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RECYCLING OF PLASTIC MATERIALS OBTAINING SECOND RAW MATERIALS IN A CIRCULAR ECONOMY PERSPECTIVE*

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Abstract

Over time, the use of plastic has grown considerably becoming one of the first causes of global pollution, so much that 80-90% of the world's waste is made up of this material which takes a long time to degrade. In this period of time, plastic items can deteriorate or turn into small pieces, that is, in micro and nano plastics. To this end, in fact, on May 21, 2019, a reference regulation was issued to ban disposable plastics with the aim of reducing the use of plastic products dispersed in the environment. Hence the objective of the case study presented, namely to obtain second raw material from plastics to guarantee environmental protection with a lesser impact following a circular economy perspective. In this regard, we present an application case study of the Ecoplast company, based in Gela, Sicily, which operates in the plastics processing sector, representing a sustainable, proactive reality in environmental issues.

Keywords: circular economy, ecodesign, plastic waste, recycling, second raw material

1. Introduction

Over the course of time, the use of plastic has gradually grown to become a real world emergency, so much so as to be one of the main causes of pollution in the world. Suffice it to say that 80-90% of waste in the world are plastic waste. The word “plastic” comes from the

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Greek word “plastikos”, meaning capable of being shaped (Choudhury and Hashmi, 2020). Since 1950, it has been noted that this product is extremely versatile and, so, from that time, an unbridled production of plastics of various types began, until today in which it is the most used material in the world. Its use is truly remarkable for its adaptability, just think of the impact resistance, temperature changes and ease of modeling. In addition to the functional advantages, it is also chosen for its inexpensive cost. An aspect that can be considered positively or negatively on the basis of the point from which it is observed is the time span used to obtain a complete degradation. The positive aspect lies in the fact that productions that use plastic are reliable, qualitative and long-lasting. The problem, as a matter of fact, lies in the lack of sensitivity and attention that man applies in relation to this issue. It often happens that the man, while being able to reuse it, does not do it and even more disperses it in the environment, causing, as already happened, serious damage to the ecosystem and, involuntarily, to himself. So the problem is not the material itself, but the behavior and the frenetic use by man. Since the early 1950s, more than 8.3 billion tons of plastic has been produced and about 60% of that plastic has ended up in the environment (Guo et al., 2020). To date, it is estimated that there are more than 150 million tons of plastic in the oceans. By 2025, it is estimated that for every three tons of fish, one ton will be plastic (Burchia, 2016). In 2050, on the other hand, the quantity of plastic at sea will exceed that of fish, according to a study by the American foundation Ellen MacArthur (World Economic Forum, 2016), which has been observing global developments in the circular economy for years. In the Pacific there is an island made up of 80% plastic, which is why it is called “plastic island”, twice the size of Texas, or three times bigger than France, a real Atlantis of junk, called Pacific Trash Vortex (Scaffai, 2011). Europe, after China, is the world's second largest plastic producer. It generates over 25.8 million tons of plastic waste every year and less than 30% of this waste is recycled (Vizzini et al., 2019).

Moreover, plastic is not biodegradable and takes between 450 and 1000 years to decompose, depending on the type considered. In this span of time it is broken up into small pieces, thus obtaining microplastic (with a diameter ranging from 4.75 mm to 0.33 mm), but there may also exist smaller particles, the nanoplastics, less than 20 μm (microns, i.e. one thousandth of a millimeter; that is: $1 \mu\text{m} = 1 \times 10^{-6} \text{ m}$) (Blue and Ardizzone, 2017). The main problem is that these ones, which accumulate everywhere, are ingested by animals all over the world, causing suffocation or serious problems to their health and in the worst cases even death. Some of these animals are also part of the human food cycle and, therefore, these substances they ingest are in turn assimilated by the latter, regardless of what happens, causing serious health problems. From the moment they enter inside the organism, they can no longer be independently removed from the body (Pecorino et al., 2018). Their presence can also cause irreversible disorders, such as genetic alterations. It can therefore be noted how a vicious circle is put in place which has as its main ring and, therefore, also as closure, the indifference of the human being. In this regard, assume particular importance, the knowledge of the impacts that these plastics cause in the seas. But it is good to note that plastic pollution does not only occur in the seas, but also in the soil and there are many events that have occurred, for example the Seveso disaster. Over the years, in order to try to manage, maintain and prevent these events, various regulations have emerged, such as the Seveso Directive and Directive 91/156/EEC. But also voluntary standards were born, adopted by companies to better manage their activities in respect of the environment, such as ISO 14000 and EMAS (Matarazzo and Baglio, 2018; Milazzo et al., 2017).

There are various types of plastics, each with different characteristics and sometimes they are difficult to dispose of. However, there have been several technological innovations to recycle these materials and thus reduce the impact on the environment (Munda and Matarazzo, 2020).

As it has already been said previously, over time, the use of plastic has grown considerably becoming one of the first causes of global pollution, so much so that 80-90% of the world's waste is made up of this material, which takes a long time to degrade and therefore disperses into the environment. In this regard, the objective of the case study presented is born, that is, obtaining second raw materials from plastics to contribute to environmental protection with less impact, following a circular economy perspective. This application case study was carried out with the Ecoplast company, located in Gela, Sicily, which operates without waste of plastic, both virgin and recycled, as excess or processing waste is recycled through special machinery in their possession. The goal is to create Eco-design products with added value, through technological innovations, from the recycling of polymers, thus transforming waste into a resource. In fact, the company produces a wide range of outputs going from waste collection bins to items for cleaning the house, kitchen and food utensils, gardening tools, bathroom accessories and much more.

2. Experimental

In 1991 the brothers Totò and Angelo Gatto founded Ecoplast Ltd, with legal and production headquarters in Gela (Sicily). In those years in Sicily there was a strong demand for tanks for water and oil. At the time, only one company in southern Italy was involved in the production of these articles. Responding to this need, the Ecoplast realizes the first mold to the 20 liter tank and, in a matter of five years, enlarges the family, producing articles from 2 to 30 liters. In the late 1990s, the molds of a bankrupt company in Palermo, SilverPlast, were purchased. Thus began the production of watering cans, buckets and basins, obtaining an increase in the range of about thirty products. Furthermore, in that period the production of items made with recycled plastic, such as the mason's bucket, also began. 2006 sets an important date in the history of the company, because about eighty molds of household products are purchased from the former Ceplan, including oval baths, kitchen containers, trays and recycled items, such as baskets for agriculture and waste bins. It is in this period that the image of Ecoplast changes thanks to the collaboration with an agency in Palermo, "Urso advertising and marketing Ltd", with which corporate rebranding and coordinated image of the products and packaging used are carried out. Thanks to the contribution of regional agents, the sales network is expanded throughout the Italian territory and Ecoplast gradually acquires more and more visibility. Furthermore, in 2012 Ecoplast expands to international markets, exhibiting for the first time at the *Ambiente* fair in Frankfurt, the largest and most prestigious in Europe. Over time, the company increases the assortment of its rubbish bins, obtaining the exclusive distribution of wheeled bins in Sicily and Sardinia. In 2014-2015 a precious meeting took place with Marco Maggioni, an internationally renowned designer and winner of important prizes and awards (16 Compasso d'Oro ADI, 16 Biennial of Industrial Design, Reddot Design Award, ADI design index, International Superstar Gold Award), which supports the made in Italy design, as well as the aesthetic, functional and sensorial qualities of the products. In 2016 Ecoplast participates for the first time in the *Ecomondo* fair and in 2018 in *Ifat*. In recent years, the company has concentrated its forces moving in an absolutely green and eco-sustainable perspective, referring to the polymers used (over 80% recycled plastic), referring to environmental and company certifications on the use of photovoltaic panels, quality control, the recycling of internal water, the use of electric motors both in the machinery and in the company vehicles and the inclusion in the market of waste collection with a series of products made exclusively with recycled material. Ecoplast now numbers customers from more than ten countries around the world, including Holland, Korea, Portugal, Malta and Japan and exhibits at fairs in Germany, Romania, France, Japan and obviously in Italy. The company's mission is to make almost all

new items with recycled plastic. New materials are also being designed to mould plastic, such as *biodegradable compounds*, that is, natural mixtures for moulding. The raw material, after purchase, is stored in the company's warehouses. Most of the time it is mixed with additives that make plastic more durable over the time according to the company's production formulas. Once this is fixed, the items are produced according to the production schedule, which is established between the production manager and the warehouse manager. Ecoplast generally uses only 30% of its production capacity: on ten machines, for example, three are used. This allows the company to be timely in the delivery of orders, even in the work overload phases. For the production cycle there are two types of production: blow moulding and injection moulding

1. The blow moulding takes place precisely through compressed air blowing of the semi-melted plastic inside the mold, formed by two perfectly symmetrical cavities. The process takes place through the gradual heating of the plastic through resistances and proceeds from top to bottom through the Parison tube, which is blown inside the mold and takes exactly the shape of its cavity.

2. Injection moulding is a process that takes place horizontally, not from top to bottom, always through a gradual process of resistance. The polymer is mixed with the dye inside the hopper. The latter pushes and heats the material gradually through a worm screw.

Machine operators try to better manage the parameters of heating temperatures and injection speed so that the product may meet the quality standards. The plastic flows out from the point of injection into the mold, formed by two parts which are not symmetrical and which, in jargon, they are called "male" and "female". From the injection point it enters in the wide part of the mold and is pressed with the cavity. The minimum thickness is that of the finished product, intended for the warehouse or semi-finished department and intended for the assembly department. The more an item is sold, the higher the warehouse requirement. The company uses plastic recovery techniques. There are internal techniques: the company recycles all production waste, which correspond to about 0.3%. All plastic is recovered through cutting mills, re-granulating the material. Different polymers are never mixed in internal recycling processes. The company uses only thermoplastic and non-thermosetting materials. Among the main polymers used are high density polyethylene (HDPE), low density polyethylene (LDPE), copolymer polypropylene (PP copo), SAN (shiny plastic, similar to polystyrene), polycarbonate (indestructible plastic, also used in the aerospace industry) and nylon (even if used in smaller quantities). Ecoplast is the largest company in southern Italy for the production of plastic articles for the home, is certified Second Life Plastic, has the ISO 9001 and ISO 14001 certifications and exports to fifteen countries, including Italy, France, Germany, Portugal, South Korea, Malta, Holland, Poland, the Czech Republic and Switzerland.

3. Material and methods

This considerable production of plastic, in addition to creating this irreversible damage in the seas, has also led to various problems in the soil, especially for disposal. More than 1300 tons of plastic wastes were shipped from Italy to Malaysia. After Malaysia, which is the first importer of Italian plastic waste, the same happens in Turkey, Romania and Poland (Repubblica Ambiente, 2020). There is an illegal dumping when, rather than properly dispose of in an approved landfill, it's used an unlicensed site where waste is dumped (Liu et al., 2016). The environmental impact of these illegal landfill, in addition, is due to also the substances that come from the last phase of the industrial activities: mercury, hydrocarbons, arsenic, deteriorating the neighboring lands and contaminating the surface water and, in turn,

the air quality (Triassi et al., 2015). Over the years, many types of plastic have been born, based on the need of the moment.

Today two macro-classes of plastic material, thermoplastics and thermosets, can mainly be distinguished. The former are the most used and are most malleable (Geyer et al., 2017). They can be modeled several times before to get rigidity. The most common materials are: Polyvinyl Chloride (PVC), Polypropylene (PP), Polyethylene (PE), Polyethylene Terephthalate (PET). At the end of its life, a product can either go directly to landfill or be recycled. There are many ways to give new life to a product. In the case of plastics, the solutions may be different (Hopewell et al., 2009):

- Energy recovery from incineration: It's a good solution to free up space in landfills and, at the same time, obtain an energy recovery, but incineration means to release dangerous substances into the atmosphere.

- Plastic recycling:
 - Primary, usually referred to as closed-loop recycling.
 - Secondary, or downgrading, where only thermoplastic can be used, the process gives products with lower properties.
 - Tertiary, for the recovery of chemical constituents.
 - Quaternary, for the recovery of energy.

- Separation:

Over the years there have been several technological innovations in the production phases of plastic recycling, such as (Valavanidis, 2018):

- Magnetic density separation (MDS): it is a technique that use a magnetic liquid as a tool for the separation of plastic materials

- Depolymerization of plastic waste: It allows to transform one type of plastic into another, thanks to the technological advancements achieved in the last decade.

- Another very important way to reuse plastics is through 3D printing. In recent years it is an increasingly used technology, even in Space. In fact, just in the International Space Station, NASA has made available a 3D “printer-like”, capable of reusing the polymer objects already present inside the Station, thus reducing consumption to a minimum, representing a very useful use during long orbit missions (Pace, 2018).

Another solution may be to Ecodesign. *Ecodesign is the direction and design activity of a product or service that has as its ultimate goal the reduction of its environmental impact, both as regards the production and for the use and final disposal.* The ultimate goal is to create products that are in line with customer and market demand and at the same time minimize the resulting environmental impact. Therefore a piece of home furniture can be obtained from recycled plastic.

4. Results and discussion

All products for waste collection are made of recycled material, as well as will all future projects of the company (for example the Doga line is one of these). Therefore a piece of home furniture can be obtained from recycled plastic. The company always tries to coordinate the various aspects: functional, sensorial, aesthetic and environmentally sustainable. Constant is the reference to nature in design. The product family initially included items to hold liquids: jerry cans, barrels and watering cans. Subsequently, household, cleaning and professional products, such as basins, trays, buckets, oval baths and jars. In the past three, four years the company has focused on the production of containers and tubs for separate waste collection, all made with recycled material. Among the projects there is that of creating a line of bathroom items made, also in this case, with recycled plastic. Specifically, regarding the Doga bathroom line: All the items that will be made will be in

recycled plastic and 100% recyclable. The company is also studying new materials for molding plastic, as biodegradable compounds, that is, natural mixtures for molding. An increase in the percentage of recycled plastic used in 2020 has been noted (600,000 kg in 2019). For the Ecologic - Ecoplus collection, on the other hand, over 80% of plastic is recycled and also has the following characteristics:

- Resistant to high and low temperatures
- Ideal for separate collection
- Flexible and non-deformable
- Dynamic RFID identification system
- Prints (Pad Printing, Screen Printing, IML)
- Customizable colors
- Value for money
- Distributed worldwide
- Comb attachment for manual and mechanized emptying (Optional)
- Reflective reflectors (Optional)

The company presents in its structure photovoltaic solar panels that allow to satisfy their energy needs. They produce around 450,000 kW / year, which means 245.00 TON CO₂. The company's machines, of Japanese production, are totally electric controlled and guarantee high efficiency in the consumption of electricity and CO₂ emissions. As for the Pos design collection (Lightweight, durable, stackable, functional: design in its highest form of expression) there are several articles, each with its own design history:

- Fluid: It is a work of art even before being a refined sink rug. It finds inspiration from nature in the branched lines of a parallel botany, the structure becomes fluid to evoke the water paths.

- Harmonia: It is the new line of food jars characterized by a highly recognizable aesthetic. The original cap facilitates stacking, a special seal protects the freshness of the contents, the ring on the base has an anti-slip function.

- Flux: It is a pure and elegant shape in a perfect balance of geometries, that is the toilet brush in its most modern representation.

- H2O: The watering can reinvented. Designed for domestic use, it makes joyful the care of indoor plants and satisfies every thirst with its three liters of water. The shape inscribed in a circular line recalls a drop of water.

- Arya: is an exclusive shape pegs holder basket, available in special colours that reminds of the Sun, water, light and nature. The shape has been created thinking about the blow of the winds and the movement of the waves.

- Myra: It is an accent of color enclosed in an essential form of pure beauty; it is a container that empties pockets and wall storage that can be positioned on any surface: in the kitchen, in the bathroom, anywhere in the house. It can be easily installed using double-sided tape or the supplied screws.

- Floria: The sign of an eternal spring in the silhouette of an imaginary flower. This is how this new sponge holder is presented, or dishcloth holder, or plastic bags to be reused, or any other object that can be welcomed among its petals. It too can be easily installed using double-sided tape or the screws supplied.

- Stilla: It is the natural conjunction of form and beauty inspired by nature. Perfect combination to hang, hold, and to have at hand every object.

5. Conclusions

This methodology, as we have already seen, has environmental, social and economic benefits. As for the economic and environmental ones, the ones deriving from the reuse

techniques are fundamental, where the company recycles all the waste deriving from the production process, but also for the creation of new products through the use of recycled plastic. Noteworthy are the data used by the company for recycled plastic (500,000 kg in 2018, 600,000 kg in 2019), which are expected to continuously increase. Thanks to recycled plastic, the production of over seventeen million empty bottles is saved per year. The energy sector must also be taken into account, where the company uses only 30% of its production capacity, thus obtaining an important energy saving, as well as the timeliness in delivering orders, even in the work overload phases. The company also with the use of photovoltaic solar panels completely satisfies its energy demand, thus ensuring high consumption efficiency but also CO₂ consumption. Another important aspect that increases efficiency in the company and in the environment is the presence of certifications: Plastic Second Life, ISO 9001, ISO 14001. So in this way, it contributes to the preservation of the planet by helping it to “breathe”, also obtaining social benefits as all people benefit from them and economic ones because, on the one hand it allows the reduction of costs due to waste, which they are reintroduced into the production process (with a Zero Waste perspective); on the other hand, because there is a constantly growing market.

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