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PLASTICS: THE BIG ENVIRONMENTAL PROBLEM OF OUR TIME

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Abstract: With the current pollution of the planet, some of the materials and substances that cause this pollution have become evident. Plastics are one of those products that, in recent years, have increasingly polluted the environment in a significant way, due to the great difficulty in being absorbed by the soil and the difficulties in being able to be reused. Our lives are surrounded by plastics and we are increasingly dependent on articles made with this material, which makes it very difficult for us to do without them. This work addresses the great problem that plastics currently represent and, at the end of it, some proposals are presented to modify our way of life, that is, to try to live without so many plastics.
Keywords: plastics, pollution, global warming, climate change, plastic substitutes.

INTRODUCTION

CLIMATE CHANGE AND THE RESULTING NATURAL DISASTERS

With the global acceptance of climate change that has become more clearly evident since the onset of natural disasters that have occurred since 2004, starting with the famous tsunami in the Indian Ocean that claimed the lives of more than 200 thousand people and damaged the livelihoods of around 1.4 million survivors by destroying fields, ponds, boats and agricultural sites (Food and Agriculture Organization of the United Nations, 2014), later in 2007, with the floods in Pakistan (Guterres, 2008: 7) and, in Mexico with the flooding of 62% of the state of Tabasco, which caused 75% of the affected population in 679 localities in 17 municipalities of the state, and material damages estimated at more than 3 billion US dollars (González Arroyo, 2017: 106). This fact made the Mexican authorities understand (and of course confirmed worldwide what many specialists had already been predicting) the implications that this climate change represents for the most unprotected and vulnerable populations. In addition, the measures and actions that must be adopted to effectively address the problem entered the political agenda. As an example of these actions, in 2007 the Mexican federal government developed the Tabasco Comprehensive Water Plan (PHIT), with the purpose of minimizing the risk conditions in the face of the continued occurrence of extreme hydrometeorological events and possible effects of climate change (Ramos Reyes and Palomeque de la Cruz, 2019: 404). That same year in Asia, a National Strategy for Natural Disaster Prevention, Response and Mitigation was developed, as well as the Law on Natural Disaster Prevention and Control in Viet Nam. Subsequently, in 2010, the Prime Minister of the Lao People's Democratic Republic issued a Decree on the National Climate Change Strategy (Food and Agriculture Organization of the United Nations, 2014).

Figure 1. *The Tabasco flood in 2007*

Note: Approximately 80% of the city of Villahermosa, Tabasco, was flooded. (National Center for Disaster Prevention, October 27, 2017); (Tabascohoy.com)

This whole situation could have been stopped in 2020 and 2021, since with the COVID-19 pandemic, new and better technologies had to be developed to allow people to fulfill their work and school obligations without leaving home, which meant a reduction in the use of transportation and other types of consumption that life without a pandemic entails (to which we must add a drop in consumption in general due to the loss of jobs and a decrease in people's purchasing power), however, this is a still recent issue and with contradictory information, such as the article published by the UNAM Science magazine written by Guerero Mothelet in June 2020[1] through which we were informed: "Record increase in CO_2 in May despite coronavirus", or what was reported by the UN in November 2020 under the headline: "Not even the COVID-19 lockdown gives a break to climate change: the gases that heat the Earth reach record levels [2]". Contrary to what was reported by the UN Mexico in December 2020, "Sustainable recovery from the pandemic is essential to closing the emissions gap: UN report [3]", or the article by Mariana Perales from the Monterrey Institute of Technology "The coronavirus arrived and affected… but the planet breathed [4]", where this expert on the subject explains how COVID-19 reduced gas emissions and helped create cleaner air.

Before the concerted efforts to reduce the impact of pollution in the 1980s, environmental control barely existed and was mainly oriented towards waste treatment to avoid local damage, with a very short-term perspective. As the pace of industrial activity has intensified, and the effects of climate change became more pronounced, pollution control was promoted as a strategy to protect the environment. To do so, two basic concepts were used: 1) the assimilation capacity, which refers to the recognition of a certain level of polluting emissions into the environment without appreciable effects on environmental and human health, which we call resilience; and 2) the control principle, which assumes that environmental damage can be avoided by controlling the form, duration, and speed of the emission of pollutants into the environment (Spiegel and Maystre, 1998: 55.2). This second concept is what concerns us.

THE PROBLEM WITH PLASTICS

It is estimated that 8.3 billion metric tons of plastics have been manufactured since the initial industrial production of this material until 2017, of which approximately 6.3 billion tons have become waste. Of these, it is estimated that only 9% has been recycled, 12% has been incinerated and the rest, that is, 79%, accumulates in landfills or invades natural environments (Parker, 2017). One of the most visible examples of plastic pollution is that of the oceans. It is estimated that on average more than 200 kilos of plastic are thrown into the seas and oceans per second, 70% of which ends up on the seabed and 15% remains floating. As a result, at least 100,000 marine animals die each year from causes associated with this type of pollution, with 700 marine species being threatened. However, despite the seriousness, this is not the only problem of plastic pollution (Fundación Aquae, s/f), as an example, we have the migration of toxics by leachates, the emission of $C0_2$ and other gases during the production, shaping and degradation stages of plastic, or the ingestion of microplastics by humans and animals, among others.

According to data from the association: *Plastics Europe* (2021: 16-17), in 2019 alone, plastic production in the world reached 368 million tons, nine tons more than in the

1. http://ciencia.unam.mx/leer/1012/aumento-record-de-co2-en-mayo-pese-a-coronavirus-
2. https://news.un.org/es/story/2020/11/1484462
3. https://www.onu.org.mx/la-recuperacion-sostenible-de-la-pandemia-es-esencial-para-cerrar-la-brecha-de-emisiones-informe-de-la-onu/
4. https://tec.mx/es/noticias/estado-de-mexico/educacion/el-coronavirus-llego-y-afecto-pero-el-planeta-respiro

previous year. Just over half of the world's plastics (51%) were produced in Asia. It is not surprising that that year, China was the country that generated the most single-use plastic waste, and was responsible for 31% of the world's plastic production, producing 82 kg per capita, while Japan, with only 3% of the world's production, managed to produce 88 kg per capita. In the NAFTA countries (currently the USMCA, which includes Canada, the United States, and Mexico), 19% of the world's plastic in total was produced, which is equivalent to 141 kg per capita, the highest figure per person (Statista, 2021). The response of governments in different parts of the world, especially due to the pressure exerted by different organizations such as Greenpeace and UN Environment, has been to implement political measures and agreements at international, national and subnational levels, all of these measures under the argument that they are "to regulate the use of plastics."

However, most of them refer to the prohibition of plastic bags and disposable plastics (so-called single-use) (UN Environment, 2018:6).

In the best scenario, if it could be thought that the ban on plastic bags were implemented correctly under a well thought-out and structured planning (which could counteract and mitigate the consequences of plastic use), this measure would not be sufficient. Governments must enact policies that promote design models focused on the circularity of the material in which plastic waste is seen as resources, while working towards the restoration of natural systems. In addition, waste management systems must be improved, and financial and fiscal incentives must be introduced to change consumer habits (retailers and manufacturers). Likewise, more resources must be allocated to research and development of alternative materials, raising consumer awareness and financing innovation (UN Environment, 2018: 6).

Thus, the main objective of this research work is to expose the current situation of plastics in Mexico, in the world, and to propose some measures that at a domestic level, help to the possible reduction of their use, seeking to modify the habits of users.

It is worth asking: what would a mode of production have to be like that had as one of its main objectives to really control the production of plastics? And if we humans are prepared to assume this new way of life?

METHODOLOGY

The research work that supports this article is based on the doctoral thesis of Mtra. Tania Sánchez, which has theoretically taken up ideas and concepts proposed by permaculture and social ecology. Thus, permaculture is presented as a philosophy that seeks to work as a group with nature as a way of life, which forces a change in the human vision of the environment and the vision of relationships between human beings. "It is leaving aside the preconceived idea of superiority of the anthropogenic with respect to other forms of life." Permaculture is a praxis with episteme (García Estrada y Col, 2017: 2175).

For its part, the social ecology proposed by Murray Boockchin states that ecological and social crises are intertwined in such a way that the domination of nature is a projection of human domination in society. The ecological crisis is not the result of individual choices, technology or population growth, but rather the main cause is the existing irrational social system (Bookchin, 2015:26). The primary objective of social ecology (to the extent that its power of radical criticism is conserved) is to harmonize the relationship of humanity with nature, and this will only be achieved if the relationship of human beings with each other is harmonized at the same time, that is, if an ecological society is aimed at (Bookchin, 1977: 13).

Thus, based on various authors, the current situation of the planet due to climate change is exposed, the problem that plastics represent in this environmental deterioration at a global level and, in particular, the specific case of Mexico, to finally offer a series of proposals that we think can help people change their attitude and habits towards plastics.

ORIGIN AND DEVELOPMENT OF PLASTICS

The rise of plastics was made possible by the rise of the petrochemical industry in the 1920s and 1930s, when chemical companies began to identify and work with oil companies. Oil refineries operate around the clock and continually generate byproducts that need to be disposed of, such as ethylene. This byproduct found its use in the plastics industry[5], with this, the continuous flow of oil not only provided fuel for cars, but also encouraged an entire culture based on the consumption of new products made of plastic.

When exactly did we enter the era of plastics? The beginning of this could be established based on various anniversaries related to science, industry or polymer technology, or a mixture of all of them (García J. M., 2014: 18), for Susan Frenkel (2012) "some claim that it began towards the middle of the 19th century, when some inventors began to develop new malleable semi-synthetic compounds based on plants, to replace scarce natural materials such as ivory. Others place the date in 1907, when Leo Baekeland invented Bakelite, the first fully synthetic polymer… [With this], "humans transcended the classical taxonomies of the natural world: the animal, mineral and plant kingdoms, now we have the kingdom of plastics and it is unlimited" (Frenkel, 2012: 22).

From a scientific point of view, it could be considered that it was in 1922, when the scientist Staudinger proposed a basic structure of macromolecules (García J. M., 2014: 18). Or the beginning of the plastic era could also be placed in 1934, shortly after the bombing of Pearl Harbor, when the director of the agency responsible for supplying the US army defended the possible replacement of aluminum, brass and other strategic metals by plastics. World War II brought polymers out of the laboratory and into the real world, and many of the major types of plastic we know today (polyethylene, nylon, acrylic, polystyrene foam…) were first produced during the war. Production increased to meet the needs of the war, and when the war ended, the industry inevitably had to find a market for such production. As one executive from the early years of plastics recalled, by the end of the war it was clear that "almost nothing was made of plastic, and anything could be made [out of it]. That was when plastics really began to infiltrate every nook and cranny of everyday life and quietly made their way into homes" (Frenkel, 2012: 22). Another moment that can be considered the beginning of the plastics era was in 1950, when global production exceeded one million tons, or in 1976, when plastics were already the most widely used materials (García J. M., 2014: 18). Figure 2 shows one of the most controversial effects of plastics production.

5. Currently, approximately 78% of ethylene production is used for the manufacture of plastics, either directly as in the case of polyethylene (PE) or as raw material for polyvinyl acetate (PVA) monomers, polyvinyl chloride (PVC) or polystyrenes (PS), in addition to being used as a copolymer for rubbers. (Sanz Tejedor, 2017).

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Figure 2. *The sea of garbage*

Note: Clothes, plastics, dead animals and even human bodies flood this sea between Honduras and Guatemala; Photo: (Carolin Power).

During World War II, Japanese troops invaded the territories of the East Indies, leaving the United States without a supply of natural rubber. Various research projects were carried out to supply this and other materials, and neoprene was born to manufacture airplane tires and military vehicles. The use of reinforced plastics made of unsaturated polyesters, fiberglass and nylon threads skyrocketed thanks to military applications, in addition to other polymers such as polypropylene, polyurethane, silicones and epoxy resins (García S., 2009: 76-77).

This is why, since the post-war period and from 1950 onwards, plastic production has maintained a constant growth. In 1950, global production of 1.7 million tons was recorded (Góngora Pérez, 2014: 7), although by the end of the 1960s its consumption had decreased slightly due to an avalanche of cheap and poor quality imitation products (Frenkel, 2012: 25). Subsequently, it maintained an average annual growth of 13.6% for 26 years. From the 1970s onwards, a multitude of scientific and technological discoveries occurred due to the advanced tools that were already available, and to a greater number of scientists working in this field. Polymer producing companies such as Down Chemical, Hitachi, Du Pont, Union Carbide New Kadel, Allied Corp, Allied Chemical, Mitsubishi Chemical, NASA, and the Air Force laboratories, supported by scientific advances, resulted in the development of new polymers to mix or alloy, although initially some were immiscible with each other, thus improving the machines and production means used in plastics, reinforced plastics and plastic reinforced materials, as well as new additives for polymers with enhanced applications and characteristics, such as resistance to higher temperatures, resistance to damage from use, greater mechanical strength, elastic moduli, resistance to chemical agents and corrosion, in addition to specific polymers for aerospace applications (such as polyamide resins called AV AMID-K and AV AMID-N, which are thermoplastic matrices with properties suitable for aerospace and military fields) (García S., 2009: 17-18).

Since 1976, production growth has continued, but at a more moderate rate. By 2012, production reached 288 million tons, which was a historical high, although it represented one of the lowest historical growth rates: only 2.86% (Figure 3) (Góngora Pérez, 2014: 7).

By 2019, global plastics production had increased to 368 million tonnes, 9 million tonnes more than in 2018. China accounted for 31% of global production (bringing the Asian bloc to 51%). Europe reduced its production compared to 2017, standing at 16%, North American countries increased their production to 19%, and Latin America and the Commonwealth of Independent States formed by the former Soviet Republic and the Middle East and Africa maintained their production (PlasticsEurope, 2021: 16-17).

The same qualities that make many plastic materials fantastic for the human world (lightness, strength and durability) also make them an environmental disaster

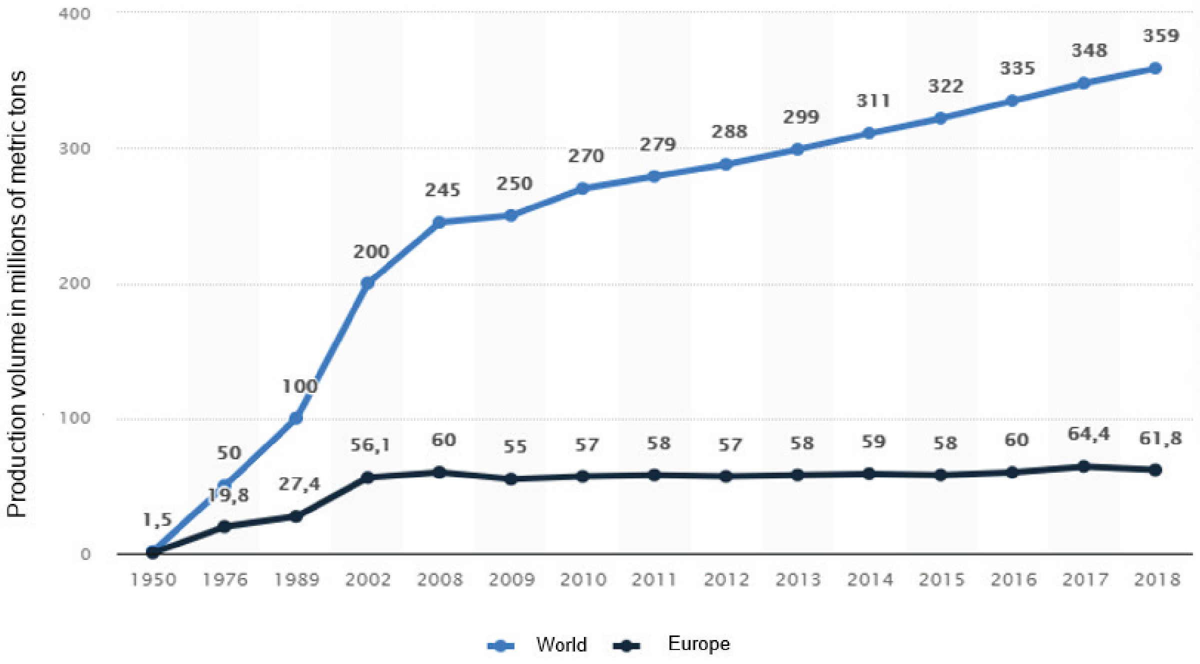

Figure 3. *Global plastics production from 1950 to 2018.*

Note: Includes thermoplastics, polyurethanes, other thermosetting plastics, adhesives, coatings and sealants. Does not include the following fibers: polyethylene terephthalate (PET), polyamides (PA), polypropylene (PP) and polyacrylic fibers. (Statista, 2019).

when they are spread throughout the natural world. Air, land and sea bear the traces of our dependence on this very durable material. A direct relationship can be established between the increasing production of plastics, the increasing dependence of humans on disposable products (such as lighters) and, with this, a constant increase in plastic pollution of the environment. As the British biologist David Barnes wrote (in Frenkel, 2012: 150): "one of the most ubiquitous and long-lasting recent changes on the surface of our planet is the accumulation and fragmentation of plastics", and this has happened within the course of a single generation or, to be exact, since the 1960s, when the era of disposability began to spread.

In general, the applications of this material involve all areas of the development of human life, from health, hygiene, food, transport, clothing and housing. Some examples that can be cited in relation to the areas where commonly used polymers are used are: a) construction and public works with pipes, paints, waterproofing, floor coverings and insulating foams, etc.; b) industrial sector with all types of parts for consumer goods, casings, gears, belts, bodywork, electrical and thermal insulators, electrical and electronic components, etc.; c) consumer industries with packaging, toys, suitcases, sporting goods, fibres for fabrics and all types of textile articles, furniture, bags, among others; d) agri-food industry mainly with containers and packaging, both in intermediate industrial treatments and in the products purchased by the end user; e) agriculture, especially in intensive crops, pipes for water transport, irrigation and drainage, soil mulching, greenhouses, films and sheets for silage or in the construction of reservoirs, etc.; and f) applications in the field of hygiene and health with the production of contact lenses, lenses and frames for glasses, all types of specialized bags, catheters, syringes, adsorbent systems, gels and shampoos, as well as recently, makeup and toothpaste, among many other products (García, J. M., 2014: 33-34).

THE PLASTICS NOWADAYS

Plastics are of utmost importance to today's society and the benefits they bring to it are undeniable. There is an increase in plastic consumption, since this material offers the possibility of minimizing human effort and has made possible the development of technology and science in the different areas of human action, in addition to having played a primary role in preventing the transmission of diseases and in obtaining better hygiene, as was the case in the COVID 19 pandemic. However, they pollute at every stage of their life cycle and, because under the current scheme and model of life, it is difficult to imagine a life that does without this material, its use, far from decreasing, continues to increase, since there is no other material (or set of) capable of replacing it, without causing more environmental and social problems.

Plastics are polymeric materials. Polymers are macromolecules composed of long chains of monomers - small molecules or particles - that are joined by a polymerization reaction. These bonds can be linear, with branches or as if they were very complex structures similar to a plate of spaghetti (Morales Méndez, 2010:15). Polymers can be natural such as starch, cellulose, rubber, collagen or silk (Reina Toresano and Gómez Soria, 2019: 17); synthetic when they are produced by chemical reactions of polymerization of monomers such as polyethylene terephthalate or PVC; and modified when they come from the chemical modification of natural polymers such as vulcanized rubber, poly cellulose acetate, cellophane or rayon (García, J. M., 2014: 9, 22). It can be said then that, in the current context, a plastic is an organic polymer to which other low molecular weight components are added, such as fillers, reinforcements, pigments, colorants, stabilizers, antioxidants, retardants, plasticizers, lubricants, compatibilizers or nucleants, among others (García, J. M., 2014: 9-10).

There are currently more than 300 types of plastic, which in general involve all areas of human life development, from health and hygiene, food, transportation, clothing, housing to any other anthropogenic activity, however simple it may be. Among the most commonly used are: polyvinyl chloride (PVC), polystyrene (PS), polyethylene (PE), polymethyl methacrylate or acrylic (PMMA), phenoplastics, polycarbonate, polyurethane (PU), polyamides, polyethylene terephthalate (PET), acrylonitrile butadiene styrene or ABS, polypropylene (PP) (Frenkel, 2012: 290).

Plastics are very noble materials due to their durability and the possibilities they offer, which have allowed great technological and scientific advances, with many benefits for humanity. However, these same characteristics have turned them into an environmental and social problem. In addition, they have been developed under a production model based on consumerism (especially under the logic of use and throw away), which is a premise of the capitalist mode of production, so that neither companies, nor consumers, nor governments assume responsibility for the environmental deterioration they have caused. This is where permaculture can have a great impact, changing the ways in which human groups relate to one another and, consequently, changing current forms of production, always seeking to introduce comprehensive systems that not only allow the reuse of discarded plastics, but also make the same production system work with nature in favour of its restoration.

PLASTICS IN MEXICO

The plastics industry represents 0.4% of the country's GDP and 2.6% of the Manufacturing GDP[6]. Mexico is the eleventh largest producer of plastics and the twelfth largest consumer of this material in the world. In addition, it is considered to be a leader in recycling in Latin America, since it is estimated that it recovers 50% of the PET that is used. The sector has an economic impact in the manufacture of countless manufactured products.

This industry generates 260,000 direct jobs and 500,000 indirect jobs, in at least 4,580 companies, with an estimated annual production of 7,000,000 tons of plastics, with a sustained growth rate since 2009 of 4.8%. (Aguirrezabal Unamunzaga, 2019: 1).

Of the economic units that make up the plastics industry and resin production in the country, 60% are microenterprises (less than 20 employees), 24% are small companies (up to 30 employees), 12% are medium-sized companies (from 31 to 100 workers) and the rest, that is, 4%, are large companies (more than 100 employees). The manufacture of plastic products according to the classification of the North American Industrial Classification System (SCIAN), is identified as branch 326, and brings together 12 activities, among which the manufacture of flexible plastic bags and films, the manufacture of plastic auto parts and the manufacture of bottles stand out for having greater economic and production value (INEGI, 2017: VII). It is distinguished by being one of the five industries with a low concentration index, although the eight largest companies represent around a fifth of the gross production value (Aguirrezabal Unamunzaga, 2019: 6). In terms of processes, 48% of the plastics industry is oriented towards packaging, 24% towards general consumption, 12% towards construction, 6% towards the electronic sector, 2% towards agriculture, 1% towards the medical sector and 3% towards other uses (Aguirrezabal Unamunzaga, 2019: 6). Regarding the distribution of companies dedicated to the manufacture of plastics, the majority are located in the center of the country (53%), 24% in Jalisco and Bajío, 16% in the North of Mexico, 5% in the south and only 2% in the Gulf, as can be seen in Figure 4 (Chávez, 2020).

In terms of recycling, the country is considered a pioneer in Latin America. According to data from the National Plastics Association (ANIPAC), 1,913,000 tons of plastic waste were recycled in 2021 alone. In the First Quantitative Study of the Plastics Recycling Industry carried out in 2021 by this institution, there are 363 companies that are dedicated to one or more plastic recycling processes in the Mexican Republic, of which 16% are considered large, 16% medium, 23% small, and 41% microenterprises, and of the remaining 4%, there is no information on this matter. 73% do collection work, 11% washing, 34% grinding, 21% pelletizing, and 11% densifying. As can be seen, some companies carry out more than one process (ANIPAC, 2021). Polyethylene is the most recycled plastic with a percentage of 51.2%, followed by PET with 22.1%, 18.2% of polypropylene, 1.8% of polystyrene, 2.1% of PVC and 4.6% of other plastics. 38% of this material comes from companies, 27% is obtained in collection centers, 26% is recovered through garbage collection, 11% is rescued from landfills, 10% from transfer centers, 7% from maquiladoras, 6% comes from individuals, 4% from the automotive sector and 4% from other places (Alegría, 2022 and ANIPAC, 2021).

6. Economic indicator that measures the contribution of the manufacturing sector - which includes the economic units dedicated to the mechanical, physical or chemical transformation of materials or substances in order to obtain new products (INEGI, 2023) - in total production. It is obtained through the elaboration of the added value in manufacturing by the total gross added value and the Gross Domestic Product. (SIGFRE-DRS, 2023).

Figure 4

Note: Plastic manufacturing companies in Mexico

It is difficult to imagine a human activity that is not somehow related to some object or type of plastic. These materials, in addition to allowing great scientific and technological advances, provide us with many conveniences that would be difficult to achieve with other types of materials and, if replaced with some other material under the current production scheme (resource extraction-production and consumption-waste), would cause worse environmental problems, such as soil erosion due to the felling of trees when using wood, or the extraction of metals, or the greater amount of solid waste and greenhouse gases released by glass production, to mention a few (Franklin Associates, 2009: ES-12).

Without a doubt, the change to circular economies, that is, those that recover materials and introduce them into new production chains, is very beneficial to mitigate the effects of pollution, especially in the case of plastics which, despite being a very resistant material, a large number of applications are designed for short periods of useful life. However, betting only on recycling does not seem enough; a radical change of values is necessary in the entire production and consumption system.

THE HARMFUL EFFECTS OF PLASTICS

The effects of plastic production on the planet are only just beginning to be understood, especially under the linear production system that is currently being used, that is, extract resources, produce, use and throw away. In addition to this, what makes plastic particularly useful is precisely what makes it more harmful, that is, it persists over time. In other words, natural systems do not have the capacity to safely absorb its components and with the amount of plastic products that are discarded and end up in the environment, it is logical that we are replacing the biosphere with mountains of plastic waste.

Even humans are contaminated with plastic, not only indirectly through the fish we eat, which previously fed on microplastics in the ocean, but also because plastic contaminates at every stage of its life cycle, from the moment oil is extracted and natural gas is used to produce it, throughout the entire production and shaping of products, and at the end of its useful life when the waste is thrown away, buried, reused, recycled or burned (Heinrich Böll Foundation and Break Free From Plastic Foundation, 2019: 8).

The initial stage of production involves two processes: a) distillation and b) polymerization and polycondensation. In the oil industry, distillation is the common process for separating petroleum derivatives. It consists of gradually subjecting the oil to high temperatures to separate its compounds in a fractional manner depending on the amount of carbon atoms they contain. This process results in the emission of gases such as sulfur oxides. (SO_x) and the nitrogen (NO_x), as polluting by-products (INECC/SEMARNAT, 2020: 17).

As for pollution from polymerization and polycondensation in the manufacture of plastics, this has various sources and depends on the type of plastic to be manufactured, mainly monomers, solvents or other volatile liquids emitted during the reaction, sublimated solids such as phthalic anhydride, carbon monoxide (CO), sulfur oxides (SO_x) y nitrogen (NO_x), among others (Gale Zabaleta and Paredes Morelos, 2014: 22).

There is a lot of empirical and scientific evidence that exists regarding the environmental problems caused by plastic waste. To cite a few examples, in March 2019 in the city of Davao, Philippines, a whale was found with 40 kg of plastic bags in its stomach (BBC News, 2019); five huge islands or patches of floating plastic have been found in the oceans.[7] (INECC/SEMARNAT, 2020: 3); in 2006, the study: *"Plastic string as the cause of leg bone degeneration in the White Stork (Ciconia ciconia)"*, it means, *plastic rope as a cause of leg bone degeneration in the white stork* (*Ciconia ciconia*); (Kwiecinski, y Col., 2006: 1-6), study carried out in Poland which found that more than 21% of the chicks of the birds analysed had their legs entangled in the plastic threads used by storks to improve the structure of the nest, which caused the partial destruction of the legs in some cases, even leading to self-attribution (SEOBirdLife and Ecoembes, 2019: 12).

Figure 5. Plastics in rivers

Note: Image of the amount of waste (most of which is plastic) that is concentrated along the Lerma River and will later end up in Lake Chapala. (Cedeño, 2019).

In 2015 the study: *Plastic waste inputs from land into the ocean* (Plastic waste inputs from land to ocean) (Jambeck et al., 2015: 768), published by the journal *Science*, revealed that in 2010 between 4.8 and 12.7 million tons of plastic ended up in the ocean. The average (8 million tons) would be equivalent to dumping a garbage truck full of plastic every minute for a year. It must be noted that the study only took into account the plastic that came from the coasts, to which must be added the tons that are thrown or fall from boats. It is estimated that if this continues, in 2030 the amount will double (two trucks per minute) and, in 2050 it will quadruple (four trucks per minute) (Reina Toresano and Gómez Soria, 2019: 24).

Another consequence of plastic production is microplastics, which can be primary, that is, intentionally manufactured as small-sized particles for industrial purposes (pre-production, resin pellets, microbeads for abrasives in cosmetics, toothpaste, poles for textile coatings, among others), or secondary, which is the result of the fragmentation of any plastic product in use, and present in the environment, as waste that includes fragments

7. There are currently five documented Garbage Patches, although others are in the making. The largest is in the North Pacific

of solid plastic, microfibers of fabric or rope, coatings that have come off or remains of wear and tear. These microplastics have become a highly relevant issue due to the risk they pose to different animal species, including humans (INECC/SEMARNAT, 2020: 9-10).

Microplastics have been found in the stomachs of various animals, and most studies on the subject focus on monitoring water, especially surface seawater. Fish can ingest them for various reasons, including mistaking them for food or, in the case of filter-feeding species, sucking them out of the water. The physiological effects of such exposure include alterations in the intestinal tract, lethargy, abnormal swimming behavior, and even death. On the other hand, predatory organisms (such as humans) can accumulate microplastics during the ingestion of prey contaminated with such residues (INECC/SEMARNAT, 2020: 11-12). One of the most widely used organisms in studies of exposure to microplastics are bivalves, in which the cellular effects associated with ingestion include immunological alterations, neurotoxic effects, and signs of genotoxicity (Avio, 2015 in INECC/SEMARNAT, 2020: 11). Microplastics enter the marine environment through various routes, such as wastewater discharged into rivers and lakes, which subsequently reaches the ocean. They also enter through land runoff, or the degradation of macroplastics that are transported to the sea, from waste disposal points in landfills, and clandestine open-air dumps. The sources of the presence of microplastics on land are related to many activities, including land transport (for example, those generated by tire wear), agricultural activities, wastewater plants, or the degradation of plastic waste (INECC/SEMARNAT, 2020: 10).

In 2018, Greenpeace conducted a brand audit to determine the impact of plastic pollution at 42 Mexican beach sites. Plastic litter was present at all randomly sampled locations. 41.5% belonged to the Coca-Cola, PepsiCo, Nestlé, and Bimbo brands.

Another finding of this study was the comparison between the results obtained on the surface of the seas, and those found on the bottom next to the reefs, regarding the number of plastic pieces per square kilometer. While the number of plastics floating on the surface was only 2 pieces/km2, at the bottom of the sites visited it reached an estimated total of 3,500 pieces/km2. Because more plastic waste was found on the bottom of the sea than floating on the surface (this is because the waste that reaches the beach eventually sinks), it is discouraging to observe the plastic waste in the sea, but it is assumed that it is only the tip of the iceberg, given that most of the waste is at the bottom and it is impossible to quantify it, much less recover it (Rivera-Garibay et al., 2020: 8-13). Just as they have changed the essential texture of modern life, plastics are also altering the basic chemistry of our bodies, thereby betraying the trust we have placed in them. All of us, even newborns, now carry traces of phthalates, and other synthetic substances such as fire retardants, stain repellents, solvents, metals, and waterproofing or bactericidal agents, in our bodies. The actual threats to human health remain uncertain (Frenkel, 2012:111).

As an example, the case of PVC, which seemed to meet the necessary requirements for medical use due to its supposed chemical stability, as noted by Frenkel (2012: 114) in 1951., the magazine: *Modern Plastics* publishes the article “Why doctors are using more plastics”, in which he details that “<<any substance that comes into contact with human tissue […] must be chemically inert and nontoxic>>, as well as compatible with human tissue and nonabsorbable, PVC seemed to

Ocean, located between California and Hawaii, and is estimated to measure some 700,000 km2 and contain around 100 million tons of garbage distributed between the surface and the seabed. (Anèl-lides, 2020).

meet the requirements, but between the end of the sixties and the beginning of the seventies, various evidences called into question this belief, among them was the discovery that vinyl chloride gas (the main substance in PVC), was much more dangerous than had been believed until then. In 1964, doctors at the PVC factory of the B. F. Goodrich company in Lousiveille, Kentocky, discovered that several workers were developing acroosteolysis - a systemic condition that causes skin lesions -, circulatory problems and deformation of the bones of the fingers of the hand, as a result of the use of PVC. In the early 70s, European researchers found evidence that vinyl chloride was carcinogenic, as detailed in the article: *Deceit and Denial; The Deadly Politics of Industrial Pollution* ("Deception and Denial: The Deadly Politics of Industrial Pollution" (Markowitz and Rosner, 2002: XIII).

Further evidence emerged in 1974, when four workers at the Goodrich factory died of the same rare type of liver cancer, angiosarcoma (Frenkel, 2012: 115). As the vinyl chloride scandal spread, other research pointed to a more insidious and uncertain risk: several widely used products might be releasing chemicals added to PVC. Robert Rubin and Rudolph Jaeger, toxicologists at Johns Hopkins University Hospital, discovered this by chance during a 1969 experiment with rat livers. As the livers were transfused with blood from PVC bags and pipes, it became clear that some unknown compound was thwarting the experiment. Jaeger realized that it was DEHP, the chemical plasticizer added to the vinyl used to make blood bags and tubes, which could contain between 40 and 80% of the chemical by weight. Since the additive does not bind to the PVC backbone (daisy chain), it can be leached (released), especially in the presence of blood or fatty substances (Frenkel, 115-116).

After thoroughly researching DEHP and other phthalates, mainly in adults, several independent toxicologists came to the same conclusion: they found that at high doses they could cause birth defects in rodents and cause liver cancer in rats and mice. And this is just one of the risks associated with the use of plastics (Frenkel, 2012: 117).

TOWARDS A WORLD WITHOUT PLASTICS

Following pressure from various organizations, such as Greenpeace and UN Environment, among others, policy interventions have been implemented at international, national and subnational levels to regulate the use of plastics. However, so far most of them refer to the prohibition of plastic bags and disposable plastics (so-called single-use plastics) (UN Environment, 2018: 6).

Germany has imposed a ban on single-use plastic waste since July 2021, and is adamant that marine waste and plastic pollution must be given high priority in global forums. Ecuador has approved a law since November 2020 that regulates the reuse and recycling of plastics and bans single-use plastics in trade.

Ghana is also one of the most committed countries on this issue and, in 2019, became the first African country to join the platform: *Global Plastic Action Partnership* (GPAP), with which the was created *National Plastics Action Partnership of Ghana* (NPAP), under the objective of developing a circular economy as the main instrument to reduce plastic waste. For its part, Vietnam has developed a development strategy to promote the marine economy, while protecting the environment and marine ecosystems, with which it hopes to become a pioneer country in the reduction of marine pollution by plastic waste (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2021). In Mexico, the judiciary has just instructed the legislature to establish, by means of laws, the ban on single-use plastics.

Currently, at least 90 countries have imposed bans on single-use plastics, and 170 countries have committed to significantly reduce the use of plastics by 2030 (OpenMind, 2021).

Another alternative that has been studied is to replace these materials with bioplastics, however, although at first glance it may seem like a very promising alternative, in reality it is not a solution that can resolve the complexity of using plastics, such as waste, since replacing a single-use plastic item with another that could also be single-use does not modify the throwaway culture (Greenpeace, 2018: 9). Another fact is that, although bioplastics are made from organic raw materials, it does not guarantee that they can be composted since they need specific conditions of humidity and temperature, among other things (like any organic waste). In addition, it must be considered that not all components of bioplastics compost or degrade, and some even need industrial procedures to degrade.

HOMEMADE SUGGESTIONS TO REDUCE THE USE OF PLASTICS

Reina y Gómez (2019), authors who have sought to reduce plastics in their daily lives propose the following measures:

First, they comment that we must keep in mind the rule of the five Rs: reject, reduce, reuse, recycle, reincorporate. They also insist on having basic rules for buying without plastic, through which we learn where to buy different types of products, always looking for those that are sold in bulk, taking advantage of the bags that exist for this purpose and that are reusable (Reina and Gómez, 2019).

For the specific case of kitchens, the authors recommend:

1.- Avoid food waste. The increased use of plastic as packaging increases food waste.

2.- Avoid buying frozen products

3.- Use glass jars as substitutes for plastic.

4.- Use napkins and cloth bags that can be washed and reused

5.- Avoid bottled water and, if necessary, use glass instead of

PET, or also use filters and even binchotan (Japanese charcoal).

6.- Drink coffee and tea without plastic (Reina and Gómez, 2019).

For household cleaning, it is suggested to either buy detergents in bulk or make your own detergents. For the latter, it is suggested to have products such as: vinegar, soap, bicarbonate, lemon, percarbonate, citric acid, sodium carbonate and essential oils. Referring to the yellow sponges with a green rough face, they comment that they are synthetic "and as they wear out, they release microfibers that will end up going down the drain," so they propose using a luffa sponge that is 100% vegetable-based. They also recommend the esparto scouring pad, wooden brushes with vegetable fibers and the copper scouring pad (Reina and Gómez, 2019, p. 94-101).

They also refer to microfibers as the most abundant plastic waste and those that end up in the stomach of many fish, microfibers that are found in the clothes we wear daily. To mitigate this problem, they recommend: avoiding synthetic fibers as much as possible, washing as little as possible, buying quality clothes that last longer, filling the washing machine, using liquid detergents instead of powder, washing at low temperatures, avoiding very long washes and air-drying clothes (Reina and Gómez, 2019, p. 103).

Regarding plastics in the bathroom, they consider that it is the place where we accumulate the most plastics. They refer to the plastic microparticles that are added to certain cosmetic and cleaning products to exfoliate, regulate the viscosity and texture of the cream, give it highlights, etc. For bathing, they recommend using wooden brushes with vegetable fibers, using solid soaps instead of liquid gel whose main component is water, buying solid shampoo or, failing that, in bulk, or you can replace it by washing your hair with baking soda and rinsing it with apple cider vinegar or lemon (Reina and Gómez, 2019, p.107-114).

Regarding oral hygiene, they recommend rinsing your mouth with: sage, clove or thyme infusion, a pinch of salt and bicarbonate, and essential oils. Plastic-free dental floss brands can be found. There are bamboo toothbrushes with vegetable bristles or brushes with replaceable heads (Reina and Gómez, 2019, p. 115-118).

In short, these are just some of the various recommendations that exist for living a life with reduced plastics. We must take the initiative by taking up these recommendations.

On the other hand, we must emphasize changing the anthropogenic conception that nature exists and acquires value to the extent that it is capable of satisfying human needs, which implies accepting the fact that each element in nature has an intrinsic value and is essential for the system to which it belongs and of which the human being is a part.

Likewise, for permaculture, pollution reflects an excess of abundance, in other words, overproduction, for which the systems designed by humans must be able to limit and redirect this abundance so that it does not cause pollution (Torres, T., 2024).

To give an example, currently the levels of carbon dioxide (CO2) in the environment have skyrocketed: there is an excess of carbon dioxide abundance as a result of human activities, a possible solution to redirect this excess would be to plant trees, since they absorb it and return it to the earth as a nutrient.

In the case of plastic production and consumption systems, in addition to redirecting the excess (circularity of the material), they must be limited and production and consumption systems established under logics of preservation and conservation of the environment must be created, which allow human needs to be satisfied.

CONCLUSIONS

Today it is impossible to live 100% without plastics, so our goal today must be to reduce their use as much as possible, however we must accept that they will not disappear from our lives so easily, even if the current situation of the planet forces us to do so.

When we think of environmental pollution caused by plastics, it is generally associated with single-use plastics, however, although these are the most visible because they end up faster in natural spaces, they represent less than 40% of total production, so we must consider the other 60%, which although they have longer life cycles, will eventually reach the ecosystems. This is why, although some progress has been made against plastic pollution, it is evident that more and better tactical actions and strategic adjustments are needed to the plastic production and consumption system (at all individual, business and State levels), not only to stop the dumping and further accumulation of plastic in nature, but also to stop extracting resources for plastic production, eliminate toxic substances and reduce procedures in the formation of products from this material, but above all, to change the attitude of human beings in their relationship with the environment and their consumption patterns.

As we have seen throughout this work, plastics represent a whole series of compounds that have become, over the years, indispensable in our daily lives. However, as we have been able to confirm throughout this work, they represent one of the most polluting elements on the planet, especially those that we cannot see with the naked eye, such as microfibres.

By knowing this situation, the task that we humans face for the future is not at all easy, but it is necessary, and we are not referring exclusively to plastics. We must also consider the waste we currently make of water in cities, when there are communities that lack this vital element. Furthermore, where is this waste water deposited? Our rivers, lakes and seas are highly polluted, and consequently so are the species that inhabit them, and from which we feed. Making good use of water is another of the uncomfortable tasks that we will have to face, if we really care about the future of this planet.

REFERENCES

Aguirrezabal Unamunzaga, I. (2019). *Plástico en México.* ICEX España Exportación e Inversiones, Oficina Económica y Comercial de la Embajada de España en Ciudad de México. Ciudad de México: Oficina Económica y Comercial de la Embajada de España en Ciudad de México- Gobierno de España.

Alegría, A. (13 de enero de 2022). En 2021, México recicló más de 1 millon de toneladas de plástico: Anipac. *La Jornada*.

Anèl-lides. (17 de julio de 2020). *Islas de plástico: Anèl-lides Serveis ambientals marins*. Recuperado el 15 de julio de 2021, de Anèl-lides Serveis ambientals marins: https://anellides.com/es/blog/islas-de-plastico/

ANIPAC. (2021). *1er Estudio Cuantitativo de la Industria del Reciclaje de Plásticos en México.* ANIPAC.

BBC News. (19 de marzo de 2019). La impresionante imagen de una ballena con 40 kilos de bolsas de plástico en su estómago. *BBC News*. Recuperado 20 de enero de 2022, https://www.bbc.com/mundo/noticias-47620369

Bookchin, M. (1977). *Por una sociedad ecológica.* Barcelona, España: Gustavo Gili, S. A.

Bookchin, M. (2015). *La próxima revolución. Las asambleas populares y la promesa de la democracia directa.* (P. Martín Ponz, Trad.) Barcelona, Cataluña, España: Virus Editorial.

Centro Nacional de Prevención de Desastres (27 de octubre de 2017) "Domingo 28 de octubre 2007: mega inundación en Tabasco", CENAPRED, México (www.gob.mx).

Chávez, J. C. (23 de diciembre de 2020). *Industria del plástico crece 3% gracias a COVID-19: Energía Hoy*. Recuperado el 15 de enero de 2022, de Energía Hoy: https://energiahoy.com/2020/12/23/industria-del-plastico-en-mexico-crecio-3-gracias-a-covid-19/

El Tiempo. (6 de junio de 2022). Nivel de CO2 en el aire es 50% más elevado que antes de la era industrial. Recuperado el 07 de agosto de 2024 de: https://www.eltiempo.com/vida/medio-ambiente/nivel-de-co2-en-el-aire-es-50-mas-elevado-que-antes-de-la-era-industrial-677934#:~:text=Antes%20de%20la%20revoluci%C3%B3n%20industrial,50%20a%C3%B1os%20de%20lucha%20ambientalista).

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. (3 de septiembre de 2021). *Conferencia Mundial Ministerial sobre Basura Marina y Contaminación por Plásticos finaliza con proyecto de resolución*. Recuperado el 20 de febrero de 2022, de Federal Ministry for the Environment, Nature Conservation and Nuclear Safety: https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Abfallwirtschaft/ministerkonferenz_meeres_plastikmuell_es_bf.pdf

Franklin Associates. (2009). *Life Cycle Inventory of three single-serving soft drink containers.* Único, PETRA, Franklin AssociatesA Division of ERG Prairie Village, Ks.

Frenkel, S. (2012). *Plástico. Un idilio Tóxico* (1a ed.). (V. Ordóñez Divi, Trad.) Barcelona, España: Tusquets Editores, S. A.

Fundación Aquae. (s/f). *Mar de plásticos: cuánto plástico hay en el mar y los acéanos: Fundación Aquae*. (Fundación Aquae) Recuperado el 20 de diciembre de 2022, de Fundación Aquae: https://www.fundacionaquae.org/mar-de-plastico-el-80-de-la-basura-en-el-mar-es-plastico/

Fundación Heinrich Böll y Fundación Break Free From Plastic. (2019). *Atlas del Plástico. Datos y cifras sobre el mundo de los polímeros sintéticos.* (2da edición ed.). El Salvador: Fundación Heinrich Böll - Break Free From Plastic.

Gale Zabaleta, M. T., & Paredes Morelos, K. M. (2014). *Evaluación del impacto ambiental al aire asociado a la producción de resinas de PVC y PP, para un caso de estudio colombiano.* Universidad de San Buenaventura Seccional Cartagena, Facultad de Ingeniería, Artes y Diseño. Cartagena: Universidad de Sanbuenaventura.

García Estrada, E., Hoyos Martínez, J. E., & Álvarez Vallejo, A. (2017). Comprensión como principio bioético de la permacultura en el planteamiento de proyectos ambientales. *Memorias del Congreso Internacional de Investigación Academia Journals Celaya. Tomo 11*, págs. 2172-2175. Celaya: Academia Journals.

García, J. M. (2014). *La Edad de los Polímeros. Un mundo de plástico.* Burgos, España: Universidad de Burgos.

García, S. (Enero de 2009). Referencias históricas y evolución de los plásticos. *Revista Iberoamericana de Polímeros, 10*(1), 71-80.

Góngora Pérez, J. P. (septiembre y octubre de 2014). La industria del plástico en México y el mundo. *Comercio Exterior, 64*(5), 6-9.

González Arroyo, H. (2017). Cambio climático y Protección Civil. En S. Lucatello, & M. Garza Salinas, *Cambio Climático y Desastres: Un enfoque en Políticas Públicas* (págs. 99-112). CDMX, México: Universidad Nacional Autónoma de México.

Greenpeace. (2018). *Un millón de acciones contra el plástico.* Greenpeace España. Madrid: Greenpeace. Recuperado el 25 de septiembre de 2022 https://es.greenpeace.org/es/wp-content/uploads/sites/3/2018/04/TOOLKIT-PLASTICOS-v3.pdf

Guterres, A. (2008). *Cambio climático, desastres naturales y desplazamiento humano: la perspectiva del ACNUR.* ONU, Oficina del Alto Comisionado de Naciones Unidas para los Refugiados. ACNUR.

INECC/SEMARNAT. (2020). *Panorama General de las Tecnologías de el Reciclaje de Plásticos en México y en el Mundo.* México: Instituto Nacional de Ecología y Cambio Climático, Secretaría de Medio Ambiente y Recursos Naturales.

INEGI. (2017). *Perfil de la fabricación de productos de plástico.* Aguascalientes, México: Instituto Nacional de Estadística y Goegrafía.

INEGI. (14 de marzo de 2023). *Industria Manufacturera: INEGI*. Recuperado el 29 de marzo de 2023, de https://www.inegi.org.mx/temas/manufacturas/

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., y otros. (13 de febrero de 2015). Plastic waste inputs from land into the ocean. *Science, 347*(6223), 768-771.

Kwiecinski, Z., Kwiecinska, H., Botko, P., Wysocki, A., Jerzak, L., & Tryjanowski, P. (2006). Plastic strings as the cause of leg bone degeneration in the White Stork (Ciconia ciconia). *Editorial Científica Bogucki*, 1-7.

Lima, Lioman (2/nov/2017) "Ropas, plásticos, animales muertos y hasta cuerpos humanos": el gigantesco "mar de basura" que tensa las relaciones entre Honduras y Guatemala". BBC News Mundo (bbc.com).

Markowitz, G., & Rosner, D. (2002). *Deceit and denial. The deadly politics of industrial pollution.* Estados Unidos de América: University of California Press.

Morales Méndez, J. E. (2010). *Introducción a la Ciencia y la Tecnología de los Plásticos.* . México: Trillas.

ONU Medio Ambiente. (2018). *El Estado de los Plásticos. Perspectiva del día mundial del medio ambiente 2018.* ONU medio ambiente / SIN Contaminación por Plásticos / India 2018, Medio Ambiente. ONU.

OpenMind. (21 de mayo de 2021). *5 alternativas para un planeta sin plástico: OpenMind BBVA*. Recuperado el 10 de febrero de 2022, de OpendMind BBVA: https://www.bbvaopenmind.com/ciencia/medioambiente/5-alternativas-para-un-planeta-sin-plastico/#:~:text=Al%20menos%2090%20pa%C3%ADses%20ya,uso%20de%20pl%C3%A1sticos%20para%202030.

Organización de las Naciones Unidas para la Alimentación y la Agricultura. (22 de diciembre de 2014). *Diez años después del tsunami, Asia está mejor preparada para hacer frente a los desastres naturales*. Recuperado el 15 de mayo de 2021, de Diez años después del tsunami, Asia está mejor preparada para hacer frente a los desastres naturales: FAO: https://www.fao.org/news/story/es/item/273427/icode/

Parker, L. (19 de junio de 2017). *El 91 por ciento del plástico que se fabrica no se recicla: National Geographic*. Recuperado el 20 de enero de 2020, de National Geographic: https://www.nationalgeographicla.com/planeta-o-plastico/2018/06/el-91-por-ciento-del-plastico-que-se-fabrica-no-se-recicla

PlasticsEurope (2021). *Plásticos -Situación en 2020. Un análisis de los datos sobre producción, demanda residuos plásticos en Europa.* Madrid: PlasticsEurope, Asociación Europea de Organizaciones de Reciclaje y Recuperación de Plásticos (EPRO).

Ramos Reyes, R., & Palomeque de la Cruz, M. A. (2019). La gran inundación del 2007 en Villahermosa, Tabasco, México: antecedentes y avances en materia de control. *Anales de Geografía de la Universidad Complutense, 39*(1), 387-413.

Reina Toresano, P., & Gómez Soria, F. (2019). *Vivir sin plástico* (Primera Edición ed.). España: Zenith.

Rivera-Garibay, O. O., Álvarez-Filip, L., Rivas, M., Garelli-Ríos, O., Pérez-Cervantes, E., & Estrada-Saldívar, N. (2020). *Impacto de la contaminación por plástico en áreas naturales protegidas mexicanas.* México: Greenpeace México.

Sanz Tejedor, A. (2017). *Productos de interés industrial derivados del etileno: Química Orgánica Industrial.* Recuperado el 20 de marzo de 2023, de Química Orgánica Industrial: https://www.rua.unam.mx/portal/recursos/ficha/75965/productos-de-interes-industrial-derivados-de-etileno

SEOBirdLife y Ecoembes. (2019). *Informe Libera. Impacto del abandono del plástico en la naturaleza.* SEOBirdLife, Ecoembes.

SIGFRE-DRS. (2023). *Indicadores Económicos: Sistema de Información Geográfica de Fuentes de Energía para la Planeación del Desarrollo Regional Sustentable*. Recuperado el 28 de marzo de 2023, de Sistema de Información Geográfica de Fuentes de Energía para la Planeación del Desarrollo Regional Sustentable: http://energia.ugto.mx/formularios/Reportes/IndEconomicoPIBManufacturero.php#

Spiegel, J., & Maystre, L. Y. (1998). Control de la contaminación ambiental. En J. (Dir) Mager Stellman, *Enciclopedia de Salud y Seguridad en el Trabajo* (Vol. 2, págs. 55.1-55.59). Madrid, España: Ministerio de Trabajo y Asuntos Sociales, Ministerio de Sanidad y Consumo, Instituto Nacional de Medicina y Seguridad en el Trabajo, Instituto Nacional de Seguridad e Higiene en el Trabajo.

Statista. (Octubre de 2019). *Producción de plástico a nivel mundial de 1950 a 2018: Statista*. Recuperado el 28 de agosto de 2021, de Statista: https://es.statista.com/estadisticas/636183/produccion-mundial-de-plastico/

Statista. (30 de junio de 2021). *La producción de plástico en el mundo: Statista*. (Statista) Obtenido de Statista: https://es.statista.com/grafico/21899/distribucion-de-la-produccion-mundial-de-plastico-por-region-en-2018/

Statista. (22 de mayo 2024). C*oncentración atmosférica de dióxido de carbono a nivel mundial 1959-2023.* (Statista) Obtenido de Statista: https://es.statista.com/estadisticas/1269928/concentracion-atmosferica-global-de-dioxido-de-carbono/

Torres, Thiago. (Julio de 2024) Curso "PDC2024, Permaulture Design Course, Certificación en Diseño con Permacultura"