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Study and Findings of Post-Consumer Waste PET (Polyethylene Terephthalate) Plastic Solubility in Amines.

Arun Kumar Awasthi, and Murugesh Shivashankar*.

Department of chemistry, School of Advanced Sciences, VIT University, Vellore, Tamil Nadu, India.

ABSTRACT

Polyethylene terephthalate plastic material consumption is increasing across the world day by day and it is used in packaging of drinking water and soft drinks. It has lot of advantages such as light weight and more durable. Post usage plastic waste management and handling is a difficult task. But there are various types of technologies available to manage the plastic waste after post usage. Reuse of plastic waste via recycling technique is effective way to manage the plastic waste. Mechanical recycling is a good technique for single polymer waste recycling while chemical recycling which convert waste plastic into small molecules. Pyrolysis is another technique to degrade the plastic waste in the absence of air. Open dumping of plastic waste is creates the severe environmental issues but it supports the biodegradation of plastic waste by microorganism. Waste to energy and other chemical recycling technologies are also good solution to manage the plastic waste .These technologies supports the manage the plastic waste. But there are still some challenges exist with current technologies. Waste PET plastic solubility with amine is an unique approach to manage the waste. In this paper we have discussed the observation and findings of solubility of PET plastic in amines at room temperature.

Keywords: Reuse, Plastic Material, Solubility, Technologies, Polyethylene terephthalate

***Corresponding author**

INTRODUCTION

The aim of the solubility study of waste PET plastic with different amine at room temperature to find an alternative and feasible way to use to post-consumer waste PET material in other applications. PET (polyethylene terephthalate) is very known plastic material. PET is having excellent moisture resistance. Beverage plastic bottles made from PET plastic and it is used for different uses in our daily life. Bottles made from PET are used for soft drink, mineral water packing. PET bottles is glossy and very flexible material. PET plastic is resistant to most of the chemicals and other materials. Bottles made from polyethylene terephthalate plastic are much more durable compared to other plastic made bottles and suitable to all summer, winter and rainy seasons. Peoples use PET made plastic for their drinking water bottle and other purpose. Post usage, generally PET bottles become part of municipal garbage or it is found in unmanaged condition. Post usage waste PET bottles collected from municipal waste are being sent for recycling and it is reused for packing of different materials.

Polyethylene terephthalate (PET) is a condensation polymers and it is very difficult to degrade by dissolving method with any solvents and other reagents. Polyethylene terephthalate is practically insoluble in most of the solvent and chemicals. It is a plastic resin and most common type of polyester. It is made from ethylene glycol with terephthalic acid. Most of the food and beverages items packed in packages made from polyethylene terephthalate and it is touching to every human in everyday of the life and post usage these empty plastic items become part of municipal, public places garbage bins. It can be recycled and reused for the same and other purposes. But there are lot of challenges in recycling of plastics like selection and segregation of the plastic materials. It creates lot of environmental issues and unable to manage the PET waste in effective way.

In the majority of PET aminolysis processes described, the polymer was in the form of powder or fibers. The reaction was usually carried out using primary amine aqueous solutions, most frequently methylamine, ethylamine and ethanolamine in the temperature range of 20-100 °C. Anhydrous *n*-butylamine was also applied as an aminolytic agent at a temperature of 21 °C [1]

Aminolysis of PET with alkanolamines (monoethanolamine,diethanolamine and triethanolamine). Reaction of PET with monoethanolamine and diethanolamine performed for 5 and 8 hours 160-190 °C [2] The aminolysis of PET yields diamides of TPA, which is known as bis (2-hydroxy ethylene) terephthalamide (BHETA) [3]

PET has been used in domestic purposes in homes like bulk plastic jars for drinking water supply to homes, hotels and industries. Bottles made from PET plastic is very useful and preserve the water for long time protected from UV and other environmental factors. There was research done on 1,5,7-triazabicyclo[4.4.0]dec-5-ene with polyethylene terephthalate beverage bottles for catalyzed aminolysis of PET [4] . Organocatalysts reveals triazabicyclodecene (TBD) as a potent catalyst for enhancing the performance of certain specialized reactions, such as the degradation and modification of PET. In addition to catalytically degrading PET back into its basic monomers, TBD may also be able to produce PET derivatives through transesterification and aminolysis reactions that could be used for high-valued applications [5]

Polyethylene terephthalate is transparent material and used for packing purpose of consumer and retail products. Soft drink and water is packed into PET made bottles and it generates lot of post-consumer waste. This waste is getting lot of attention to utilize the waste. Recycling process is an effective process to reuse the waste PET into other application. Waste PET can be recycled by two methods mechanical and chemical recycle. Waste PET can be cut into small pieces and it will melted and convert into other items .Hydrolysis by sodium hydroxide has been used for recycling of PET waste [6] . Mono ethanol amine (MEA) was used to convert PET waste into water soluble amide Aminolysis of waste soft drink bottles made from PET done by using mono ethanol amine using sodium acetate as a catalyst at 170-190 deg.c for 4 hours and at 200 deg.c for 3 hours[7]

The chemical recycling is a process which results waste plastic into small molecules of liquids and gases. Chemical recycling has lot of advantage generating high yields. There are lot of end use of chemical recycling are pyrolysis, gasification, hydrogenation, steam or catalytic cracking. Pyrolysis technique has lot of advantages such as operational, environmental & financial advantages.. Pyrolysis is an alternative technique to landfilling. To avoid more space of landfilling and high incineration cost of plastic waste, gasification is an excellent process to utilize the plastic waste. Air is used as a gasification agent. The benefit of air is to reduce the cost. There are some recycling techniques can be done by adding chemicals. These techniques are hydrolysis, glycolysis, aminolysis, methanolysis. Aminolysis of polyethylene terephthalate is carried with ethanolamine [8].

There is another study on the aminolysis of PET with ethylenediamine without catalysis and propose a procedure to isolate trimer and a,u-diamine oligomer products[9] Chemical recycling of polyethylene terephthalate waste is a very interesting topic . use of ethanolamine for the aminolytic degradation of PET waste in the presence of different simple chemicals such as glacial acetic acid, sodium acetate and potassium sulphate as catalysts[10]. There are lot of analytical techniques in addition to weight loss to characterize the products resulting from the aminolysis of poly ethylene terephthalate has been applied to characterize the final product [11]

There were another way of chemical recycling of polyethylene terephthalate waste flakes depolymerized at 190 deg.c using ethanolamine in the presence of dibutyl tin oxide [12] There were another method of depolymerisation of polyethylene terephthalate .In this method polyethylene terephthalate waste was treated with ethanolamine under reflux using microwave oven in the presence of sodium acetate, sodium bicarbonate and sodium sulphate [13].Post consumer plastic bottle converts into flakes. These flakes was blend with polycarbonate and blend shows the hig glass transition temperature when this blend is tested by DSC [14].Microscopic study done on waste flakes of polyethylene terephthalate by adding aqueous methylamine and cetyl ammonium bromide was used as a catalyst in degradation process [15]. There is another study done on environmental effects of waste PET bottles and management of waste PET and to propose the tools to minimized and analyse the environmental effects can be minimized. Recycling of waste PET is a good solution to manage the waste PET in effective way. But there are lot of issues shown in recycling process are collection of waste PET bottles, landfill and incineration. But all the methods are complex [16].

Polyethylene terephthalate is a light weight material and used in many applications like packing and it is having moisture barrier property with high shatter resistance and containing carbon di oxide which is very suitable for water and beverage bottles. Post-consumer waste it is a good idea to use waste PET in other applications apart from recycling. The use of waste PET as a reinforcement component for asphalt concrete pavement [17]. Waste PET is depolymerized by glycolysis with different amounts of various glycols like propylene glycol, triethylene glycol and poly ethylene glycol in the presence of Zinc catalyst [18

Chemical decomposition of waste PET is very good technology to manage the waste PET and use in another good application and utilize the waste material in effective way. Chemical recycling of waste PET can be categorized into four main process are glycolysis, methanolysis, hydrolysis and aminolysis [19]. Post consumer polyethylene terephthalate waste is degraded by glycolysis process in the presence of calcium and zinc stearate[20]. Poly ethylene terephthalate material is used in packing, textiles and electronic components. Chemical recycling is best technology to manage the waste PET and transform into oligomers and reutilize for the another good applications. Waste PET fibres is chemically depolymerized into bis (2-hydroxyethyl) terephthalate by utilizing ethylene glycol [21]

In this paper we will study the outcome of waste PET plastic dissolving with selected amines at room temperature. The blend product obtained from after amine reaction with waste polyethylene terephthalate can be useful for thermosetting resins such example epoxy resins etc. curing in construction, industrial bonding application. The mixture blend were characterized by methods of Fourier transform infrared spectroscopy (FTIR).

MATERIALS AND METHOD

Waste PET

Waste plastic (PET) obtained from empty soft drink bottle sample made from various available local brands of soft drinks. Prior the experiment, slice the waste PET plastic into small pieces.

Amines

Diethylenetriamine sample, product from USA, Lot No.34598 HMV, made from Sigma Aldrich (Lab R&D use only). Triethylenetetramine, made from S.D .Fine Chem Limited, Mumbai, Pack code 36212L05,F103/1205/0606/13 . Vestamin IPD (Isophorondiamine) ,made from Evonik speciality chemicals (Shanghai) Co. Ltd.68,Liahe Road (D3 block) SCIP ,Shanghai PRC. Vestamin TMD (Trimethyl, hexamethylene diamine) ,made from Evonik Industries AG –coating & additives,Paul-Baumann-str-1D45764 marl,Germany,DENT ,14011303, Country of origin –Germany, Supplier Aroma Chemical Agencies, Mumbai

FTIR (Fourier Transform Infra red).

The equipment was used a FTIR with ATR (Atteneuated total reflectance) of Perkin Elmer, Spectrum 100 and software is spectrum one to characterize the blends. The resolution of the equipment was 4 cm^{-1}. The spectra band recorded range from 650 to 4000 cm^{-1}.

Blend Experiment

Slice the waste PET plastic bottles into small pieces and weigh 1 gms each and dissolve into 100 gms Di ethylene triamine and 100gms triethylene tetra mine, 1gm waste plastic pieces into 27 gms trimethyl hexamethylene diamine and 1gms waste PET plastic pieces into 100 gms Isophoron diamine, 5 gms waste PET plastic into 100 gms diethylene triamine and leave at room temperature (23Deg.C to 28Deg.C) for observation. Please refer figure 1 and figure 2 .

RESULTS AND DISCUSSION

In the reaction of polyethylene terephthalate and primary amine like diethylenetriame, triethylenetetramine, trimethyl hexamethylene diamine and isophoron diamine. After reaction between PET (Polyethylene terephthalate) and amine, amides derivatives are created.

Characterization of 1gm waste PET &100 gms Diethylene triamine blend (DETA)

The FTIR spectrum of PET and diethylenetriamine blend shown in figure 3. IR spectra 3353cm-1 and 3283cm-1 confirms the presence of N-H stretch which shows the presence of primary amine in stretching zone. IR spectra 2925cm-1 and 2813cm-1 confirms the presence of C-H stretch very sharp peak in the stretching zone.IR spectra 1597 cm-1 shows the presence of N-H bend in the bending zone. IR spectra 1455cm-1 shows the presence of C-C stretch in bending zone.IR spectra 1351cm-1shows the presence of C-H rock.IR spectra 1128 cm-1shows the presence of C-H stretch very sharp peak. IR spectra 826 cm-1 shows the presence of C-H opps aromatic ring very sharp peaks

The IR spectrum of blend was confirm be after 8 days , During characterization ,it is observed that there is no IR spectra of –CONH appears and hence it shows there is no dissolution of waste PET in Diethylene triame

Charecterization of 1gm waste PET & 100 gmsTriethylenetetramine blend (TETA)

The FTIR spectrum of PET and triethylene tetramine blend shown in figure 4. IR spectra 3354 cm-1and 3278 cm-1 confirms the N-H stretch which shows the presence of primary amine in stretching zone.IR spectra 2931cm-1 shows the presence of C-H stretch very sharp peak.IR IR spectra 2807cm-1 shows the presence of C-H stretch very sharp peak.IR spectra 1907cm-1 shows the presence of C=O stretch weak peak.IR spectra 1604cm-1shows the presence of N-H bend.IR spectra 1455cm-1showing the presence of C-C stretch (in ring).IR spectra 1271cm-1showing the presence of C-O stretch from ester. IR spectra 1124cm-1shows the presence C-N stretch very sharp peak .

The IR spectrum of blend was confirm be after 8 days , During characterization ,it is observed that there is no IR spectra of –CONH appears and hence it shows there is no dissolution of waste PET in triethylenetetramine

Characterization of diethylenetriamine(DETA)

The IR spectrum of pure diethylenetriamine solution shown in figure 5. for reference purpose study.IR spectra 3356cm-1and 3275cm-1confirms the N-H stretch which shows the presence of primary amine in stretching zone IR spectra 2923cm-1and 2813cm-1 shows the presence of C-H stretch very sharp peak in stretching zone.IR spectra peak 1589cm-1 shows the presence of N-H bend.IR spectra 1455cm-1shows the presence of C-C stretch. IR spectra 1353 cm-1 shows the presence of C-H rock. IR spectra 1128cm-1 shows the presence of C-H stretch very sharp peak.IR spectra 826cm-1 shows the presence of C-H opps aromatic ring very sharp peak.

Characterization of Triethylenetetramine (TETA)

The IR spectrum of pure triethylenetetramine solution shown in figure 6. For reference purpose study. IR spectra 3352cm-1 and 3277cm-1 confirms the N-H stretch which shows the presence of primary amine in stretching zone. IR spectra 2930cm-1and 2807cm-1 shows the presence of C-H stretch very sharp peak in stretching zone.IR spectra 1597cm-1 shows the presence the N-H bend.IR spectra 1455 cm-1 shows the presence of C-C stretch. IR spectra 1347cm-1shows the presence of C-H rock.IR spectra 1125cm-1shows the presence of C-H stretch very sharp peak.IR spectra 763cm-1 shows the presence of C-H opps aromatic ring very sharp peak.

Characterize the Waste PET & DETA blend & Waste PET & TETA blend after 15 days

Charecterize the 1gm waste PET & 100 gms diethylene triamine and 1 gm waste PET & 100 gms Triethylene tetra amine blend Vs. Triethylene tetraamine , Diethylene triamine & Waste PET .

The IR spectrum of waste PET and diethylenetriamine blend shown in figure 7. IR spectrum 3275cm-1confirms the N-H stretch in stretching zone.IR spectra 2931cm-1 and 2808cm-1 shows the presence of C-H stretch very sharp peak in stretching zone.IR spectra 1597cm-1 shows the presence of N-H bend. IR spectra 1455cm-1shows the presence of C-H stretch very sharp peak.IR spectra 1348cm-1 shows the presence of C-H rock.IR spectra 1125cm-1 shows the presence of C-H stretch very sharp peak. IR spectra 766cm-1 shows the presence of C-H opps aromatic ring very sharp peak, The IR spectrum of blends was confirm be after 15 days , During characterization ,it is observed that there is no IR spectra of –CONH appears and hence it shows there is no dissolution of waste PET in diethylenetriamine.

The IR spectrum of waste PET and triethylenetetramine blend shown in figure 7. IR spectrum 3279cm-1confirms the N-H stretch in stretching zone.IR spectra 2924 cm-1 and 2813cm-1 shows the presence of C-H stretch very sharp peak in stretching zone.IR spectra 1595cm-1 shows the presence of N-H bend. IR spectra 1455cm-1shows the presence of C-H stretch very sharp peak.IR spectra 1348cm-1 shows the presence of C-H rock.IR spectra 1128cm-1 shows the presence of C-H stretch very sharp peak. IR spectra 825 cm-1 shows the presence of C-H opps aromatic ring very sharp peak, The IR spectrum of blends was confirm be after 15 days , During characterization ,it is observed that there is no band of –CONH appears and hence it shows there is no dissolution of waste PET in triethylenetetramine.

The IR spectrum of pure diethylenetriamine solution shown in figure 7.IR spectra 3275cm-1confirms the N-H stretch which shows the presence of primary amine in stretching zone IR spectra 2924cm-1and 2813cm-1 shows the presence of C-H stretch very sharp peak in stretching zone.IR spectra peak 1598cm-1 shows the presence of N-H bend.IR spectra 1455cm-1shows the presence of C-C stretch. IR spectra 1353 cm-1 shows the presence of C-H rock. IR spectra 1128cm-1 shows the presence of C-H stretch very sharp peak.IR spectra 826cm-1 shows the presence of C-H opps aromatic ring very sharp peak.

The IR spectrum of pure triethylenetetramine solution shown in figure 7. IR spectra 3277cm-1 confirms the N-H stretch which shows the presence of primary amine in stretching zone. IR spectra 2931cm-1and 2807cm-1 shows the presence of C-H stretch very sharp peak in stretching zone.IR spectra 1597cm-1 shows the presence the N-H bend.IR spectra 1455 cm-1 shows the presence of C-C stretch. IR spectra 1347cm-1shows the presence of C-H rock.IR spectra 1125cm-1shows the presence of C-H stretch very sharp peak.IR spectra 763cm-1 shows the presence of C-H opps aromatic ring very sharp peak.

The IR spectrum of PET (polyethylene terephthalte) shown in figure 7.IR spectra 3299cm-1shows the presence of –OH group. IR spectra 2919cm-1and 2851cm-1 confirms the aliphatic stretching .IR spectra 1713cm-1 confirm the carbonyl stretching. IR spectra 1576 cm-1shows the presence of ring structure. IR spectra 1504cm-1 shows the presence of -C-C- (aromatic). IR spectra 1455 cm-1 shows the presence of -CH2- bending.IR spectra 1408cm-1 shows the presence of aromatic skeleton stretching.IR spectra 1240 cm-1shows the presence of –C-O- stretching ester group .

The IR spectrum of all the blends was confirm be after 15 days , During characterization ,it is observed that there is no band of –CONH appears and hence it shows there is no dissolution of waste PET in diethylenetriamine and triethylenetetramine.

Characterize the Waste PET &DETA blend, Waste PET&Isophoron amine blend & Waste PET & trimethyl hexamethylene diamine blend with higher amount of waste PET in below mentioned different amine solutions.

We have increased the concentration of waste PET into different amine solutions to see the dissolution behaviour of waste PET at room temp. Because sometine lower concentration of polymer amount does not show the accurate results and it is very unclear to see the dissolved polymer concentration in the amine solution at different temperature . Chareterize the following blends with higher concentration of waste PET after 7 days at room temperature

- 5gms waste PET plastic &100 gms Diethylene triamine blend
- 5 gm waste PET plastic &100 gms Isophoron diamine blend
- 5 gms waste PET plastic &26.85 gms of trimethyl hexamethylene diamine blend

The IR spectrum of waste PET and diethylenetriamine blend shown in figure 8. IR spectrum 3279cm-1confirms the N-H stretch in stretching zone.IR spectra 2927cm-1 and 2813cm-1 shows the presence of C-H stretch very sharp peak in stretching zone.IR spectra 1595cm-1 shows the presence of N-H bend. IR spectra 1455cm-1shows the presence of C-H stretch very sharp peak.IR spectra 1351cm-1 shows the presence of C-H rock.IR spectra 1127cm-1 shows the presence of C-H stretch very sharp peak. IR spectra 771cm-1 shows the presence of C-H opps aromatic ring very sharp peak, The IR spectrum of blends was confirm be after 7 days , During characterization ,it is observed that there is no IR spectra of –CONH appears and hence it shows there is no dissolution of waste PET in diethylenetriamine.

The IR spectrum of waste PET and Iso phorondiamine blend shown in figure 8. IR spectra 2937cm-1,2948cm-1 and 2897cm-1 shows the presence of C-H stretch very sharp peak in stretching zone.IR spectra 1605cm-1 shows the presence of N-H bend. IR spectra 1460 cm-1shows the presence of C-H stretch very sharp peak.IR spectra 1363cm-1 shows the presence of C-H rock.. IR spectra 769cm-1 shows the presence of C-H opps aromatic ring very sharp peak.The IR spectrum of blends was confirm be after 7 days , During characterization ,it is observed that there is no IR spectra of –CONH appears and hence it shows there is no dissolution of waste PET in Isophoron diamine.

The IR spectrum of waste PET and trimethyl hexamethylene diamine blend shown in figure 8. IR spectrum 3284cm-1confirms the N-H stretch in stretching zone.IR spectra 2868cm-1,2907cm-1 and 2952cm-1 shows the presence of C-H stretch very sharp peak in stretching zone.IR spectra 1600 cm-1 shows the presence of N-H bend. IR spectra 1469cm-1shows the presence of C-H stretch very sharp peak.IR spectra 1364 cm-1 shows the presence of C-H rock. The IR spectrum of blends was confirm be after 7 days , During characterization ,it is observed that there is no IR spectra of –CONH appears and hence it shows there is no dissolution of waste PET in trimethyl hexamethylene diamine.

During characterization, It is observed that there is no IR specra of amide (-CONH) appears into waste PET & Diethylene triamine , waste PET & Isophoron diamine & waste PET &Trimethyl hexamethylene diamine blends

Fig.1 Slice the post-consumer soft drink bottle waste PET plastic pieces into small pieces

Fig.2 Dissolve the waste PET plastic pieces into Di ethylene triamine and Triethylene tetramine, Trimethyl, hexamethylene diamine, Isophoron diamine

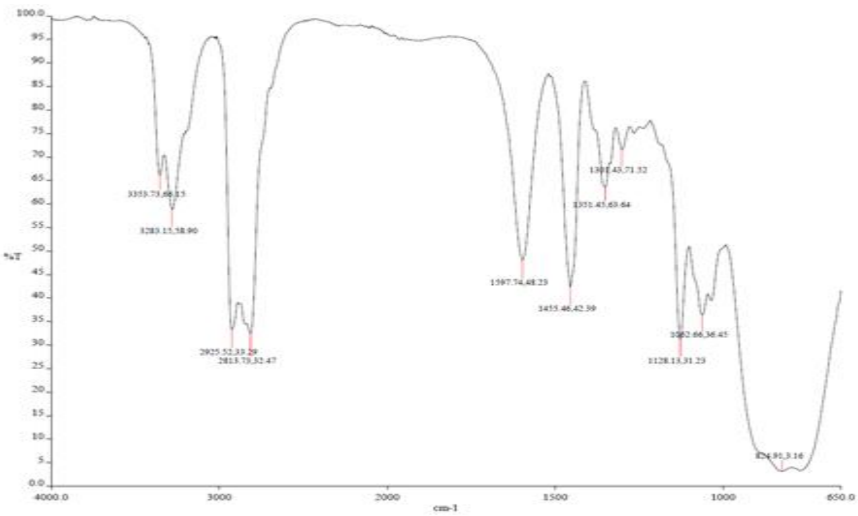

Fig. 3 IR spectrum of Waste PET with Diethylene triamine - After 8 days

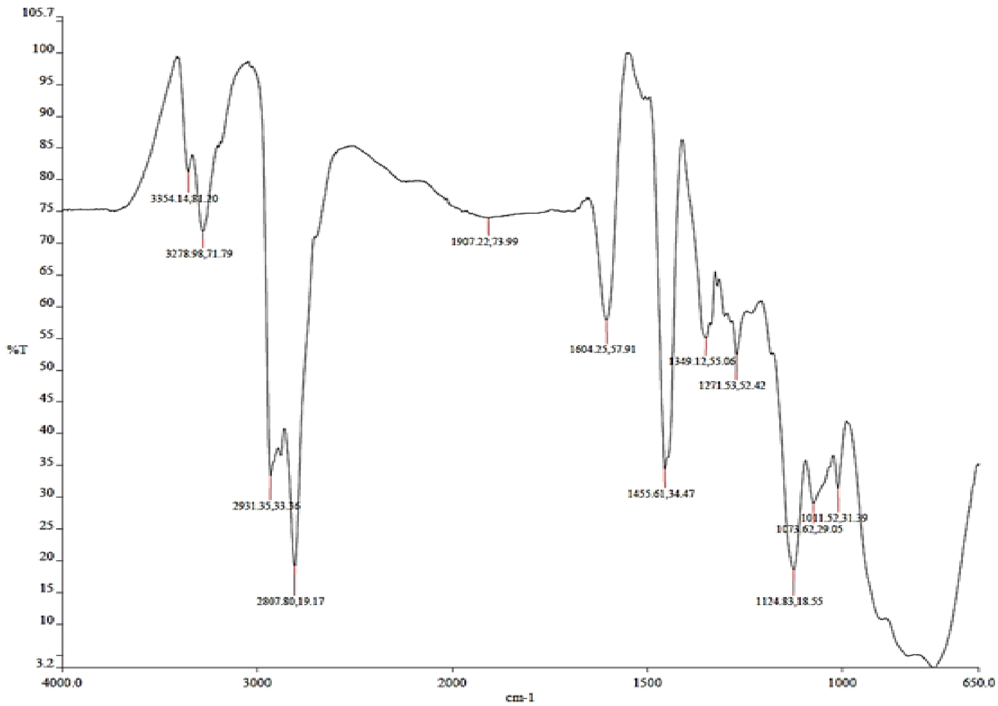

Fig. 4 IR spectrum of Waste PET with Triethylene tetramine - After 8 days

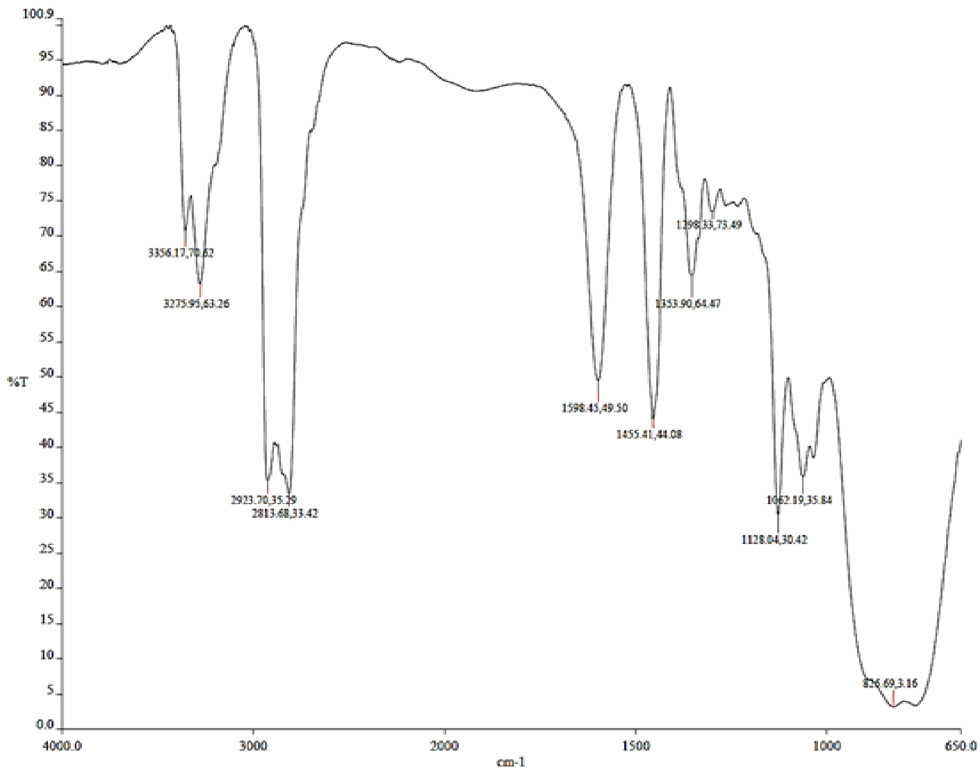

Fig. 5. IR spectrum of diethylene triamine

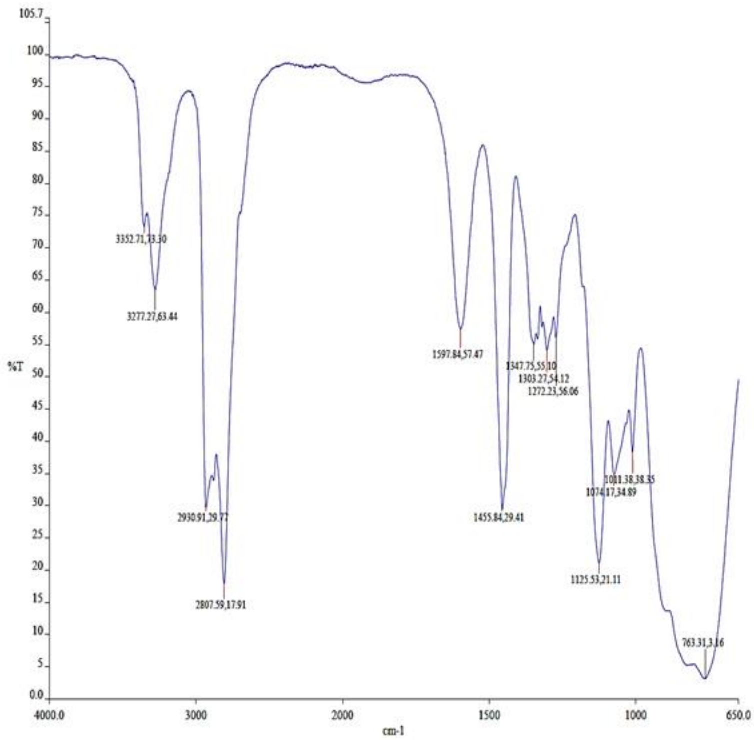

Fig. 6. IR spectrum of Triethylene tetramine

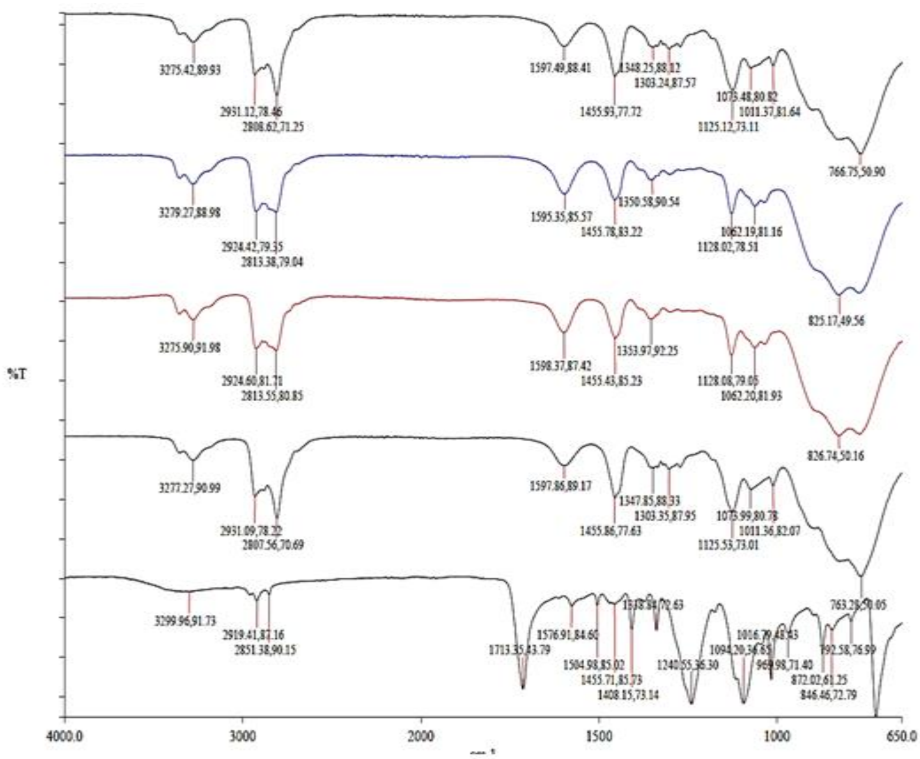

Figure. 7 IR spectrum of waste PET & DETA blend & Waste PET & TETA blend Vs.DETA Vs TETA Vs.PET after 15 days

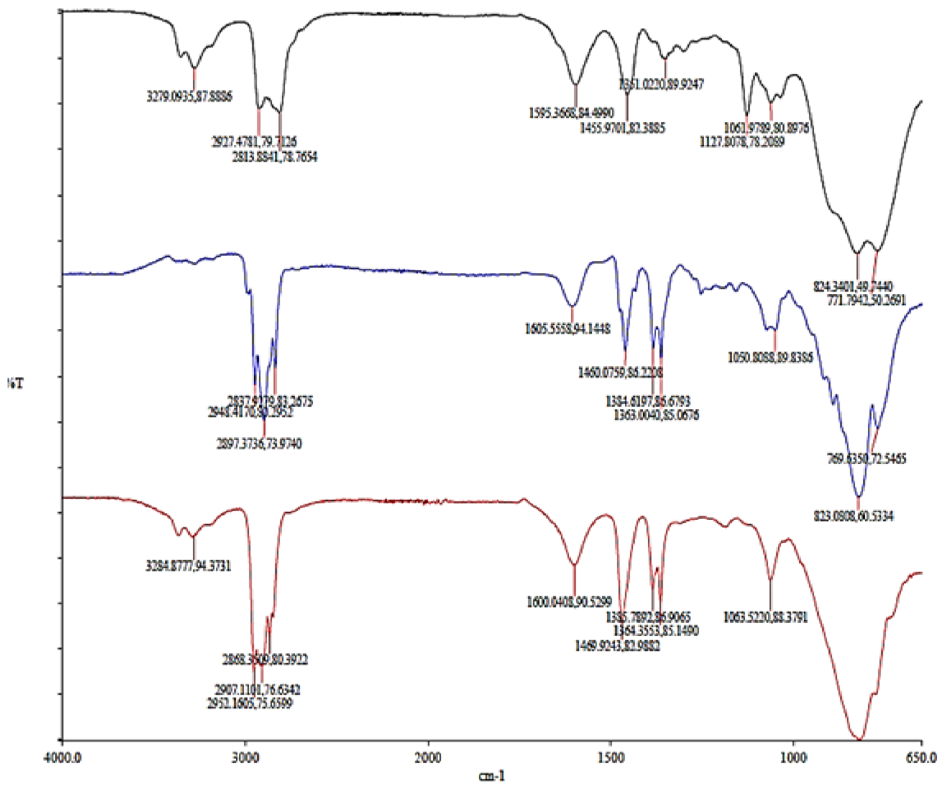

Figure. 8 IR spectrum of waste PET & Diethylene triamine blend , waste PET & Isophoron diamine blend & waste PET & Trimethyl hexamethylene diamine blend after 7 days

CONCLUSION

It is observed from above study that waste PET (Polyethylene terephthalate) in not dissolved in TETA (Triethylenetetramine) and DETA (Diethylene triamine) solutions after 8 days and 15 days .It is confirmed by FTIR characterization and there is no spectra (–CONH) appears in both the blends. There is also study done with higher concentration of PET (Polyethylene terephthalate) waste mixed with different amine solutions (Diethylenetriamine, Isophoron diamine and Trimethyl hexamethylene diamine) for 7 days to observe the solubility behaviour of PET waste at room temperature . It is confirmed by FTIR characterization ,there is no spectra (-CONH) appears in all the blends . It is conclude from above all the studies and observations that waste PET is not soluble in above mentioned amine solutions at room temperature.

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