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Polyester Fabric Scrap Recycling

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Abstract: Textile recycling is a significant challenge to be addressed in 2022. Once in landfills, natural fibers can take hundreds of years to decompose. They may release methane and CO_2 gas into the atmosphere. Additionally, synthetic textiles are designed not to decompose. In the landfill, they may release toxic substances into groundwater and surrounding soil. The synthetic fiber raw materials are totally imported from abroad as polyester and nylon. The annual consumption is nearly 530 thousand tons. As the recycling processes aren't applicable, the new technology for recycling this scrap is a value-added process. Produced Ecofriendly textile from recycled raw material is one of the most achievable goals in this study and it will help mitigate the impact of climate change. The optimum yield (92%) in this work was achieved at temperature of 150^0C and time of 180 minutes. Methanol was used as a solvent.
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1. Introduction

Synthetic fabrics made of petrochemicals are not readily biodegradable, meaning the result will always be existent and hence cause environmental problems [1-3].

Over the last few decades there has been a major shift in the materials chosen by manufacturers, designers and consumers alike. Whereas natural fibers dominated the scene fifty years ago, we now see an abundance of synthetic and man-made materials taking centre stage. The industry is overrun with polyester, polypropylene, and nylon because synthetics are cheaper and easier to produce in large quantities. This may be good for the bottom-line, but it is damaging the environment in a big way contributing an overwhelming amount of chemicals, waste and carbon emissions [4-6].

In Egypt the recycling of synthetic fibre in environmental friendly ways isn't found. The ways used to get rid of the waste are: incineration, landfill and its use in low value industry. The importance of recycling textiles is being increasingly recognized. The increase in demand and consumption for synthetic textiles is a result of global population growth and improvement of the living standards [7-10].

A value-added material from fabric scrap that can be used in different applications such as producing fibre or plastic products should be developed. This will strongly contribute to reducing municipal solid waste in the environment, decreasing imports of raw materials, and thereby saving foreign currency. Furthermore, this will encourage the establishment of small businesses working on the recycling of synthetic scraps and the creation of new and productive job opportunities. The aim of the present work is to develop a value-added material from fabric scrap and produce ecofriendly fiber to mitigate the impact of climate change resulting from improper way of waste disposal [10-15].

Expected Impact:
Textile recycling of polyester fabric scrap offers the following benefits:
1. Reduction in the landfill volumes.
2. Reduction in consumption of industrial energy and water.
3. Pollution avoidance.
4. Creating an added value to the current zero value polyester fabric scrap.
5. Saving natural resources.
6. Lowering greenhouse gas emissions and usage of chemicals.
7. Encouragement of solid waste management
8. Mitigating the impact of climate change.

2. Materials and methods

Black polyester fabric scrap:

8 grams of black polyester fabric scraps, 300 millilitre of methanol and 11.6 grams of potassium hydroxide KOH were added into a 500-millilitre flask. The flask was connected to a reflux condenser to condense the methanol vapour with a magnetic stirrer. The heat source was a hot plate. The experiment with

the previous mixtures was conducted for 3 hours until complete dissolving of black fabric. Afterwards, the mixture was left to cool down, and then it was filtered using Buchner funnel, filter paper and a suction pump (Figure 1) while washing with 100ml of methanol. The residue after filtration was then taken and left to dry in an oven on 150 degree Celsius for about 180 minutes to make sure all the methanol content was vaporized and then the dried residue was grinded into fine particles. The grinded residue was analyzed by the FTIR spectroscopy by mixing it with potassium salt. The sample after that was dissolved in distilled water and the mixture was heated with stirring on 60 degree Celsius until the turbidity of the water was less

20 grams of charcoal powder was added to the mixture to remove any color of fabric dyes. The mixture was then filtered using a funnel and a filter paper. After that, 10 milliliters of concentrated sulphuric acid Conc.H_2SO_4 was diluted by distilled water, and then added to the filtrate drop by drop. The mixture was then filtered by Buchner funnel using suction pump and the residue was taken and put in the oven to dry on 150 degree Celsius (Figure 2). The dried residue after FTIR analysis turned out to be Terephthalic acid TPA with about 92% yield.

Figure 1: Dissolving the Black polyester fabric scrap using methanolysis process

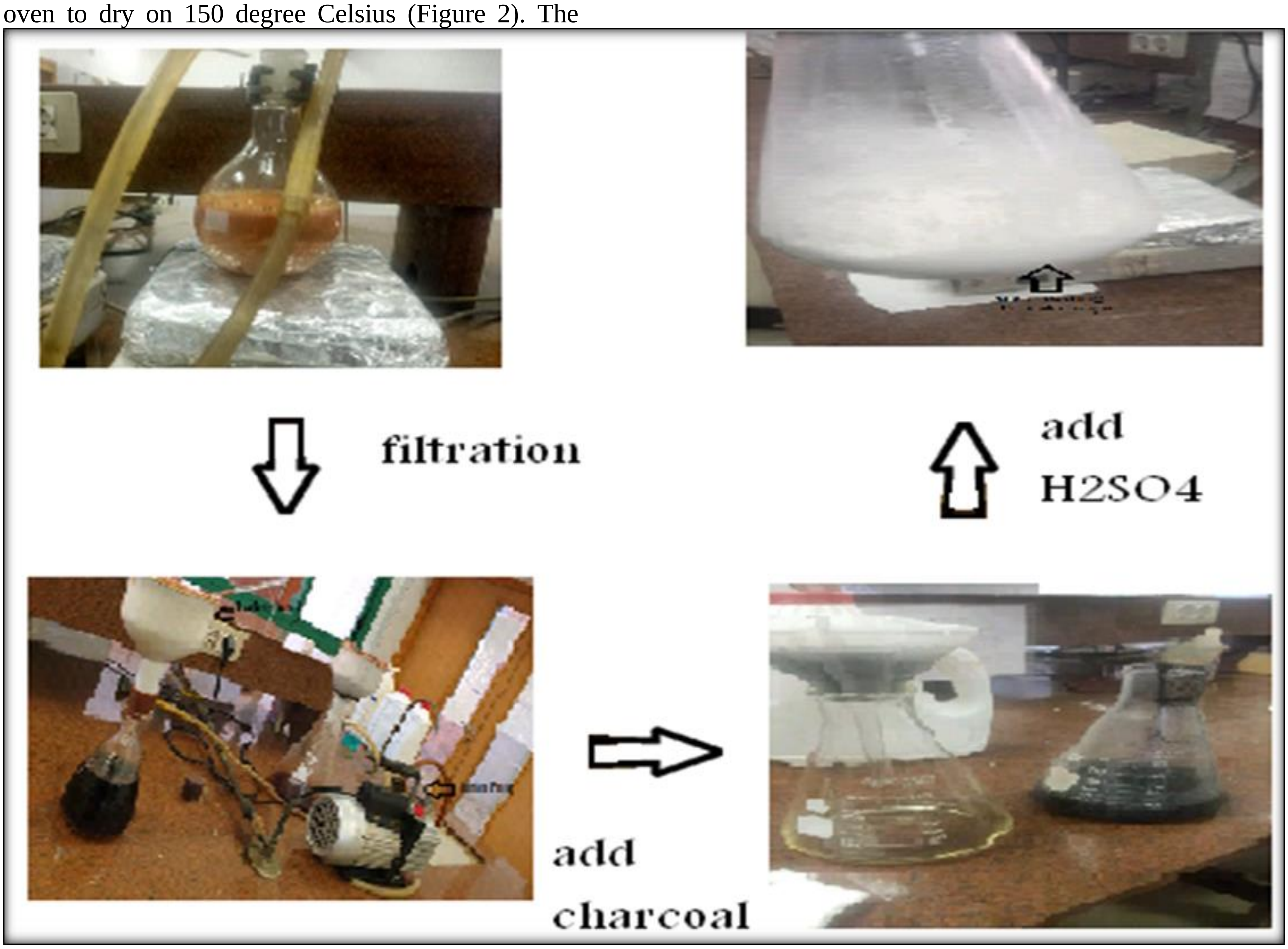

Figure 2: Chemical treatment for colour removing

White polyester fabric scrap:

8 grams of white polyester fabric scraps, 300 milliliters of methanol and 11.6 grams of potassium hydroxide KOH were added into a 500-millilitre flask. The flask was connected to a reflux condenser to condense the methanol vapor with a magnetic stirrer; the heat source was a hot plate. The experiment with the previous mixtures was conducted for 3 hours until complete dissolving of the white fabric. Afterwards the mixture was left to cool down, and then it was filtered using Buchner funnel, filter paper and a suction pump (Figure 3) while washing with 100ml of methanol. The residue after filtration was then taken and left to dry in an oven on 150 degree Celsius for about 180 minutes to make sure all the methanol content was vaporized. The dried residue was grinded into fine particles. This grinded residue was analyzed by the FTIR spectroscopy mixed with potassium salt. The sample after that dissolved in distilled water and the mixture was heated with stirring on 60 degree Celsius until the turbidity of the water was less.

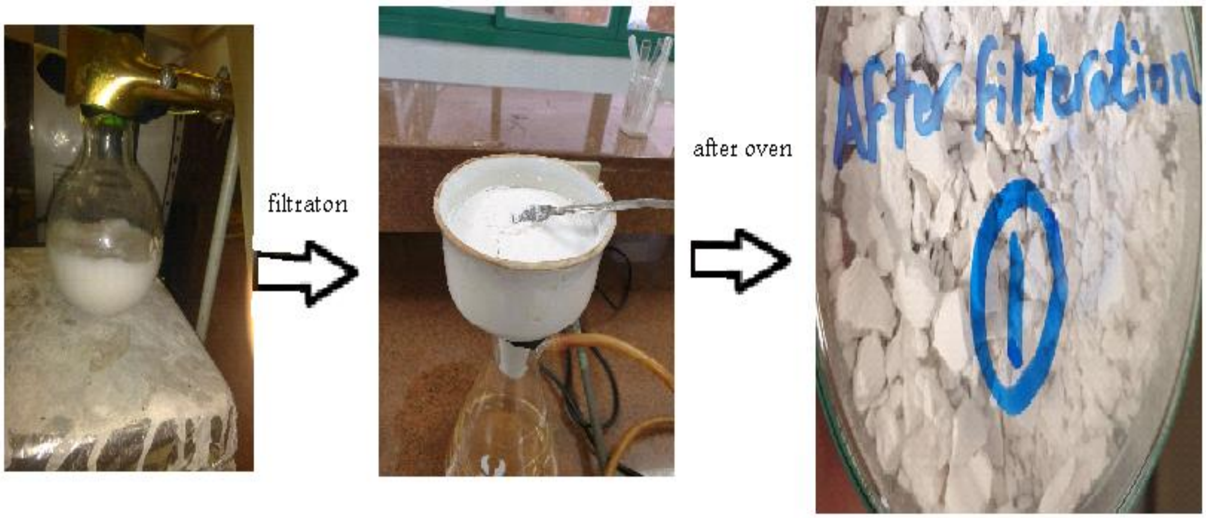

Figure 3: Dissolving the white polyester fabric scrap using methanolysis process

The analysis of the end products for black and white fabric scrap (Figure 4) was done using several techniques including SEM, FTIR and XRD.

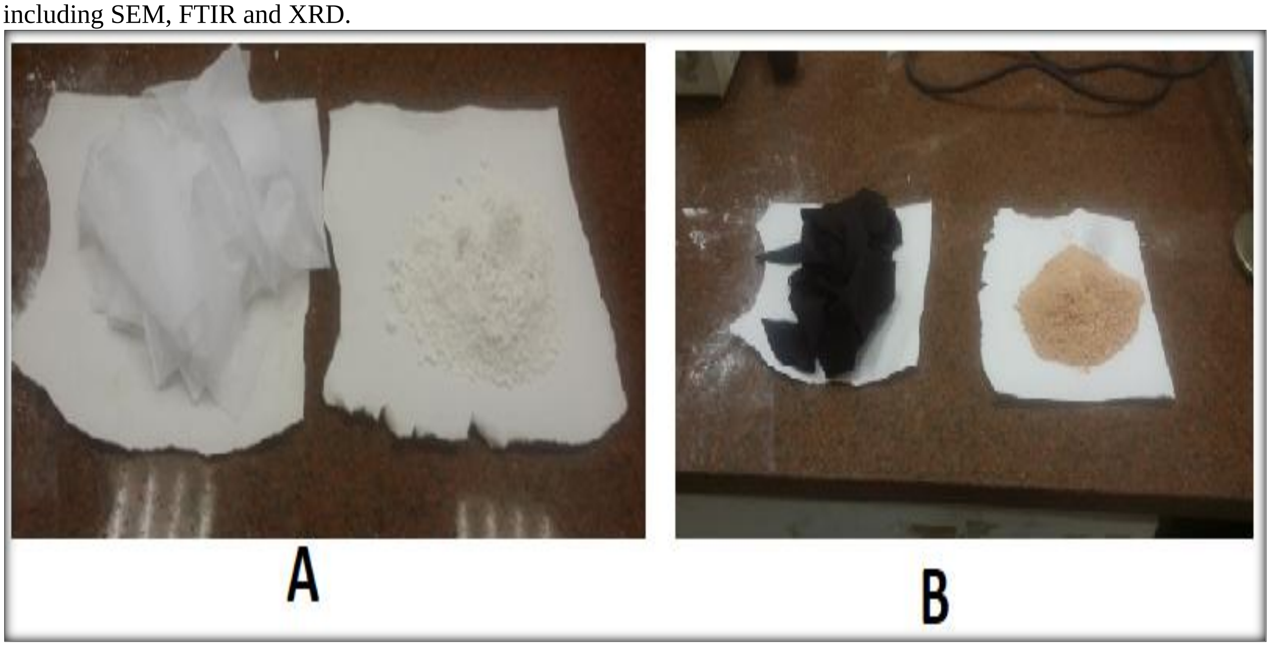

Figure 4: The Final products of white (A) and black fabric scrap (B) after chemical recycling

3. Results and Discussion

SEM Analysis:

The result of SEM analysis of end product in Figure 5 for A: White fabric and B: Black fabric

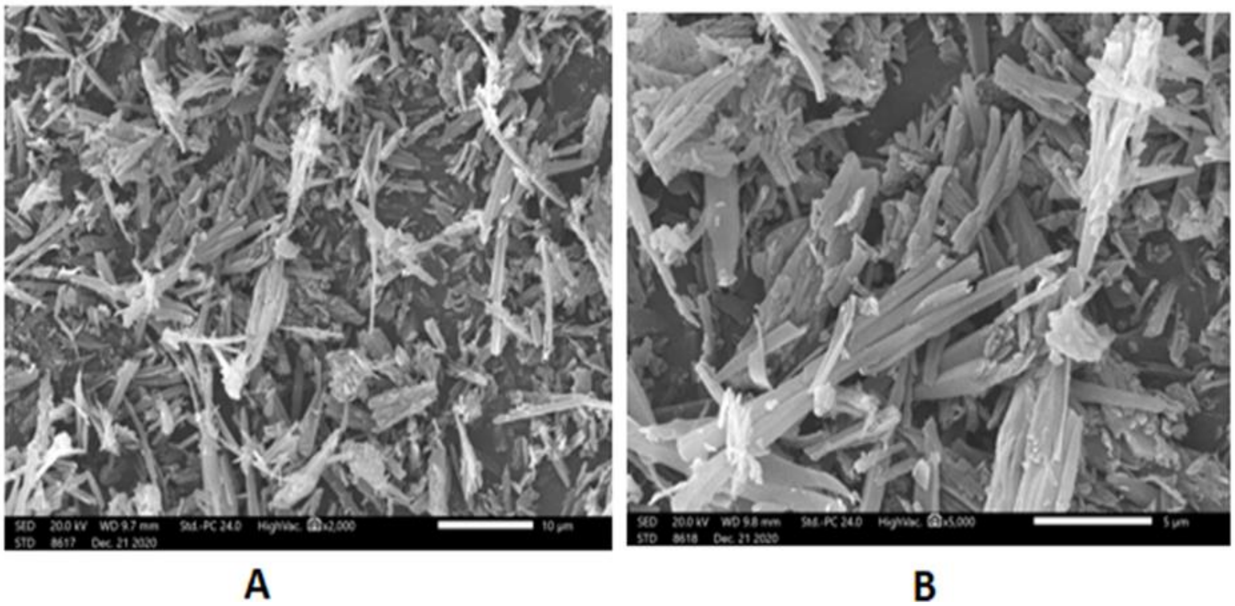

Figure 5: SEM analysis of fabric scrap (A: White , B : Black)

FTIR Analysis:

The aim of using FTIR analysis is to determine the existence of functional groups that exist on the fabric FT-IR spectroscopic study for the solid materials that show different functional groups. The FTIR charts for end products and raw materials are shown in figures 6 to 8[16-20].

Standard polyester sample:

The FTIR spectra showed a wide band with two maximum peaks at 3697.85 cm^{-1} and 3429 cm^{-1}. This band can be assigned to the O–H stretching mode of hydroxyl groups and adsorbed water. Moreover, this broad peak band in the range of 3200–3650 cm^{-1} is attributed to the hydrogen-bonded OH group. Peaks at 1797.9 cm^{-1} might be related to the carbon-oxygen dingle bonds that displayed stretching movement. In the region 500–900 cm^{-1}, there is a peak at 712.6, 796.98 and 874.62 cm^{-1} which is assigned to C–H out-of-plane bending. The peaks in 1797.9cm^{-1} are due to the double bond C=O stretching vibrations.

The FTIR analysis was done for the following samples:

1-Black Polyester Fabric scrap (B PSF scrap) and White Polyester fabric scrap (W PSF scrap) Figure 6

2- B PSF and W PSF scrap after chemical recycling (figure 7 and 8)[21-25].

Fabric scrap:

The FTIR spectra of black and white fabric scrap (figure 6) indicates absorption bands confirming the presence of backbone of polyester polymer. The wide peak was around 3200-2900 cm^{-1}. The peak at 1797.9 cm^{-1} might be related to the carbon-oxygen dingle bonds that displayed stretching movement[26-35].

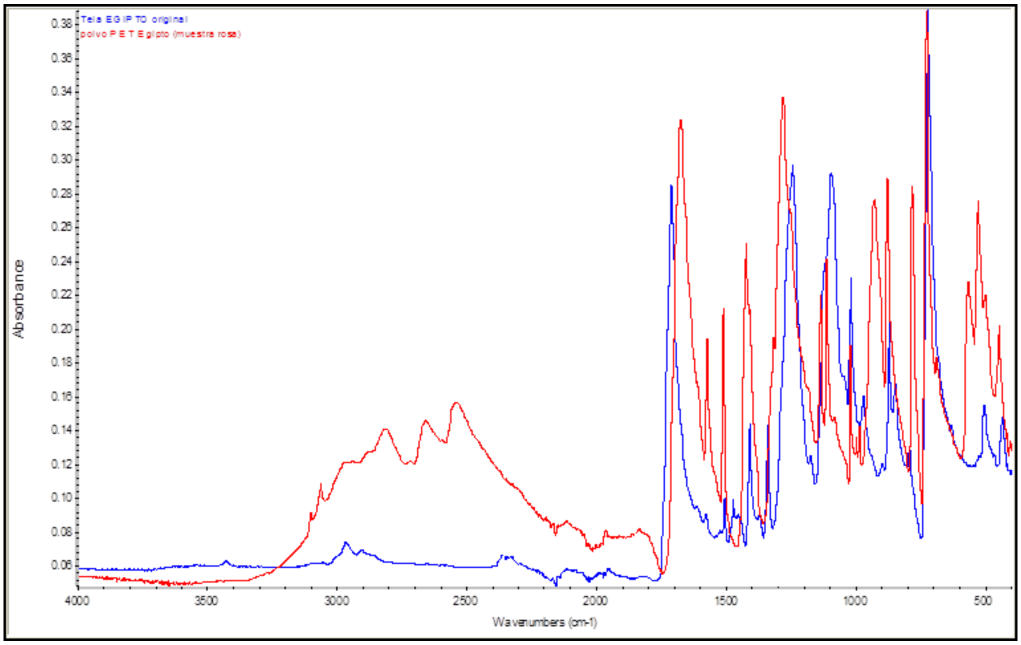

Figure 6: FTIR of the two samples fabric scrap (red: white PSF & blue: black PSF)

Black polyester fabric scrap:

The FTIR spectra of black fabric scrap were tested after chemical recycling and several treatments to detect the effect of chemicals on dye removing and conversion process. (Figure 7) indicates the absorption bands confirming the presence of backbone of polyester polymer[36-45].

The wide peak was around 3200-2900 cm^{-1}. The peak in 1797.9 cm^{-1} might be related to the carbon-oxygen dingle bonds that displayed stretching movement.

From the unique peaks, the sample is Terephthalic acid (TPA) which is an organic compound with formula $C_6H_4\ (CO_2H)_2$. This product is a commodity chemical, used principally as a precursor to the polyester PET. There are several peaks related to the presence of the remaining dye in sample.

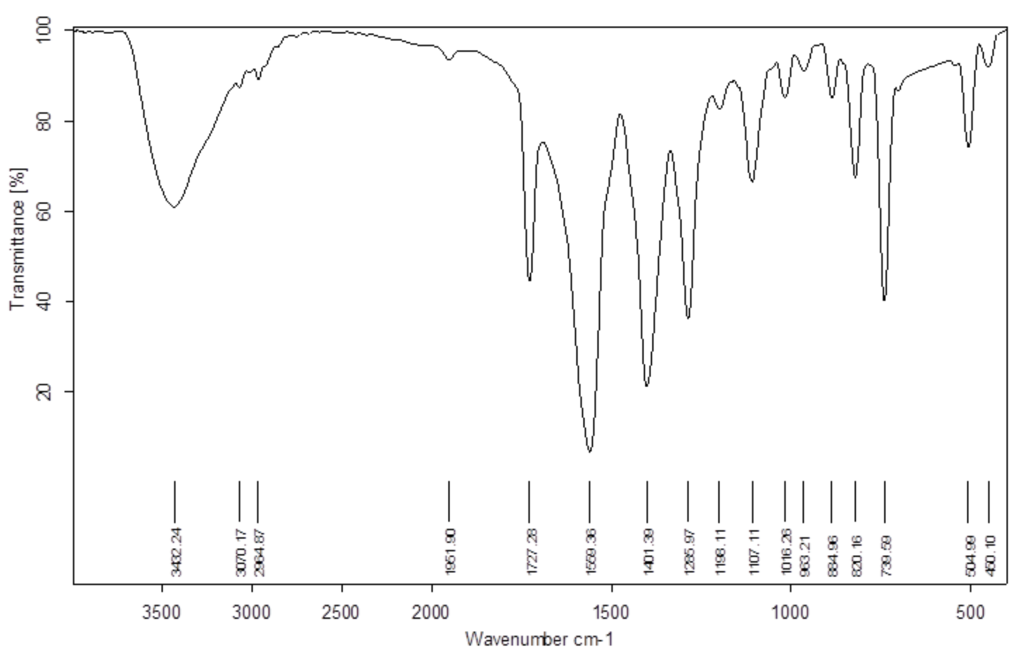

Figure 7: The FTIR of B PSF scrap after chemical recycling

White polyester fabric scrap:

The FTIR spectra of white fabric scrap were tested after chemical recycling and several treatments to detect the effect of chemicals on dye removing and conversion process. (Figure 8) indicates absorption bands confirming the presence of backbone of polyester polymer.

The wide peak was around 3200-2900 cm^{-1}. The peak in 1797.9 cm^{-1} might be related to the carbon-oxygen dingle bonds that displayed stretching movement.

From the unique peaks, the sample is Terephthalic acid (TPA) which is an organic compound with formula C_6H_4 $(CO_2H)_2$. This product is a commodity chemical, used principally as a precursor to the polyester PET. There are several peaks related to the presence of the remaining dye in sample[46-50].

XRD spectroscopy:

XRD Spectroscopy is a non-destructive chemical analysis technique which provides detailed information about chemical structure, phase and morphology, crystallinity, and molecular interactions. It is based upon the interaction of light with the chemical bonds within a material[50-57].

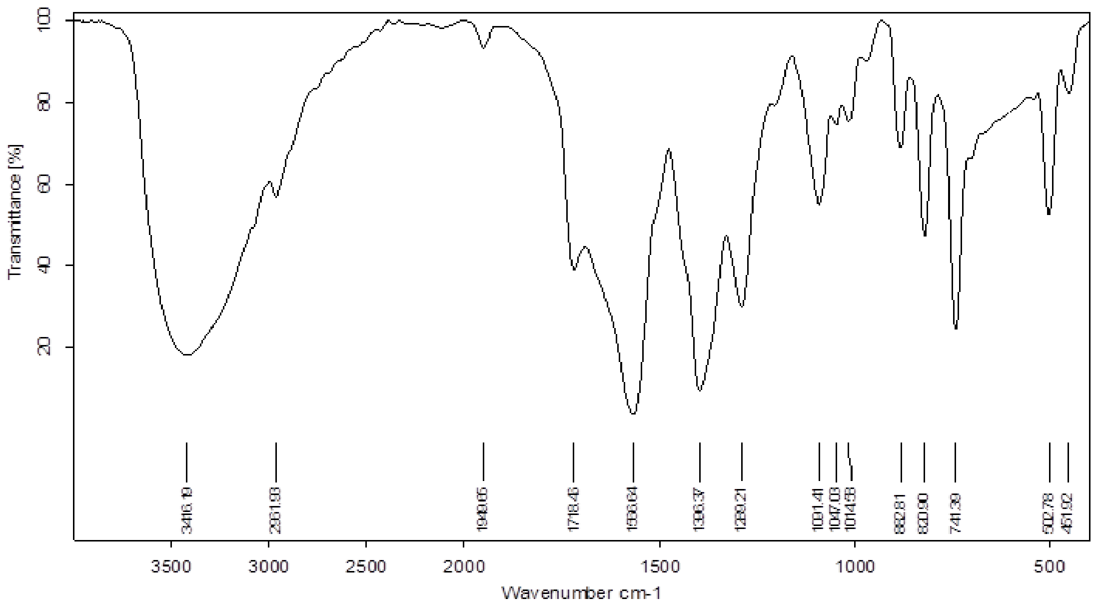

Figure 8: The FTIR of W PSF scrap after chemical recycling

The analysis of end products of chemical recycling process in figure 9.

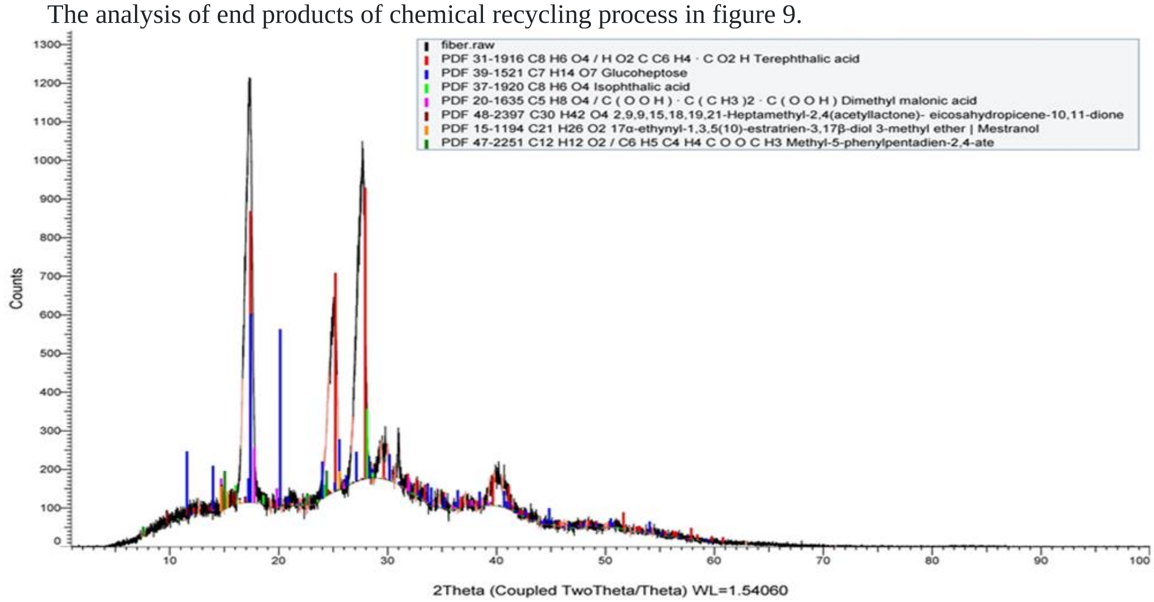

Figure 9: XRD analysis of Black and white fabric scrap after chemical recycling

Conclusion:

- The temperature and time have a huge impact on the TPA yield, and the quantity of the materials used. As different variables and conditions were used it was found that the optimum conditions are when the reaction time is 180 mins, reaction temperature 150 degree Celsius, the quantity of the polyester fabric scraps are lager and hence the yield is greater.
- After further trials the used methanol was reused in the reaction by taking the liquid precipitate from the filtration of the reaction and putting it in a distillation column at 60 degree Celsius. Then, the condensed vapour of methanol was used from the distillation column in a new reaction with the procedure used. The results were the same with slightly smaller yields of TPA.
- The chemical recycling of polyester fabric scraps is seemingly promising as it produces a reusable chemical product with low cost and low power consumption. It is a futuristic industry and sooner than later the zero value of polyester fabric scrap will be valuable.

Declaration

Conflicts of interest/Competing interests:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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