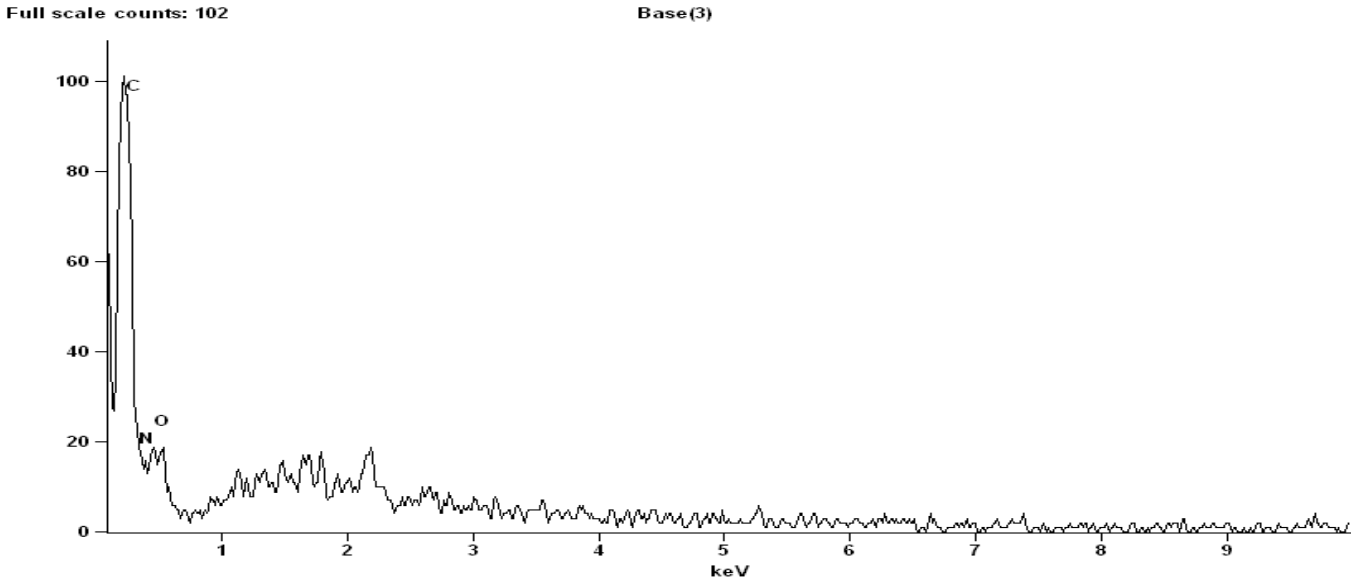



Live Time: 30.0 sec.

**Figure-4a:** Element Detection of IPN 27.

Table-7b: For Element Detection of IPN 27 (Quantitative Results) Base.

| Element Line | Net Counts | Net Counts Error | Weight % | Atom % | Formula |
|---|---|---|---|---|---|
| C K | 549 | +/- 40 | 81.82 | 85.70 | C |
| N K | 0 | +/- 11 | 0.00 | 0.00 | N |
| O K | 74 | +/- 15 | 18.18 | 14.30 | O |
| Total | | | 100.00 | 100.00 | |




Live Time: 30.0 sec.

**Figure-4b:** Element detection of IPN 27.

**Table-7c:** For Element Detection of IPN 27 (Quantitative Results) Base (3).

| Element Line | Net Counts | Net Counts Error | Weight % | Atom % | Formula |
|---|---|---|---|---|---|
| C K | 649 | +/- 45 | 81.52 | 85.46 | C |
| N K | 0 | +/- 15 | 0.00 | 0.00 | N |
| O K | 91 | +/- 17 | 18.48 | 14.54 | O |
| Total | | | 100.00 | 100.00 | |

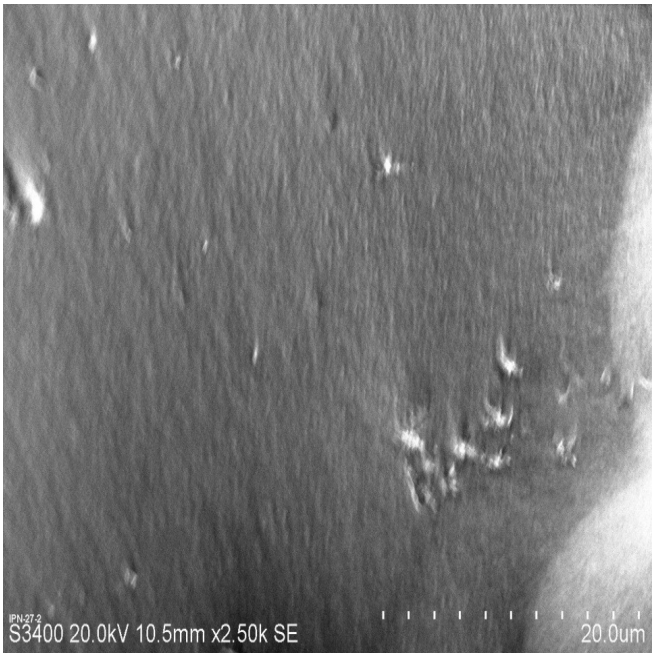



**Figure-5a:** SEM Morphology of IPN 27.

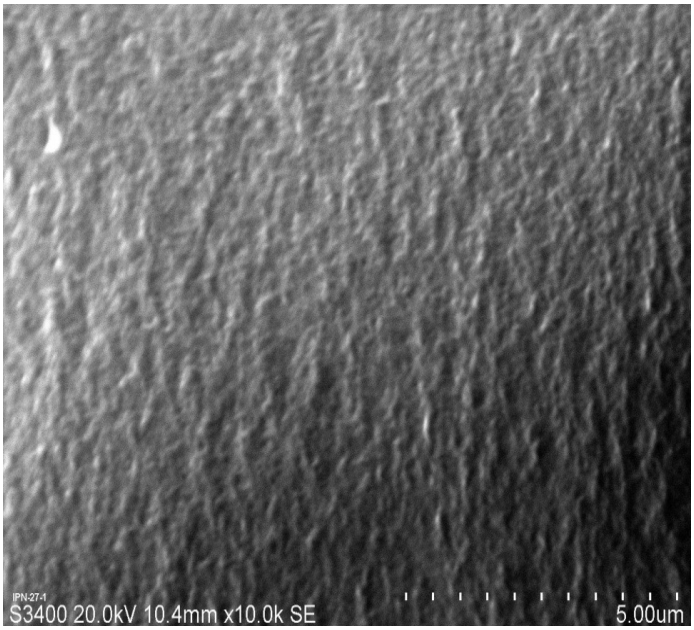



**Figure-5c:** SEM Morphology of IPN 27.

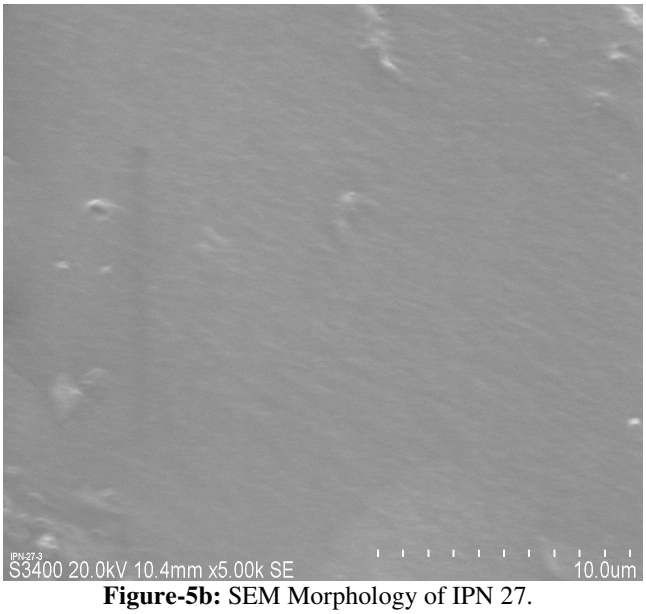



**Figure-5b:** SEM Morphology of IPN 27.

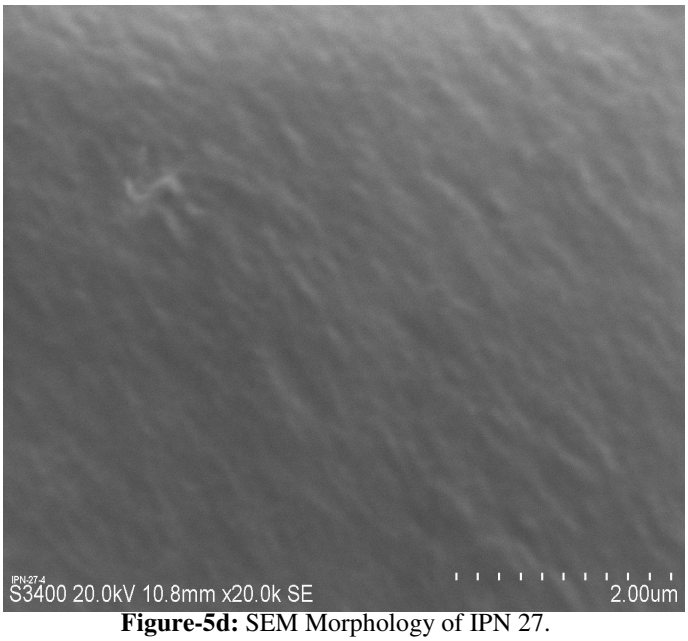



**Figure-5d:** SEM Morphology of IPN 27.

## Conclusion

In view of the rapid consumption of the petroleum product and growing demand for the use of polymeric material, synthesis of polymers from agricultural resources like soybean oil and dye monomer of cardanol achieved tremendous impact in the present world. New polymer (IPNs) produced from vegetable resource is cheaper, thermally stable upto $500^0$C (known from TGA, DSC, WXRD studies) with high mechanical strength Thus these polymers can be used in different fields. These polymers are highly cross linked hence, though plastics with dual phase continuity i.e crystalline and amorphous and other materials like adhesives, brake lining, abrasive, varnishes, paints etc. can be prepared from these, for widely use.

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