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Sustainable Transformation in Modest Fashion Through "RPET Technology" and "Dry-Dye" process, using Recycled PET Plastic

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Abstract: ***Clothing and textile industry are one among the biggest contributors of the landfills affecting the world's environment. This industry is ranked third in contaminating the globe, after oil and agriculture industry. Various reasons involved for this, would be excessive demand and supply of cheap clothing (fast fashion) which leads to more waste. The customers are unware of what they buy? The consumers should first understand fashion- "Fashion is what we require or feel every day, it includes creativity, mood, tradition and lifestyle". Today fashion industry is huge in terms of global business contribution. In spite of its popularity, as other businesses it also has gloomy character involved, where pressure is to reduce cost, fast fashion, toxic chemicals and dyes used, misuse the labor efforts, textile waste and over consumption of energy. This study analyses how we can reduce textile waste, water and energy by using Dry-Dye method on Recycled polyester derived from PET bottles. The basis of the research is to convey attention to the Modest Fashion customers as the material created by these innovations best suits their necessity, remembering their wellbeing and advantages to the worldwide condition.***

Keywords: Sustainability, Fabric, clothing, Dry-Dye, Fashion Industry, RPET, Textile, Modest Fashion

I. INTRODUCTION

Clothing world is looking forward to a sustainable future with eagerness to use exciting new technologies and innovations. This would require all segments of the industry to get involved and take up enormous steps to form the new sustainable world. Sustainable fashion is chosen for ecological reasons which will bring better and secured future. It will also help add value for products created by arcticians and maintain its unique design feature. The plan is to empower every person involved in the supply chain and assure our condition and upgrade the lives of the customers, masters and manufactures around the world. [1]

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The quickened pace of utilization in the Western world has prompted an expansion in clothes and fabrics discarded in the trash as opposed to being recycled or reused. The motivation behind is to expand comprehension of how attire and material utilization can turn out to be progressively manageable. Garments are frequently disposed of when a lot of their potential lifetime is left. Numerous altruistic associations consequently gather utilized attire and exchange it as second-hand garments.

In the case of reusing garments results in a lessening of the ecological weight of the existence cycle of apparel. [2] Recycling and reuse of traditional customary items such as glass, paper, plastic, and tin is very common. . [3]

Textile waste is a rapidly growing sensitive issue in regards to the effects on the environment caused due to excessive consumption of clothes and its waste. The graph (Fig.1) shows the contribution of percentage waste disposal worldwide in 2018. This data helps us to manage the waste and recycling through consciousness. Post textile waste is undiscovered item with a great potential of reuse and recycle. [4]

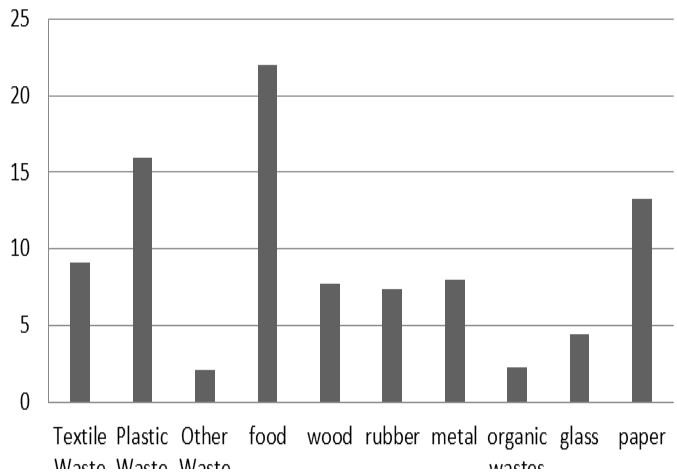

Fig.1. Plastic and Textile waste Contribution to the Global Environment (%)

"Fashion is not only about feeling good but also should do good". Sustainable Fashion is no longer a choice but a necessity in today's world. The fresh designers should have courage to be disruptive and have the valor to create the unexpected. There is a goal to create something new out of discarded. Sustainable designs can be characterized as eco or ethical items which are created, sold and utilized in maintainable way. The entire cycle involved from evolution to recycling of the product may be called as life cycle of the product. (Fig.2). [5] when the product passes through various stages of its life it can be defined as life cycle of that product.

The various sequence of stages the products goes through are Design development, introduction in the market, growth, maturity, and decline of the product. As the product reaches to its last stage of life cycle, innovation of new recycled design idea prompts through. The right use of natural resources can save the environment and encourage the designers to recycle and reuse the end products. [6]

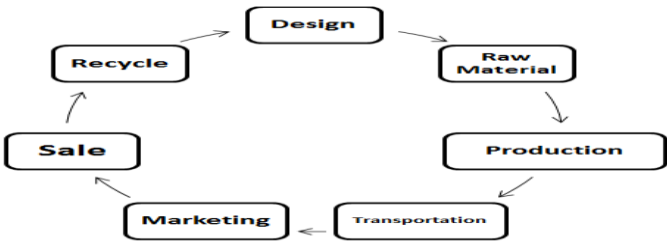

Fig.2. Product Life Cycle

A. Textile Waste

There are various ways in which the textile wastes can be recycled. The fibers from the fabric or textile material is either shredded or pulled out, these fibers sometimes along with new fibers are twisted and converted into new yarns. These yarns are then cleaned and passed through a process called carding. Finally they are spun into fresh yarns which are ready for knitting or weaving. Some of the fibers are not converted into yarns but are compressed and used as fillings for mattresses. In case of polyester textiles the fabrics are granulated, melted and reconverted into fibers. Fiber recycling can be done with the disposed chopsticks, which is a major waste in Far eastern countries. [7]

The heavy use of chemicals in the textile manufacturing industries drastically pollute the oceans and aquatic life as their waste contains highly contaminated toxins. This polluted water leads to harmful diseases for the mankind which may even cause premature deaths. [8]

The environment is being damaged more with the growth of textile industrial wastes as it also contains polyester micro fibers. With every wash 7000,000 micro fibers are lead towards the oceans which becomes the part food chain ending up on human's plate. These plastic fibers take more than 200 years to biodegrade. Fig.2. [9]

B. Polymers and Cotton in Fabric

Polymers run from engineered polymers to normal biopolymers, for example, DNA and proteins. An oligomer is a particle that comprises of a couple of monomer units. "Macromolecule" is utilized for individual particles of high sub-atomic weight and "polymer" is utilized to mean a substance made out of macromolecules. It very well may be shaped amid polymer fabricating and furthermore because of polymer debasement forms or notwithstanding amid use conditions. Since oligomers are excluded in concoction databases, their distinguishing proof is a mind boggling process. [10]

Cotton is the most common sustainable textile fabric. It is a soft and breathable fabric. Cotton recycling is not as easy as it seems to be. For developing new raw material from old cotton textiles, the fabrics need to be shredded or cut into small pieces; this reduces the quality and strength of the cotton fibers as they are short staple fibers. The staple length is very important to determine the stability and suppleness of cotton yarns. The more drawn out the staple, the better is the quality of cotton. Thus, recycled cotton is often blended with recycled plastic converted into fibers for creating new clothing or textile. Cotton when blended with other fibers makes more strong and durable fibers. [11]

There is an evident rise and demand for "Generation M" in the Gulf region today. The new Arab designers and consumers want a change in their conventional way of dressing. the demand for modest fashion is now beginning to expand outside the Middle East region and even capturing the western world. The modest women are now looking for "luxury modesty", which mean stylish and futuristic modest clothing beautifully engraved with belief and modernity. As there is considerable growth in Muslim population around the globe, the demand for modest clothing has also increased substantially. [12]

II. PLASTIC WASTE

Huge number of PET bottles are disposed every year in the landfills. By 2021 it is evaluated that the number of PET bottles will increase to 583.3 billion. These bottles contain Bisphenol A (BPA), (Chemical Used to make the plastic clear and hard) this chemical is very harmful to human health and contain high toxic chemicals. Plastic bottles are considered to be non-degradable as they take around 700 years or more to decompose. Less than 10% of these PET bottles are being recycled. If the clothing industry takes initiative to convert PET bottles into polyester fabric this will help to protect the earth and our future.

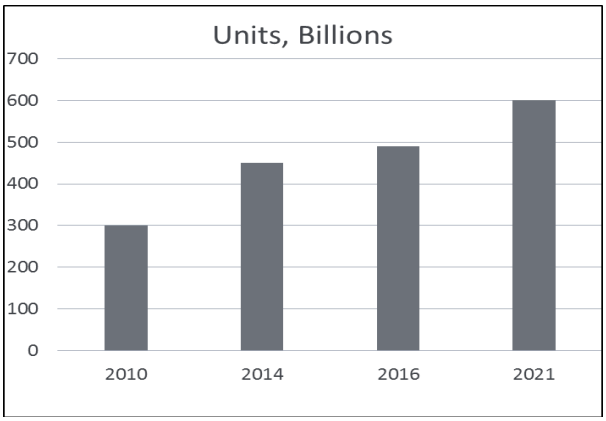

Fig.3. Global PET bottle Production

More than 300 million tons of plastic is manufactured worldwide every year out of which only 10 percent of it is recycled and more than 7million tons end up in the oceans every year. The PET bottles made plastics which can be completely recycled but these bottles do not biodegrade or photodegrade for long years which means they break down into polymers these polymers absorb toxins over the period of time and pollute our oceans and seaways, affect our soil, and animals. Plastic waste absorbs organic pollutants like BPA. This takes ages to degrade and decompose in landfills, resulting the damage for our environment. Around 20,000 plastic bottles are manufactured every second. (Fig.3). [13]

A. Textile Recycling

Textile recycling leads to both, environmental and economic benefits. It prevents a lot of contaminating toxins and conserves energy that are utilized to make materials from new materials. Textile recycling may reduce the demand for chemical based dyes and fixing agents. The space required for landfills will reduce.

This will also lead to reduction of transportation cost and pollution via transportation as recycle material will be locally available. There is various method of recycling.

Close-loop recycling demonstrates an item can be reused once more into itself; this recycling is centered on production network supportability. The frameworks are grown with the goal that the majority of the materials made in merchandise can be reused, typically for use in a similar sort of items. The assembling procedure is normally planned in view of reusing. For e.g., cans made of Aluminum can be reshaped and reused in the form of new jars or containers with minimal material corruption or waste creation. [14]

Open-loop recycling shows that it tends to be reused into different sorts of items (for example PET bottle into fiber). Here the recycled materials are changed over into new materials. This implies the contribution to the reusing procedure is changed over to another new item is created which is completely different from the original item. [15

III. LITERATURE REVIEW

Polyester which can be characterized as "long-chain polymers artificially made of ester (85%), dihydric liquor and a terephthalic corrosive". Which means it links various chemical compounds inside the fiber strands. Polyester can also be stated as saturated and unsaturated polyesters.

Polyesters, in which the polyester backbones are saturated, are referred as saturated polyesters. They are less reactive as compared to the unsaturated polyesters. They comprise of low atomic weight fluids utilized as plasticizers and as reactants in shaping urethane polymers, and straight, high sub-atomic weight thermoplastics, for example, polyethylene terephthalate (Dacron and Mylar). Glycol and a corrosive or anhydride is regular reactants for the saturated polyesters.

Unsaturated polyesters allude to that group of those polyesters in which the backbone comprises of alkyl thermosetting gums portrayed by vinyl unsaturation. These polyesters are generally used in reinforced plastics.

Though we are all aware Polyester is a manmade artificial fabric which is harsh on body. Yet, there are many positives to this fabric like, the fibres of this fabric is very strong which makes it durable in nature, it is wrinkle resistant, dries quickly, less maintenance required and very good drapability.

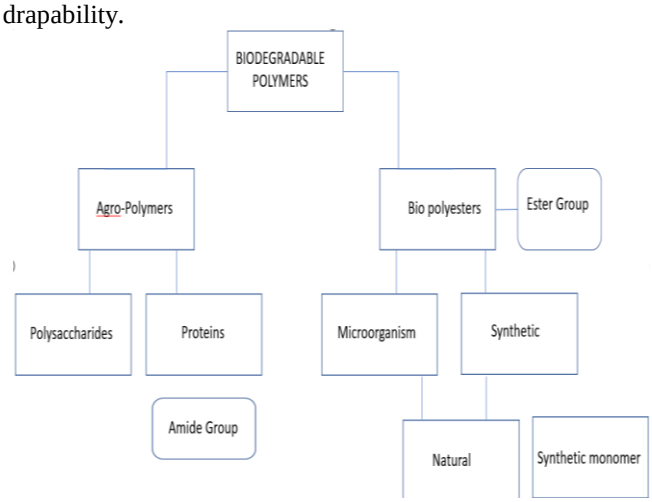

Fig.4. Structure of Polymers

Polymers that separates or breaks down after its planned reason by bacterial deterioration procedure to result give out effects, for example, gases (CO2, N2), water, biomass, and inorganic salts may be called as Biodegradable polymers (Fig.4). These polymers to a great extent comprise of ester, amide, and ether useful gatherings and are made of both naturally and artificially discovered polymers. Many packaging materials have been used which are bio degradable and edible which have been used in past decades. [16]

A. Fabrics used in Modest Clothing

Conventional Abayas are mainly made of polyester fabrics which is synthetic in nature and is chemically produced. The chemicals like sodium hydroxide and carbon disulphide are used in making polyester fibers which are derived from crude oil, gasoline or coal. In this fashion world where there is a cut throat competition, modest fashion sector has made a soft entry into the design business through hijabs and Abayas [17]. This change in the industry has been accepted by the consumers of modest fashion in a responsive manner and they took quick actions in experimenting new designs and fabrics which can be used in the modest world (Fig.5). Understanding customer preferences and producing as per their choice is most important for a designer from fashion point of view. [18]

The value of the world's apparel and textile market totaled $1,254.1 billion in 2015 which showed the increase of 4.8% from a year previous year. It is predicted the apparel market is going to grow 5.7% by 2020. Data source: Market Line (2017)

Heritage, culture and history is a confident reflection of clothing style in The Islamic Fashion or Modest clothing.

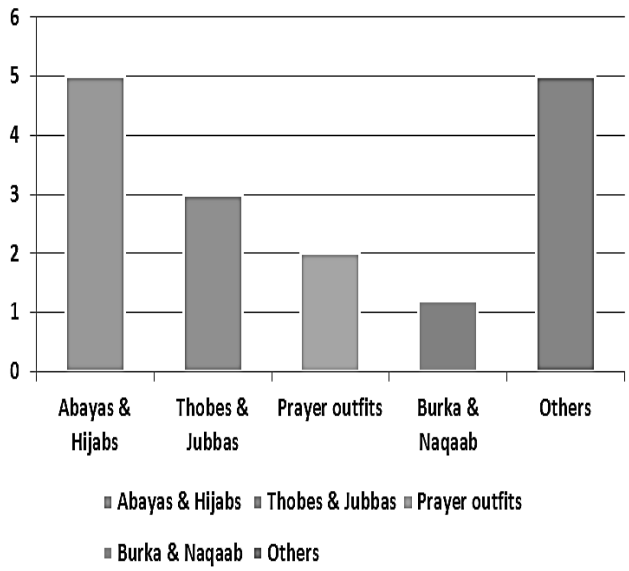

Fig. 5. Global Islamic Clothing Market Share (Sales %)

The journey of Abaya has evolved in the past few years and there has been remarkable change in modest fashion industry, the black robe has travelled a long way and has now adapted beautiful designs and silhouettes. Abaya is not only considered to be a religious symbol now but also has invaded the western world of global fashion and also has embraced the leading brands. (Fig.6). [19]

According to the report of Dame Ellen MacArthur's foundation published in 2017, Textile industry creates greenhouse emissions of 1.2 billion tons a year. It is estimated that every second either one full truck of fashion apparels are disposed in the landfills or burnt.

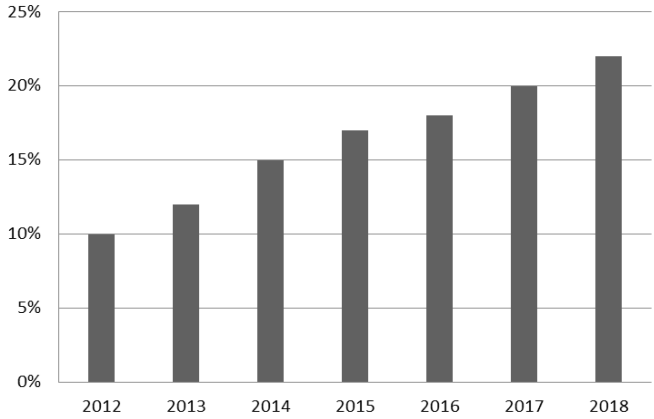

Fig.6. Rise in Modest Fashion Industry - the Global scenario.

In spite of plastic being dangerous for environments wellbeing, the conversion of plastics into clothes would be beneficial. While producing RPET yarns 50% of less energy is needed as compared to the virgin polyester yarns. Carbon emissions released is less than 55% and 20% less water used. Textile recycling may be defined as reusing or reprocessing of textile fibers, scrap to convert into new fresh yarns.

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The Modest clothing or Islamic Fashion is a reflection individual 's personality which shows one's confidence in tradition and respect of their culture and history.

Table-1

Traditional Fabrics used for Abayas (Haya clothing)

Nida • A Soft and luxurious fabric, • branded and expensive Abayas • 100%polyester	Internet • Heavy weight fabric • slippery hand-feel • overtone in shine • 100% polyester
Lexus • A Matte finish fabric • soft hand-feel • Good drape • 100% polyester	Poly Crepe • granular texture • light weight to medium weight • 100% polyester
Satin • soft, shiny light weight fabric, • smooth and slippery hand-feel • "Silky Helwa"(local language) • 100% polyester	Jersey • Stretchy knit fabric • Polyester & Lycra

Types of fabrics isn't the primary thing that strikes a chord when we consider health, however it plays an important role which should be regarded. The conventional Abaya is made of fabric which is 100% polyester, worn by the women in Gulf region. [20]

Table-1 Polyester is a general term for any fabric or textile made using plastic yarns or fibers. It is a synthetic and man-made polymer, which, is technically called as polyethylene terephthalate (PET). It is created by the combination of ethylene glycol and terephthalic acid. Though, it sounds scientific, in common words it can be called as plastic. These fabrics contain huge amount of chemicals and toxins which are hazardous to health while manufacturing as well as after the product is ready. Manufacturing of polyester is one of the main reasons for air and water pollution in the global context leading to many health diseases. This fabric is closely woven, hence not very suitable for warm climatic regions.

The textile used for Abaya is 100% Polyester which is thick in nature and non-porous. The advantage which this fabric has is the least maintenance required as it is wrinkle free because of the chemicals like brominated flame-retardants and formaldehyde are used. These chemicals are highly toxin in nature

Customers fail to understand that when a label attached to the garment reads as "No shrinkage, Anti-perspirant, wrinkle free, water repellant, anti- flame or anti-static" are all against the law of health and skin. These fabrics are highly chemically treated which penetrates in the skin of the wearer, leading to various diseases and skin allergies. [21]

Today we all are leading *"Busy lifestyle rather than healthy life style"*. The intake of chemicals through various channels are increasing every day. Abaya is made of polyester fibers and yarns and dyed in darkest shade of black which is difficult to achieve by maintaining the tensile strength of the fabric. Thus, it requires huge quantity of dye and chemical treatments which contains toxins that may damage the skin eventually. [22]

IV. AIR-DYE AND RPET PROCESS FOR RECYCLING

A. Dry-Dye Process

'Dry-Dye' is a new and innovative technology which is more reasonable and sustainable technique of dyeing a fabric. This is varied from the conventional dyeing method as it uses 90% less water and 85% less energy during the dyeing process. This methods works the best when used on synthetic fabrics. Thus, we have tried and explained how Dry-Dye can be used on Abaya fabrics made of RPET (recycled polyethylene terephtalate) which comes from plastic bottles.

(Fig. 7) The wet processing in textile units are one of the highest water consuming industries, 17-20% of industrial pollution comes from traditional textile dyeing, printing & treatment, contributing to 72 toxic chemicals in water supplies, out of which 30 are persistent. "Dry-Dye" technology will help to reduce these water contamination. Traditional method of dyeing, such as or cationic dyeing or vat dyeing, produces visually fair outcomes but it uses toxic chemicals and enormous quantity of water. Decoration of synthetic textiles have been done by sublimation printing from years, but this process has restricted results in application. Dry-Dye process higher level of results compared to sublimation printing and old wet dyeing methods. This technology also lowers damaging impacts on the environment. As no bleaching and cleaning agents are used resulting in richer and lux look. Air is the main an ideal transport medium in this process. The liquid dye is alternated with air as a method of transport in jet-dyeing machines which is a step towards reduction in water and chemical consumption. [23]

The airflow with moisture ensures the stable dispersal of temperature on the fabric and in the machine, producing better results of dyeing. The Airflow mechanization illustrates the combination of best possible results. With the interaction of various technical involvements and functions, economic and ecological advantages over the conventional dyeing methods are attained. Overall reduction of dye processing time would be 25% and 90% less water consumption.

This process does not pollute water in the dye application process. The use of air in place of water in application of color, no hazardous toxins are emitted and almost zero water is wasted. The energy used is reduced in a huge way lowering the cost involved with high satisfaction levels. This method does not involve the use of printing machines, ovens, boilers or cleaning agents, leading to less pollution. Also provides the customers the choice/option for sustainable life style in realistic manner, thereby initiating a change in the global environment.

This method of "Dry-Dye" technology gives better conclusion (sharper, luxurious hand feel and clean on either side of the fabric) when compared to the traditional wet dyeing and printing process.

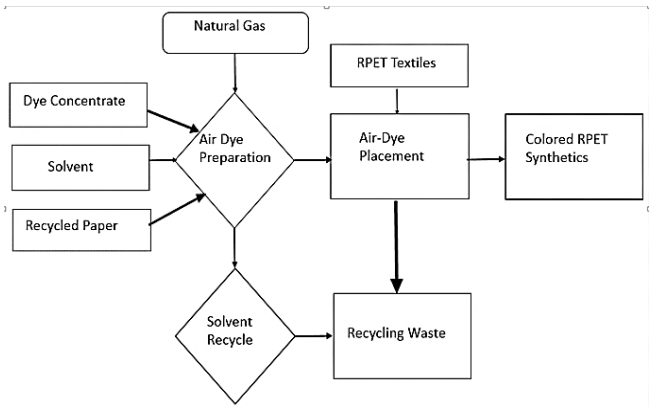

Fig.7. AIR-DYE PROCESS for Dyeing RPET Textiles

Manual color pallets may not provide the best required results, thus use of software for achieving the right color, this technology derives the formula which helps to attain the expected color resulting in reduction of lead time for manufacturing, less sampling & wastes... [24]

B. Recycled Polyethylene Terephthalate (RPET)

Polyester is produced using a non-sustainable resource that harms the ecology and effects amid the extraction process. It is non-bio degradable in nature and takes many years to decompose. Thus the board of PET waste has turned into an imperative social issue. [25]

Table-2 reflects that properties of recycled polyester are better than virgin polyester textiles. As discussed below RPET technology is a simple process in comparison to the production of Virgin polyester. Production of RPET textiles involves 85% less energy and 90% Less Water consumption and releases less 50%- 65% Carbon and Sulphur Dioxide. [26]

Table-2 Virgin Polyester and Recycled Polyester

CRITERIA	VIRGIN POLYESTER	RECYCLED POLYESTER
The moisture or dampness recovery	Moisture regain of virgin Polyester is less	Moisture regain of virgin Polyester is more.
Rigidity of Fiber	The bending length/rigidity of fiber in Virgin polyester is more	Recycled polyester is more fluid and drapes better.
Crease Recovery	Crease recovery of virgin polyester is slightly better.	Crease recovery of recycled polyester is slightly less as compared to virgin.
Tearing strength	Almost the same on both fabrics	Almost the same on both fabrics
Color Fastness	Similar in both fabrics	Similar in both fabrics
Rubbing Fastness	Both with similar results	Both with similar results
Shrinkage	More Shrinkage in virgin polyester	Less in recycled polyester
Price	1/10th more expensive than recycled polyester, fluctuates as per demand.	1/10th less priced, more stable for longer term.

PET bottles are **fabricated** in the same polymer as **polyester**, Bionic Yarn can separate them and revamp them into "reused" polyester. The yarn produced using this substance can be utilized instead of virgin polyester. Polyethylene terephthalate cannot be made in single procedure. It is made by the response of two synthetic compounds known as Purified terephthalic corrosive (PAT) and ethylene glycol (EG). Few Properties of Polyethylene terephthalate:

- Crystallinity: >=45%
- Density: 1.38~1.40g/mm^3
- Melting Temperature: 254-256°C

PET plastic is one of the most useful plastics among other plastics. These bottles can be washed and broken into small pieces to give them a new dimension.

C. Recycled Polyester Process

Polyester is one of the most popular synthetic fibre which is made from crude oil. It is a composition of long chains of polymers (polyethylene terephthalate (PET). Polyester is strong, long lasting and easy to dry. Recycled polyester is made from waste PET bottles. Scientifically, recycled polyester behaves or performs better in all aspects as compared to Virgin polyester, including strength and functional versatility.

Also is has been observed that it has a lower environmental impact than conventional virgin polyester as less energy is required. Recycled polyester can be made in two varied methods; chemical recycling & mechanical recycling.

The process Mechanical Recycling process uses clear plastic (polyethylene terephthalate) bottles which are also derived from PET resin. These bottles are cleaned, flaked, melted and made into new polyester fibres. This method uses the waste post-consumer waste and consumes less energy during the process. Recycling PET bottle is more useful other wastes from plastic streams as it is high in plastic resin. PET bottles are mostly clear material which is compared to other plastics purer and without any colorants or any other additives. It is passed through FDA demands for food packaging, which removes all hazardous chemicals from the plastic bottles.

Chemical Recycling includes utilizing synthetic compounds to separate, or depolymerize, the polyester fiber once more into its unique monomers, which would then be able to be polymerized once more into new materials. The polyethylene terephthalate (PET) polymer comes back to its unique ethylene glycol and terephthalic corrosive monomers by means of chemical equations. When it is polymerized once again into PET resin and polyester, the subsequent material is not different from virgin polyester. This strategy is very costly and fundamentally utilized for colored and finished polyester items. There may be various benefits of chemical recycling, which may include:

- As the process leads to creation of new chemicals or monomers, this can be used to create many more new products instead of only polyester.
- The cleaning process of the waste need not be strict as in the case of mechanical recycling process.

A dangerous chemical, antimony trioxide is used as a catalyst while producing of PET resin. The resin is used in for both the productions, for PET bottles as well as virgin polyester. The antimony trioxide is suspected to be carcinogenic potential for human body and this is against environment. This harmful chemical leaches out through air and water when heated. The chemical recycling process helps in getting rid of this chemical called antimony trioxide from the original source (PET bottles) and can re-catalyze the PET resin with another alternative catalyst. This is not been practiced by the manufacturers as replacing antimony trioxide is expensive and this is a very cheap chemical. Recycled polyester, gives opportunities for the circular economy [28].

Plastic bottles are fabricated with polyethylene (PET), which is a form of polyester that is mostly corresponding to clothing industries. Both are real polymers, a subsidiary of non-renewable energy sources. This textile made out of the PET fiber is basically polypropylene and it is ten times stronger than a virgin polyester.

The production process of RPET textiles involve a few steps, like- collection of PET bottles which are sterilized, cleaned (the caps, labels and stickers are removed), dried and crushed into small chips or flakes. (Fig.8). these plastic flakes are then heated, the molten plastic is passed through a spinneret to form fine lengths of yarn. These yarns are wound up in spools and passed through Crimping machine which helps to create fluffy texture to the fiber. This yarn is bladed and woven into recycled polyester fabric. The fabric is now ready to get dyed through the "Dry-Dye" technology. The ready fabric is then converted into the beautiful "Black Robe" called "Abaya" in the world of modest fashion. Making of single Abaya consumes more than 50 PET bottles. This modernization of use of both these technologies would bring far reaching alternative in the Fashion world.

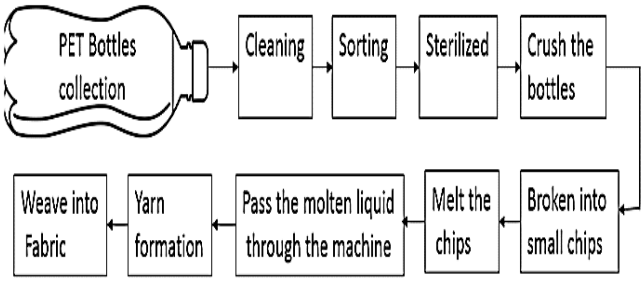

Fig.8. Process to convert Plastic bottles into RPET Textiles

D. PET to Fiber Process

Drying Process of the PET bottles which helps to remove the dampness from the plastic chips/flakes to 0.004% as moisture can be the reason for decadence in the linear chain of the molecules and result in lessening the viscosity. These plastic flakes enter the crystallization bed which helps in eliminating the wetness by using the process of fluidization (It is a process where flakes are converted from solid chips to fluid state). The air temperature for the column dryer and fluid bed is approximately ranging from 170 degree C to 185 degree C which is enough to remove the moist bits from the polyester flakes.

The dry flakes are then transferred to the extruder via column dryer which has an outlet for dry chips. This drying unit also contains a bin bag that removes the micro dust particles like; sand and other impurities. The air circulates within the dryer which is then filtered and heated by the heaters at the required temperature.

The most important function here is the Air Pressure Regulator (APR) as It allows the dry air to enter the dryer system. There is a bower that intakes the air and passes it through cool tubes with the temperature varying from 5-7degree C leading to the formation of water vapor that exists in the air. Further to this, it then passes through two towers; regeneration and operational towers. Both containing silica cylinders or cubes and work together. They approximately function for 6-8 hours to remove the extra dampness from the atmosphere.

The next step is to go through a high-volume manufacturing technique known as Extrusion, where the polyester chips are melted and formed in a sustained figure. During this process the dry plastic flakes are fed through the hopper into the barrel of the extruder. These are then melted by the heaters set along the barrel. The temperature is very important for the final melting of plastic.

It is now time for yarn formation through spinning beam, which is very convenient and economical way to manufacture synthetic fibers and yarns. The melted polyester chips are passed through the spinnerets to form polyester yarns. The control of the molten flow is done by the metering pump, which controls the flow heading towards the spin head.

It also ensures all unmolten particles are removed so that they to obstruct the way while spinning. The air passed through the quench chamber helps in cooling the fibers formed. The temperature of the air is at approximately 20 °C and flows mildly. As soon as the cooling air corresponds with the spun filaments it solidifies to become fiber. The airflow should flow uniformly to get uniform filament diameter in the fiber that is spun. Small variation in the quench air may give disastrous results in filament diameter [29].

V. CONCLUSION

To conclude, around 2.4 trillion gallons of water is used every year during the dyeing process of synthetic fabrics. The use of Air-Dye system in textiles will drop water and energy usage by 95% and 86% respectively. Use of RPET textiles would reduce the plastic waste, a major positive impact on environment. Moreover, Textile Industry will achieve many more benefits like reduction in fabric damage in addition to environment sustainability. During production, using Air-Dye technique, fabric damage is only 1% as compared to 10% in traditional methods. With the increase in demand of modest clothing around the globe, the use of alternative fabric (RPET) is recommended instead of virgin polyester which can serve as an equipment to influence the positive change in our society.

A world without plastic and abundance in water seems profound, "it is like dream come true". We are going to lead a better and greener world. Most of the energy can be consumed via natural resources. Leading to economic and environmental growth globally.

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