UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Escuela Técnica Superior de Ingeniería del Diseño

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

School of Aerospace Engineering and Industrial Design

Conceptualization and design of a water bottle using biodegradable materials

Master's Thesis

Master's Degree in Design Engineering

AUTHOR: Zhang, Jiahe

Tutor: Magal Royo, Teresa

ACADEMIC YEAR: 2022/2023

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Escuela Técnica Superior de Ingeniería del Diseño

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Escuela Técnica Superior de Ingeniería del Diseño

Conceptualization and design of a water bottle using biodegradable materials

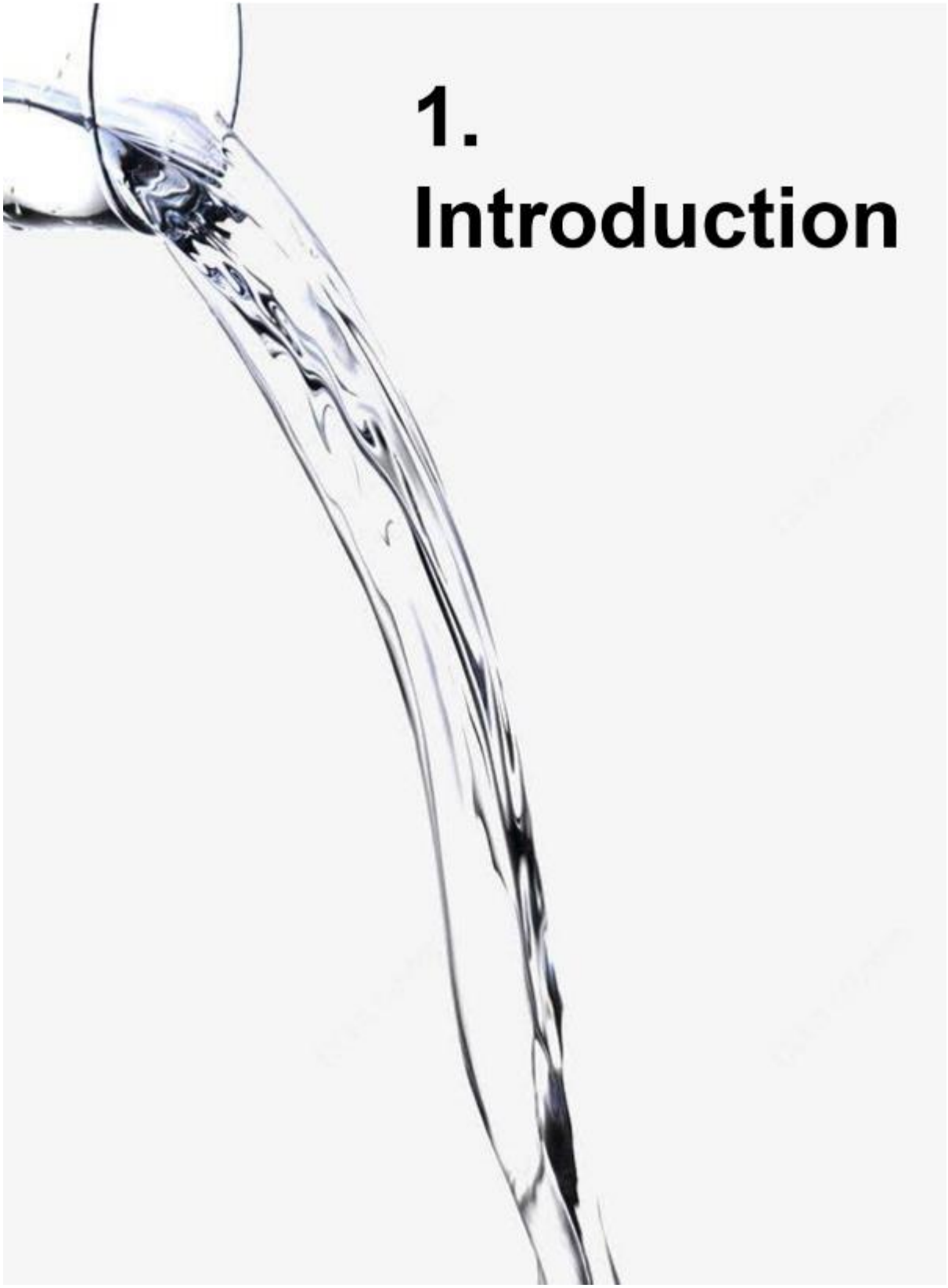
TRABAJO FINAL DE MASTER
Máster Universitario en Ingeniería del Diseño

REALIZADO POR
Jiahe Zhang

TUTORIZADO POR
Teresa Magal Royo
Consuelo Esteve Sendra

CURSO ACADÉMICO: 2022/2023

Content



1. Introduction

1. Introduction

The present project focuses on the search for innovative solutions for bottled water packaging, with the aim of reducing the environmental impacts generated by the inadequate management of traditionally used materials. In this regard, the research was carried out to determine the most relevant characteristics of these materials and their implications in economic and social terms. Based on these findings, the weaknesses of the materials used were identified, and the urgent need to minimize the generation of waste and develop new products made from biodegradable materials, committed to the quality and safety of the product as well as environmental sustainability. This project is focused on searching for innovative solutions for bottling water, with the objective of reducing the environmental impacts generated by the inadequate management of traditionally used materials. In this sense, an exhaustive investigation was carried out to determine the most relevant characteristics of these materials and their economic and social implications. Based on these findings, the weaknesses of the materials used were identified, as well as the urgent need to minimize waste generation and develop new products made from biodegradable materials, committed to product quality and safety, as well as environmental sustainability. These advances constitute a significant contribution in the search for more effective and sustainable solutions for bottling water.

For this, the history of water packaging is explored, from the first glass containers to the most commonly-used ones today, such as Polyethylene terephthalate (PET) its belongs to the family of polyesters. Studying their evolution provides a better understanding of the Industrial Revolution that occurred with the introduction of these containers, as they were practical, versatile and cost-effective for the bottled beverage industry, including bottled water. However, their high demand and global manufacturing resulted in evident environmental damage. Even though plastic bottles and plastic, in general, offered significant benefits to industrial development, their environmental and social consequences led to the implementation of new waste management methods, focused on reuse, recycling, and waste and natural resource reduction. Thus, a new consumption pattern is encouraged that is committed to ancestral reuse practices, such as glass containers and shopping bags, that did not allow for waste and enable the generation of more sustainable strategies for bottled water manufacturing.

Nowadays, industries and the economic model are focusing on reducing the consumption of products that can pose environmental and communal risks. This has led to a search for new technologies and research to address the problem of excessive pollution in ecosystems such as the sea, which affects biodiversity, society, and the world economy. This new economic model presents great opportunities for the biodegradable packaging market produced from natural materials.

The aim of the project is to design a bottle for drinking water using biodegradable materials for runners that do not harm the environment and are safe and of high quality for consumers, making it competitive in the current upsurge of biodegradable packaging market. All necessary information about this new bottle will be presented with the ultimate goal of contributing to solving current environmental problems and improving the quality of ecosystems.


2.
Objectives

2. Objectives

General objective

Design and develop a sustainable solution for a bottled water that utilizes biodegradable materials, ensuring a safe and high-quality product.

Specific objectives

- Research and analyse the environmental impacts generated by traditional water bottles and to demonstrate the importance of designing sustainable solutions.
- Conduct a comprehensive literature review of the development and evolution of plastic water bottles, identifying the key innovations and trends in the field of sustainable packaging, and proposing alternative solutions for more sustainable and cost-effective packaging.
- Evaluate the performance and feasibility of a new sustainable bottle solution considering its ability to maintain the safety, quality, and freshness of bottled water.

3. Pollution of the environment and waste of resources

water is life

3. Pollution of the environment and waste of resources

Due to rapid development of the economy, people's material living standards also showed an upward trend, prompting greater demand for all kinds of goods, thus promoting the consumer market for all kinds of products packaging industry demand increased. As a key driving force in the manufacturing industry, the packaging of products is of great significance in protecting products, facilitating transportation and improving sales of products, and at the same time, consumers are increasingly inclined to consume good product packaging. (Kumar et al., 2021).

Although all kinds of commodity packaging have brought convenience to our life, at the same time, also formed a heavy burden for our ecological environment, most of which a plastic as the material of the packaging after the first use was abandoned, this plastic in the natural environment to completely degrade takes nearly 200 years, even the paper-plastic packaging also takes nearly 80 years of degradation time. Some regulations have also set up laws to restrict disposable plastic products, so it is clear that biodegradable materials play an important role in the choice of packaging materials for products.

The pollution of the environment and the wastage of resources are serious problems that arise from the consumption and packaging of products, especially those that use single-use plastics. Plastic waste is responsible for a significant amount of environmental pollution, as it can take hundreds of years to completely degrade (Courtney Lindwall, 2020).

Furthermore, the production and transportation of products also contribute to environmental pollution. Production often requires large amounts of energy and natural resources, while transportation often involves emissions of greenhouse gases and other pollutants.

To reduce environmental pollution and resource wastage, it is important to adopt more sustainable consumption and packaging practices. This may include choosing products with packaging that is easy to recycle, reuse or compost, and reducing the use of single-use plastics. It can also choose products that are locally produced, as this reduces the need for long transportation processes (Courtney Lindwall, 2020).

Other options to reduce pollution and wastage include appropriate recycling, proper waste management, and the adoption of responsible consumption practices, such as choosing durable products and avoiding food waste. It can all play an important role in reducing environmental pollution and resource wastage, and it is important to take action now to ensure a more sustainable future.

3.1 Pollution caused by plastic water bottles and other plastic products

Nowadays, there are different plastic water bottles and various plastic products everywhere, although to a certain extent our lives provide convenience, because of the excessive use of

plastic water bottles and plastic products, our survival of the Earth's environment has caused a particular impact and pollution. Plastic products accumulation that occurs in the environment, causing damage to wildlife habitats and even negatively affecting humans is known as plastic pollution (City of Westminster,2023).

Plastic pollution, like many polystyrenes, polypropylene, polyvinyl chloride, and other products produces pollutants that are white in colour, hence the term “white pollution”.

This effect is polluting land, water and sea in different forms and types, and has an irreversible impact on people's living environment.

The plastic water bottles commonly used in daily life also pollute the environment. Every year, many discarded plastics water bottles enter the ecological environment and cause long-term and deep-rooted ecological problems because they are difficult to degrade. First, plastic bottles mixed in the soil will make the soil harder, which will affect the absorption of nutrients and water by crops, eventually leading to a reduction in crop production and bringing economic losses to humans. Secondly, plastic bottles abandoned in land or water bodies may be swallowed by animals as food, thus leading to animal death (Knight Geof, 2012).

Other plastic products used in daily life also have a significant impact on the environment and pollution. Some plastics containing chlorine can release harmful substances into the surrounding soil, groundwater or surrounding water sources, so animals drinking these water sources can have health effects; plastic materials are often scattered into the sea in the form of plastic beads via cargo ships, forming marine litter, and these plastic beads, along with plastic bags and plastic food containers, are the source of most marine debris.

Mostly, plastic can affect a variety of negative ways, particularly marine ecosystems. Single-use plastics, in particular, contribute to the pollution of the marine environment and can harm marine species by entanglement or ingestion. Plastic waste can also lead to the death of marine animals, as it can interfere with their natural behaviour and the food web. Plastic can affect ecosystems in a variety of negative ways, particularly in marine ecosystems. Single-use plastics, in particular, contribute to the pollution of the marine environment and can harm marine species by entanglement or ingestion. Plastic waste can also lead to the death of marine animals, as it can interfere with their natural behaviour and the food web (United Nations, 2021).

Furthermore, plastic waste can cause environmental damage that is not limited to marine species. This plastic accumulates on shorelines and in the ocean, it can impact the composition of the ecosystems by altering the structure of marine communities, reducing species diversity, and changing ecosystem functions.

Overall, the plastic pollution crisis is a significant problem that can have far-reaching negative impacts not only on marine ecosystems, but also on human health and the global economy. Taking action to reduce our consumption of single-use plastics, adopting more sustainable consumption and packaging practices, and increasing awareness of plastic waste

and its negative environmental impacts can all help mitigate this problem. It is essential that we take immediate action to address this issue and ensure a more sustainable future for our planet.

In addition to its negative impact on the environment, plastic pollution can also affect the economy and coastal communities. Plastic waste can harm the tourism industry by creating unsightly litter on beaches and reducing the desirability of beach destinations. This, in turn, can have a negative impact on the local economy by reducing tourism revenues and hurting the livelihoods of those who depend on the industry. The results of *Ocean Conservancy's* 2019 annual report indicate that plastic bottles and bottle caps are among the ten most common objects on beaches, ranking fifth and sixth respectively (Ocean Conservancy, 2019).

Also, the plastic waste can also directly impact coastal communities by reducing the productivity of fisheries and aquaculture operations. Plastic debris can damage nets and other equipment, killing marine organisms and contaminating seafood. This can lead to a decrease in the availability of seafood and other marine resources, which can negatively impact the economy and food security of coastal communities. Overall, addressing plastic pollution is crucial not only for the health of our planet, but also for the sustainability of our economies and coastal communities.

Image 1. Plastics water bottles in ecological environment

Source: (Change.org, 2023)

3.2 Waste of water resources

The planet we live on water and it is one of the most abundant compounds on earth, where three-quarters of the earth's surface area is covered by water, but freshwater resources only account for 2.5% of the total water resources, and of these freshwater resources, 70% are ice and permanent snow in the mountains, Antarctic and Arctic regions. So, the fresh water resources available for people's daily life are still not abundant enough (Baidu, 2023).

Water scarcity is both a naturally occurring and human-caused phenomenon. There is enough freshwater on our planet for 6 billion people, but it is very unevenly distributed and too much of it is being wasted and polluted, or even used in unsustainable ways.

Water scarcity has affected every continent. Some 1.2 billion people, almost one-fifth of the world's population, live in regions where water resources are naturally scarce, and another 500 million people are approaching this situation. Another 1.6 billion people, almost a quarter of the world's population, face economically linked water scarcity, and although there is no such thing as global water scarcity yet, more and more areas are suffering from chronic water shortages (United Nations, 2023).

Water is an essential resource for life. Despite its apparent abundance, only a small amount of water on Earth is suitable for human consumption. Additionally, a significant portion of freshwater resources are concentrated in specific countries or regions, which means that many countries and communities are facing serious water scarcity issues.

Water waste is another major problem in many places, as potable water is wasted every day, especially in agriculture, industry, and human consumption. Pollution is also a serious concern, as it affects water resources and reduces the amount of water available for human consumption and the environment. Overexploitation of groundwater is another concerning issue around the globe, with many regions extracting more water than they can replenish, causing even greater water scarcity. Additionally, climate change is impacting water resources, with an increase in heat waves and droughts, making water scarcity an even more significant problem in the future. In summary, water scarcity is a serious and complex problem that affects many people and communities worldwide.

3.3 Zero-waste

Zero waste is the absence of waste in our daily lives. It is one of the strategies and concepts for environmental protection and sustainable development. The core concept is to simplify life, not to waste excessively, to consume only the necessities, to reduce garbage generation and to reduce recycling, through reducing or not to use/not to buy disposable products, exchange, purchase and use second-hand goods, natural materials, homemade and other ways to practice zero-waste life, thus achieving the goal of sustainable development and environmental protection (Bea Johnson, 2013).

This movement emerged in the 1970s when it was given its name thanks to chemist Paul Palmer, founder of the Zero Waste Institute. Palmer noticed that the chemicals discarded by the technology companies that were emerging in Silicon Valley were reusable, leading him to found a company to find new uses for these waste chemicals and thereby reuse some of their components, (Palmer, 2005).

By 1995, psychologist and Urban Ore founder, Daniel Knapp travelled to Australia to give talks on waste minimization. After several years in the United States discussing the concept of *“Total Recycling,”* which was later used to define a *“zero waste*” approach for the entire country, this idea arrived in the Australian Capital Territory (ACT) to create the *"No Waste by 2010"* campaign, (urbanore.com, 2023)

From 2000 onwards, a broader zero waste movement began to take place, as demonstrated by the creation of the *"Zero Waste Conference"* held in Kaitaia, New Zealand. From there, more environmental organizations adopted the concept of zero waste, and an International Zero Waste Alliance (IZWA) was formed in Beaumaris, Wales in 2003.The main intention of zero waste is to minimize waste production and generation as much as possible through the 5Rs: Reduce, Recycle, Reuse, Reject, and Recover. (World Economic Forum, 2023)

Waste is one of the meta-problems of the modern world, and to tackle it we need a new approach that goes to the root of the problem. This solution involves redesigning our relationship with resources, rethinking how we produce and consume, and focusing on how we make decisions collectively. Simply cleaning up the mess or managing waste better is not enough to address this global challenge (Zero Waste Action Plan, 2020).

Finally, Zero Waste proposes a significant reduction in the amount of waste generated, which in turn reduces the number of natural resources needed for waste production and management. Additionally, the Zero Waste strategy can foster innovation in the industry and promote the circular economy, which can generate jobs and economic benefits. This strategy can also help reduce pollution and increase collective environmental awareness.

3.3.1 Reduce

The term of reducing the consumption of natural resources arises from the need to preserve and protect the limited natural resources of the planet, such as water, energy, and materials (*Kevin Wandrei,* 2018). This approach aims to achieve sustainable management of natural resources and a reduction in the environmental impact associated with their extraction, production, and consumption. In addition, the responsible and efficient use of natural resources can also contribute to a more sustainable economy and greater social and environmental stability. Therefore, the reduction of natural resource consumption is a key action in the search for a more sustainable and balanced society in its relationships with the natural environment.

Reducing the waste of water resources is one of the methods of zero waste. We should strengthen water management through technical and economic management means, adjust the structure of water use, improve the way of water use, use water scientifically, reasonably, in a planned and focused way, improve the utilization rate of water and avoid the waste of water resources. In particular, we should do a good job of propaganda among all people and make use of activities such as World Water Day to educate everyone to use water scientifically in their daily work or life and consciously save water, so as to achieve that everyone is responsible for saving water (United Nations, 2023).

In our daily life, we can save water by changing the way we use water, and at the same time, we can also use some water-saving household appliances at home, such as water-

saving refrigerators, water-saving faucets, water-saving toilets, etc. By changing the habits in our daily life, we can reduce the waste of water resources.

3.3.2 Reuse

Reuse of water resources refers to the technically feasible and economically reasonable situation, through engineering measures can be adjusted to use and have a certain guarantee rate of that part of the amount of water resources, it is less than the amount of natural water resources. Surface water resources include only the water volume controlled by the water storage project and the water volume cited by the water diversion project; groundwater resources are only technically feasible and do not cause a continuous decline in the groundwater level of the extractable water volume. The sum of the two, that is, the amount of reuse of water resources. Reuse of water resources must be considered in conjunction with the basin planning engineering measures. The amount of reuse of water resources will decrease rapidly with the different water supply requirements of different production sectors and the increase of the guarantee rate (World Bank, 2020).

Moreover, the amount of water reuse excludes the part of water that is beyond human control or should not be used (such as flooding and the amount of water entering the sea necessary to protect the river environment) and is more realistic, so the practical value of water reuse should be studied.

The American Department of Health & Human Services and the Centre for Disease Control and Prevention, CDC points out that water reuse in engineering refers to treating and recycling water used in various human activities so that it can be used again in a closed cycle or as an alternative resource (CDC, 2023). Some of the ways in which water can be reused in engineering are:

- Irrigation systems: Water used in various activities such as bathing, washing clothes, dishes, etc. can be properly treated and reused to water gardens and crop fields.
- Cooling systems: Water used in cooling systems for power-generating turbines or air conditioners can be properly treated and reused for the same purpose.
- Energy production systems: Process water used in power plants for energy generation can be treated and reused in the same energy production process.
- Wastewater treatment systems: Wastewater produced in cities and municipalities can be treated and reused for agricultural purposes or for recharging underground aquifers.
- Industrial systems: Water used in industrial processes can be treated and reused for the same use or for other industrial processes.

The United States Environment protection Agency, EPA indicates all these cases, water reuse helps to reduce the consumption of freshwater and decrease the amount of contaminated water discharged into rivers and lakes, (EPA, 2017). The water reuse has several benefits, including:

- Water savings: By reusing water, the amount of water needed for an industry or process is reduced, resulting in economic savings and a lower demand for water resources.
- Reduction of pollution: By reusing water, the amount of wastewater generated is reduced, and therefore, the pollution of the environment.
- Reduction of treatment costs: By reusing treated water, the need to treat new water is reduced, which can reduce treatment costs.
- Reduction of carbon footprint: Water reuse can also help reduce the carbon footprint of an industry or process by reducing the energy needed to treat and transport new water.
- Increase in water supply security: Water reuse can help ensure a constant and secure water supply for an industry or process, even in times of water scarcity.

3.3.3 Recycle

The principle of sustainable use of water resources to ensure the sustainable development of human society, economy and living environment. The idea of sustainable development was put forward in the 1980s in the search for a solution to the contradiction between environment and development, and the issue of sustainable use was raised in the field of renewable natural resources accordingly. The basic idea is that in the development of natural resources, attention should be paid to the balance between the adverse environmental side effects caused by the development and the expected social benefits achieved (Jarvie, 2016).

In the development and utilization of water resources, in order to maintain this balance, the principle that water sources for drinking and land productivity should be protected, the principle that biodiversity should be protected from disturbance or balanced development of ecosystems, and the principle that renewable freshwater resources should not be over-exploited and polluted. Therefore, in the development and utilization of water resources, the life support systems and ecosystems on earth must never be harmed, and the water resources needed for sustainable social and economic development must be reasonably supplied to meet the water requirements of all industries and sustainable water supply.

The recycling of water at an industrial and engineering level involves treating and reusing wastewater for other purposes, such as irrigation, industrial processes, and recreational

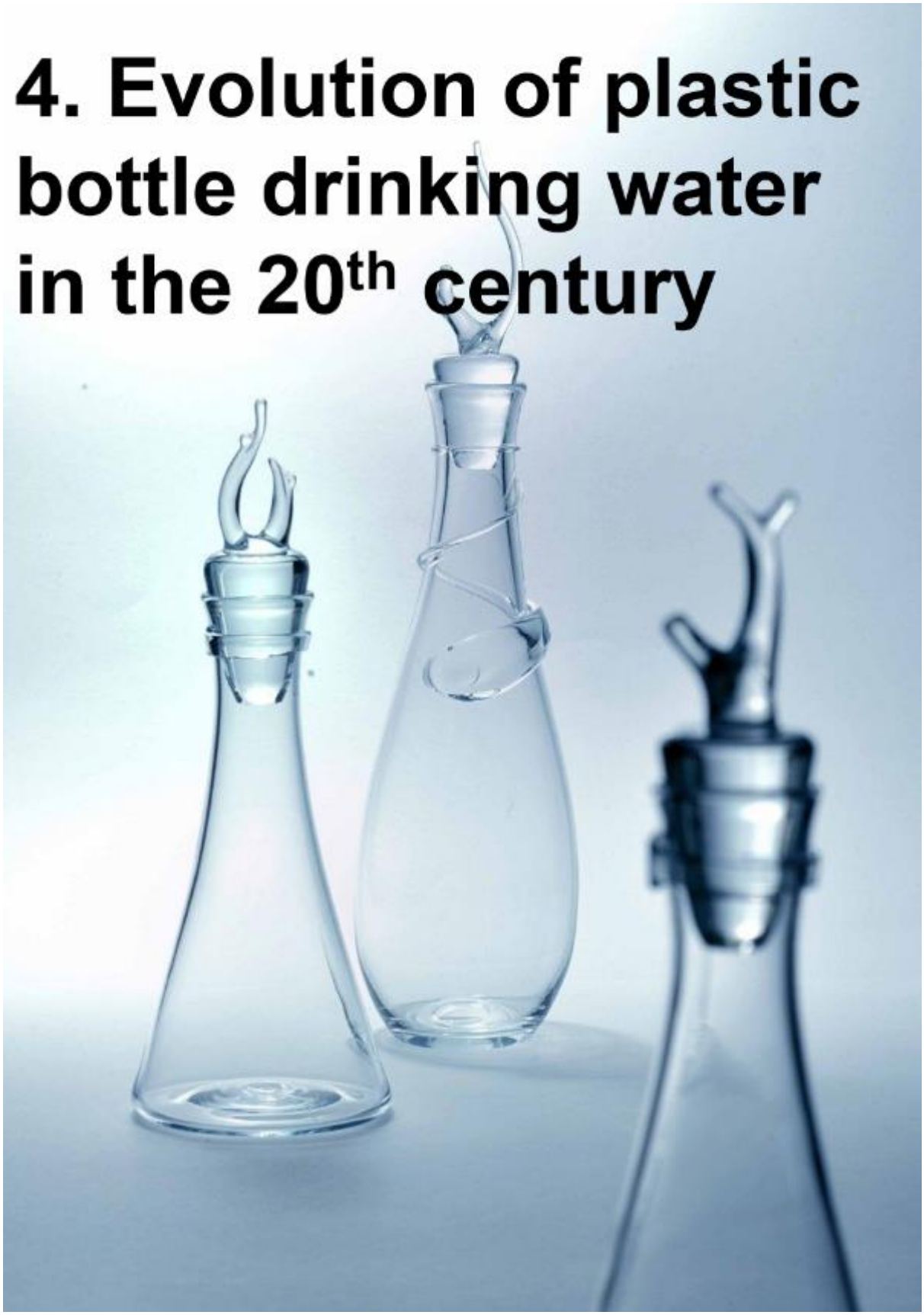
activities. This can be achieved through wastewater treatment processes and advanced water treatment techniques, which remove impurities and contaminants to obtain high-quality water.

The benefits of water recycling at an industrial and engineering level are numerous, including the conservation of natural freshwater resources, the reduction of water and sewage costs, and the prevention of water pollution. Additionally, water recycling can contribute to the reduction of greenhouse gas emissions and the promotion of sustainability and social responsibility in the industry (Saporti & Robins**,** 2021)

In conclusion, water recycling at an industrial and engineering level is an effective and beneficial solution for the sustainable use of water resources, environmental protection, and the promotion of responsible and sustainable practices in the industry.

Recycling natural resources is important to reduce the consumption of raw materials and prolong their lifespan, reduce the amount of waste sent to landfills, and decrease environmental pollution. By recycling, we can conserve the limited natural resources we have, reduce the energy needed to produce new products, and promote responsible and sustainable practices in the industry. Additionally, recycling is an effective way to tackle environmental challenges and promote a culture of preserving natural resources for future generations.

4. Evolution of plastic bottle drinking water in the 20th century



4. Evolution of plastic bottle drinking water in the 20th century

As long as people live, they need to drink a lot of water every day, and water is a basic component of the human body, so human daily life activities and water are inseparable. This gave birth to a class of products, bottled drinking water. It can be said that the emergence of this type of product, gradually changed our way of life or habits.

During the Roman Empire, Roman baths were built throughout Europe to take advantage of natural springs for drinking and bathing. However, bottled water was not utilized until 1621 in Holly Well, England, due to the resurgence of mineral and medical therapy in Europe and America during the 17th and 18th centuries. Eventually, thermal baths became very popular among the upper classes, who believed in the healing and toning properties of these baths and began to drink hot spring water from glass bottles as home remedies. Moreover, contamination of water resources in cities and rural areas led people to seek uncontaminated drinking water from natural sources. Thus, in European countries such as Spa in Belgium, Vichy in France, Ferrarelle in Italy, and Apollinaris in Germany, the bottling and distribution of mineral water for therapeutic purposes began and sold in pharmacies. (BCC Research, 2018)

4.1 History of the bottled drinking water

When it comes to the history of bottled drinking water, we can go back in time to the birth of bottled drinking water in the 19th century. According to testimony, the world's first bottled drinking water appeared in France around 1850. The first bottle was created with glass. Since the beginning of civilization, glass has been one of the most common containers used by people for storing and preserving their belongings. However, until the Middle Ages, the use of glass was limited to a select few privileged individuals who kept its composition and production a secret, using glass for embellishing, protecting, and storing food, medicine, oils, etc (Roetell, 2021).

In 1790, the French government offered a reward to anyone who could find a way to store food for a certain amount of time to feed Napoleon's army. Scientist as Nicolas Appert, found a solution when he discovered that food in glass containers preserved its properties and did not change after heating. Before the 20th century, glass production was done by hand. However, after extensive research, the first machine to achieve large-scale production and packaging of glass was manufactured in the 1900s. In 1925, a single-chamber machine with four chambers was introduced, which was later increased to five and later to six chambers. Now, 20 chamber machines can produce 800,000 bottles per day (Ecovidrio, 2022)

The evolution of glass packaging manufacturing demonstrates the significance of engineering innovation in streamlining production and improving efficiency of business processes. In this regard, engineering materials and processes are important in improving the

quality, durability, and performance of glass packaging, thus ensuring its safety, functionality, storage, and preservation.

In 1855, Vittel mineral water, which was believed to help treat kidney, biliary and liver diseases, was licensed by the government to be filled in earthenware jars and sold in pharmacies as a health product. Subsequently, Perrier, the same brand as Vittel, also entered the history stage. Perrier is actually a doctor named Louis Perrier, in 1888, a farmer bought the "boiling water" (Les Bouillens) water source, which was granted a concession in 1863 but was not operated properly in the first period, and operated it together with Perrier (Pierre, 2017).

Image 2. Evolution of glass bottles

Source: (Chuck Milber, 2016)

Perrier analyzed the chemical composition of the spring water, identified its therapeutic effects, perfected the bottling process, and then sought investment in Perrier bottled water from the British aristocracy. Until 1903, after the French government nationalized both Vittel and Perrier, the British aristocracy invested in Perrier and officially named the water source Perrier. The Perrier bottled drinking water bottle is made of glass. The design of the pear-shaped Perrier mineral water packaging bottle is still in use today (Rui,2005).

Once this bottled drinking water was introduced, it immediately became the royalty, business tycoons and politicians to show off the identity of the exclusive luxury. By 1908, Perrier's sales exceeded 5 million bottles.

With the development of railroad transportation and industrial technology innovation, bottled drinking water began to become popular. Until 1968 Vittel brand of bottled drinking water bottle material began to use plastic bottles, the reduction in packaging costs played a decisive role in the price of bottled mineral water, plastic packaging also makes bottled water lighter and easier to transport. From this point on, plastic bottled drinking water began to gradually reach thousands of households.

It wasn't until the 1970s that a plastic miracle called PET emerged and changed the game. Polyethylene Terephthalate had been in use since 1941. DuPont chemists created it while

experimenting with polymers to make textiles. In 1973, another scientist, Nathaniel Wyeth, patented the first PET bottle. Lightweight, safe, economical, and recyclable. In other words, the perfect vessel to set the groundwork for your next bottle marathon. Perrier and Evian crossed the Atlantic around this time, creating a rage for bottled water. PepsiCo finally entered the water business and launched Aquafina in 1994. Coca-Cola continued with Dasani in 1999. Both brands use recycled tap water. According to Beverage Marketing Corp. U.S. water sales have increased 284 percent between 1994 and 2017. Information reported by The Wall Street Journal. Between 1960 and 1970, the average person bought between 200 and 250 liquor bottles per year. Elizabeth Royte describes data from the Recycling Center in her book Bottlemania. She added that many of these purchases include returnable bottles. According to Euromonitor International's 2017 Global Packaging Report published by newspaper, The Guardian, 1 million plastic bottles are purchased every minute worldwide as of 2017. According to The Plastics Industry Association, plastic bottles and cans represent roughly 75% of the weight of all plastic packaging in the United States today (Downey, 2017).

Image 3: Industry of Plastic Bottles

Source: Societé de Moulages l'ontenayslens, SMF (2023)

4.2 Types of plastic bottled water today

Bottled drinking water is sealed in plastic bottles, glass bottles or other containers, without any additives that can be directly drinking water. This bottled drinking water is mainly divided into three types: Drinking natural mineral water, drinking pure water, other drinking water.

4.2.1 Drinking natural mineral water.

Natural mineral water is groundwater that springs naturally from the depths of the earth or is artificially extracted without being polluted, and contains a certain amount of mineral salts, trace elements or carbon dioxide. Under normal circumstances, its chemical composition, flow

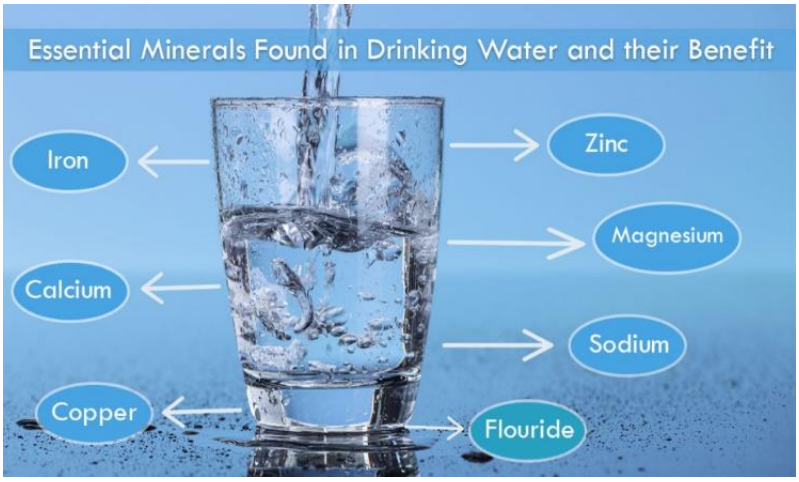
rate, temperature, and other dynamic indicators are relatively stable within the natural fluctuation range, allowing carbon dioxide to be added to drinking water (McGrane, 2019).

Mineral water for drinking is a type of bottled drinking water that comes from underground sources of natural mineral water. This type of water is rich in minerals such as calcium, magnesium, and potassium, as well as trace elements and mineral salts, which give it a distinctive flavour. Additionally, drinking mineral water can be divided into various types, such as natural mineral water, spring mineral water, and sparkling mineral water. It is important to highlight that mineral water for drinking must comply with specific regulations and is subject to strict quality control standards to ensure that it is safe for human consumption.

Regulations for drinking mineral water are established by the Food and Drug Administration (FDA) in the United States. These regulations set limits for contaminants in bottled water that must be followed by mineral water producers to ensure that the water is safe for human consumption. Additionally, the FDA sets labelling requirements for mineral water producers to provide accurate and useful information about the nutrient and mineral content of the mineral water. It is important to note that these requirements and regulations may vary between different regions and countries, (FDA, 2023).

The main difference between bottled mineral water and other types of bottled water is the chemical composition of their minerals and trace elements. Mineral water is naturally rich in minerals and trace elements and its mineral composition remains constant over time at the place of origin, while other types of bottled water can be subjected to filtration or chemical treatment processes to remove or add minerals or other components. Therefore, mineral water is considered by many to be the healthiest and most natural option, although pure bottled water can also be a healthy and safe alternative to drink.

Image 4. Essential Minerals in drinking water



Source: AquaVita, (2019)

4.2.2 Drinking pure water

Drinking pure water is water that meets the sanitary standards for drinking water and is processed by distillation, electrodialysis, ion exchange, reverse osmosis and other appropriate processing methods to remove minerals, organic components, harmful substances and microorganisms from the water.

This type of water is safe for human consumption and does not contain any contaminants or minerals that may be harmful to health. Unlike mineral water, pure water is completely free of minerals and trace elements, which may have some health benefits such as reducing the risk of kidney damage caused by prolonged consumption of mineral-rich water. It is important to note that the process of mineral removal may alter the taste of the water, which may be a consideration when choosing between different types of drinking water.

Water purification is an important part of public health and general well-being. The history of water purification includes a wide variety of methods, each designed to remove contaminants present in drinking water. Physical processes such as filtration, sedimentation, and distillation; biological processes like slow sand filters or biologically active carbon; chemical processes such as flocculation and chlorination; as well as electromagnetic radiation using ultraviolet light are all used to reduce dangerous concentrations of suspended particles, bacteria parasites, algae, viruses, fungi and dissolved and particulate matter found in drinking water. Strict standards are often determined by local governments and international organizations around the world regarding the quality of drinking water, with minimum and maximum limits for allowed quantities of contaminants depending on whether it will be used for human consumption or agricultural irrigation (ISO, 2023).

Image 5. Drinking Pure Water

Source: (Asian Enviro Labs, 2023)

4.2.3 Other drinking water

Other drinking water is the formation of the flow from the ground to the surface of the spring, or higher than the natural water level of the natural animal water layer sprayed out of the spring, or deep well water and other water sources for the processing of water made.

Drinking water is water that has been subjected to various treatment processes to remove impurities and contaminants that may be harmful to human health. These processes may include filtration, chlorination, and the removal of minerals and bacteria, among others. It is

important to note that drinking water is closely regulated and monitored by government agencies responsible for ensuring its quality and safety for human consumption. Additionally, there are various sources of drinking water, such as public supply systems, wells, and springs, and each one requires specific treatment to ensure its potability.

Water purification is of great importance for public health because access to safe drinking water is essential for preventing diseases. According to the World Health Organization (WHO), 88% of the 4 billion cases of diarrheal diseases each year are attributed to unsafe water and inadequate sanitation and hygiene, while 1.8 million people die from diarrheal diseases each year. The WHO estimates that 94% of these cases of diarrheal diseases can be prevented through modifications to the environment, including access to safe drinking water. Therefore, reducing deaths from waterborne diseases is an important public health objective in developing countries. Simple techniques for treating and storing water in the home, such as chlorination, filters, and solar disinfection, could save many lives each year (WHO, 2017).

Image 6. Drinking water bottles

Source: (Keith Leslie, 2016)

4.3 Functionality and use

Currently, plastic bottles are widely used to package and distribute water, carbonated beverages, juices, sodas, and other liquids. The capacity of the bottles varies depending on the packaged product and consumer needs. For example, water bottles generally range in size from 250 ml to 1.5 litres, while soda bottles can have a capacity of up to 2 litres. Regarding their relation to activities, plastic bottles are popular in sports activities, picnics, and outdoor events due to their portability and convenience. They are also widely used in the hotel industry

and in the food sector to package and distribute beverages and other liquids to their customers (Sierra & Plazas, 2010).

Bottled water is potable water that has been treated, packaged, and sold for human consumption. Some of the uses and functionalities of bottled water include:

- Providing safe access to potable water in emergency situations or in areas with non-potable water.
- Offering a convenient alternative for consuming potable water when access to nearby sources of potable water is limited.
- Serving as a beverage option for those who prefer the taste or convenience of a sealed bottle.
- Compliance with sanitary requirements and quality standards established by regulatory bodies.
- Providing an alternative to high-sugar and calorie-containing drinks.

However, it is important to note that excessive use of bottled water can contribute to the accumulation of plastic waste and its impact on the environment. The choice between consuming tap water or bottled water depends on various considerations, including local water quality and personal comfort.

It is known that the global annual production of plastic bottles is very high, which can have negative impacts on the environment due to the generation of plastic waste that can persist for decades in the environment. In addition, the disposal and pollution of plastic bottles can affect the fauna and flora of ecosystems, which can have a negative impact on biodiversity. On the other hand, some positive impacts of plastic bottles may include their ease of transport and storage, which can contribute to the reduction of production and distribution costs of packaged products.

4.4 Traditional materials for packaging water.

There are various kinds of beverage packaging on the market, according to the different materials used, the main beverage packaging on the market are polyester bottles (PET), metal, paper packaging and glass bottles, these four kinds, from the market share, glass bottles accounted for about 30%, PET accounted for 30%, metal accounted for nearly 30%, paper packaging accounted for about 10% (Benyathiar & Kumar, 2022).

4.4.1 Glass

Glass is one of the most common materials to pack water with the longest history of use. In the 1980s and 1990s, we drank soda, beer and champagne, all in glass bottles, and even now,

glass still has a significant weight in the packaging world. Glass containers are non-toxic and tasteless, and look transparent, allowing people to see the contents at a glance, giving a sense of beauty.

Moreover, it is good barrier, impermeable, do not have to worry about spilling or put a long time will have bugs in, plus the price is low, but also can be repeatedly cleaned and disinfected for reuse, itself not afraid of heat and high pressure, simply a set of thousands of advantages in one, so many food vendors used to hold drinks. Especially not afraid of high pressure, very suitable for fizzy drinks, common champagne, beer, soda, etc.. But the glass packaging containers also have some disadvantages. The main problem is the weight of the self, and brittle, easy to break. In addition, it is not convenient to print on new patterns, icons and other secondary processing, now the use of the amount has gradually become less.

Nowadays, the shelves of large supermarkets are rarely used to make glass containers of beverages, in some places with low consumption power, to see the glass bottles of carbonated drinks, sparkling water, etc.. (Augustyn, 2022).

Image 7. Manufacturing process of bottles in glass factory

Source: (Motion Elements, 2023)

4.1.2 Aluminium

In the 1980s, metal packaging began to take the stage. The emergence of metal cans for beverages has improved people's living standards. Currently, metal cans are divided into two-piece cans and three-piece cans. Three-piece cans use materials mostly thin tin-plated steel (tinplate), two-piece cans of materials mostly aluminium alloy plate.

Because aluminium cans have better sealing and ductility, but also suitable for low-temperature filling, so it is more suitable for gas-generating beverages, such as carbonated beverages, beer, etc…At present, in the market, the use of aluminium cans is more widespread than iron cans more widely, you can see in the cans of beverages, almost all of which are packaged in aluminium cans.

In China's Guangdong regional market, some very representative of the beverage, the tin can package, more thick sense. To talk about the advantages of metal cans, it is quite a lot. It is not easy to break, easy to carry, not afraid of high temperature and pressure and air humidity changes, but also not afraid of the erosion of harmful substances (Mordor, 2022)
It has excellent barrier properties, light and gas, and can prevent air from entering the oxidation reaction, so that the beverage is preserved for a longer time. And metal cans have a good surface decoration, convenient to draw a variety of patterns and colours.

In fact, most of the drinks in metal cans are colourful, and the pattern is very rich. Finally, metal cans are convenient for recycling, and more friendly to the environment. But metal packaging containers also have its drawbacks, on the one hand, its chemical stability is poor, so acid and alkali are more afraid, too high acidity or alkaline too strong, will slowly let the metal corrosion. On the other hand, if the inner coating of the metal packaging is of poor quality or the process is not up to par, it will make the beverage tasteless

Image 8. Ever & Ever's aluminium bottles

Source: (Emily Gosling,2019)

4.1.3 Multilayer film

The Tetra Pak™ containers, which are multilayer containers containing paper, low-density polyethylene (LDPE), and aluminium, are widely used for aseptic packaging in the food and beverage industry. The pulp and paper industry can easily recycle the paper in the package cartons. However, the LDPE waste from the products cannot be easily separated from the products and, therefore, is currently only reused or used for energy recovery (The food tech, 2018).

Early paper packaging generally used high-strength raw cardboard. However, pure paper packaging materials are difficult to use in beverages, now with paper packaging, almost all of the composite material of paper, common Tetra Pak™, Comet pack™ and other paper-plastic composite packaging containers.

Tetrabrick Composite™ is a multilayer film composed of different materials inside the Polyethylene (PE) film or aluminium foil can be protected from light and air, and the taste will

not be affected, so it is more suitable for short-term preservation of fresh milk, yogurt and long-term preservation of dairy drinks, tea drinks and juice and other beverages. The shape of a Tetra pillow, aseptic square brick, etc… However, the pressure resistance and sealing barrier of paper-plastic composite containers are not as good as glass bottles, metal cans and plastic containers, and they cannot be heated and sterilized, so the pre-formed cartons will reduce their heat-sealing performance during preservation due to the oxidation of PE film, or become uneven due to creases and other reasons, causing the problem of difficulty in feeding the filling machine to occur (Georgiopoulou & Pappa, 2021)

Image 9. Tetra Pak™ packaging examples

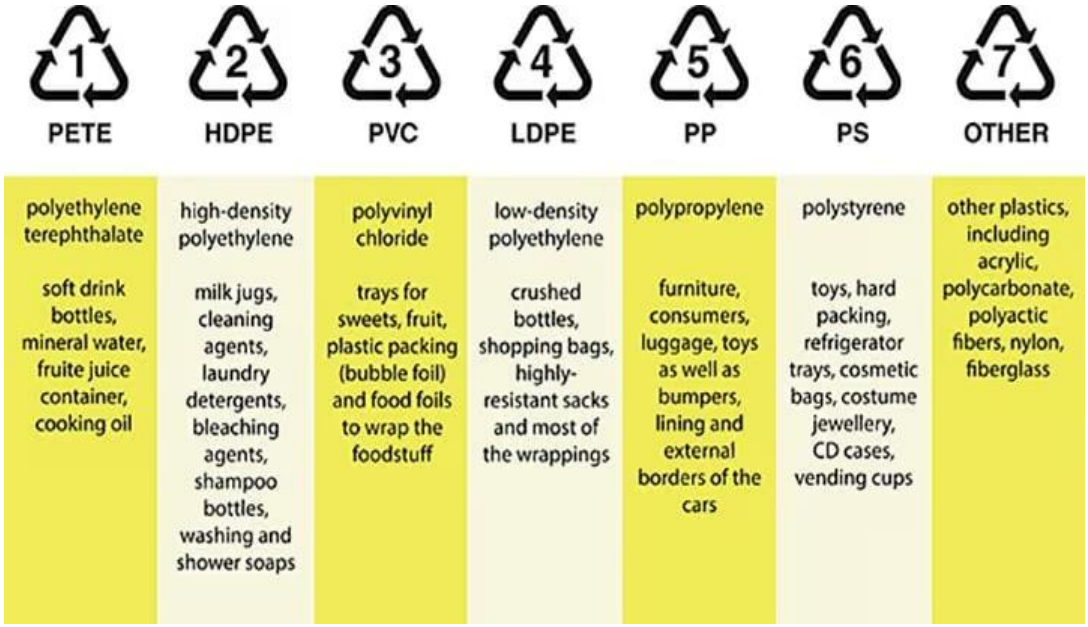
Source: (Stuart Mitchell, 2018)

4.1.3 Plastic bottles

Plastic packaging is very common in the beverage industry. Soft drinks, fruit juices, vegetable juices, teas and other beverages all have plastic packaging for their products. If you usually pay attention to the bottom of plastic bottles, you will find that the majority of plastic bottles have icons like the one below at or near the bottom. This is a common international classification of plastics, with different numbered markings indicating different materials of plastics. Currently, there are several main types of plastic bottles used most in the beverage industry. Plastic is a popular material used for the production of packaging and bottles due to its durability and versatility. Plastics used in packaging and bottles can vary depending on their specific application (Statista, 2023)

There is a classification of a wide variety of materials on the market and their different recycling processes made a series of identification codes necessary. These were created with a symbol that dates back to 1970, and that reflects the steps of the recycling process: collection of materials, recycling and new recycled products. There are various ways to classify plastics, for example, through the plastic recycling code, Resin Identification code or Plastic Identification Code of the SPI (Society of Plastic Industries) (Juste, 2020)

Image 10. Plastic codes.



Source: (eartheasy, 2019)

Currently, Polyethylene terephthalate, (PET), is one of the most common plastic materials used for the production of beverage bottles due to its high transparency, chemical and mechanical resistance, and low cost. Other common plastic materials used in the production of packaging and bottles are Polyethylene, (PE) and Polypropylene, (PP) which are used in the production of bottles for liquids, food and chemicals.

Image 11. Different types of plastics bottles

Source: (Moss grup, 2023)

Types of plastic bottles

Polyethylene terephthalate, (PET)

Is an extremely common resin material that belongs to category 1 in the plastic classification mark (ECHA, 2021). The plastic bottles of mineral water, fruit juice and carbonated beverages that we normally drink are made of it. The proportion of PET bottles used in carbonated beverage packaging is close to 60%. PET is a resin material that was first developed in the 1940s by British scientists John Whinfield and James Dickson. It was first commercialized in the 1970s as a material for beverage bottles, and since then has been widely used in the production of packaging and bottles due to its high transparency, chemical and mechanical resistance, and low cost. PET is produced from two basic materials, ethylene glycol and terephthalic acid, which are polymerized to form polymer chains. These chains can be moulded and sculpted to form bottles and other containers (Sintac, 2022).

PET plastic materials are gaining a lot of attention worldwide because they are a sustainable packaging option and the primary type of plastic used for beverage bottles. This is due to their excellent chemical resistance to organic materials and water, as well as their high strength-to-weight ratio.

Is a polymer obtained by a polycondensation reaction between terephthalic acid and ethylene glycol, and belongs to the group of synthetic materials known as polyesters. It is a linear thermoplastic polymer with a high degree of crystallinity and can be processed using various methods, such as extrusion, injection, and blow moulding. Rapid cooling is needed during processing to prevent excessive growth of spherulites and crystal lamellae, resulting in increased transparency. The reason for its transparency upon rapid cooling is that the crystals do not have enough time to fully develop and their size does not interfere with the wavelength of visible light, according to quantum theory

General properties of PET are:

- Use temperature -100～120℃, bending strength 148-310MPa.
- Water absorption: 0. 06%-0.129%
- Impact strength: 64.1-128J/m
- Rockwell hardness: M 90-95
- Elongation: 1.8%-2.7%

PET is a strong, hard synthetic material that belongs to a family of thermoplastics, which means it can be heated, melted and cooled into many shapes and sizes. It is made from a mixture of oils and petrochemicals and is popular in manufacturing, where it is used to produce bottles and jars. In fact, almost every plastic bottle is made from PET. It is suitable for a range of beverages, including carbonated, non-carbonated and dilutable beverages, fruit juices and bottled water (Britannica, 2023).

The most important advantages of PET are:

- Good mechanical properties, impact strength is 3~5 times of other films, good folding resistance.
- Resistant to oil, fat, dilute acid and alkali, and most solvents.
- It can be used for a long time in the temperature range of 55-60℃, and can withstand high temperature of 65℃ and low temperature of -70℃ for short term use, and its mechanical properties are little affected in high and low temperature.
- Low gas and water vapor permeability, both excellent resistance to gas, water, oil and odour performance.
- High transparency, can block ultraviolet rays, good glossiness.
- Non-toxic, tasteless, good health and safety, can be directly used for food packaging.

Some of the benefits of PET plastics for the environment, economy and industry are:

- Environmental Benefits: are a sustainable packaging option and can be recycled. They can be made from recycled materials, reducing the reliance on virgin materials. Their durability and high strength-to-weight ratio means that they can be used for a longer period of time, reducing waste.
- Economic Benefits: are cost-effective to produce and transport. They are the primary type of plastic used for beverage bottles, which has helped create a large and profitable recycling industry PET recycling can create jobs and contribute to the economy.
- Industrial Benefits: have excellent chemical resistance to organic materials and water, making them suitable for a wide range of industries. Their transparency and high shine make them ideal for packaging, as the product inside is clearly visible. They are lightweight and easy to transport, which can reduce transportation costs and emissions.

PET is a milky white or light yellow highly crystalline polymer with a smooth and glossy surface. It has good creep resistance, fatigue resistance, abrasion resistance and dimensional stability, low abrasion and high hardness, and has the greatest toughness of any thermoplastic: good electrical insulation properties, little affected by temperature, but poor corona resistance. Non-toxic, weather resistant, good stability against chemicals, low water absorption, resistant to weak acids and organic solvents, but not resistant to heat and water immersion, not resistant to alkali (HangZhou, 2017).

PET is used in clothing fibres, liquid and food containers. It has a high glass transition temperature, slow crystallization rate, long moulding cycle, significant moulding shrinkage, and poor dimensional stability. Despite these drawbacks, PET exhibits excellent resistance to moisture, chemicals, and mechanical stress. To enhance the properties of PET resin,

nucleating agents, crystallization agents, and fiberglass reinforcement agents can be used (Material-Properties, 2023).

One of the key properties of PET resin is its high heat deflection temperature and long-term usage temperature, which sets it apart from other thermoplastic engineering plastics. This means that PET resin can withstand high temperatures without deformation or degradation, making it suitable for different applications.

PET (reinforced PET) is mainly processed by injection moulding method, other methods include extrusion, blow moulding, coating and welding, sealing, machining, vacuum coating and other secondary processing methods. It must be fully dried before moulding.

Polyethylene terephthalate is produced by exchanging dimethyl terephthalate with ethylene glycol or by esterifying terephthalic acid with ethylene glycol to synthesize bis(hydroxyethyl) terephthalate, followed by polycondensation reaction. It is a crystalline saturated polyester, with an average molecular weight of (2-3) ×104 and a ratio of heavy average to numerical average molecular weight of 1.5-1.8. The glass transition temperature is 80°C, Martin's heat resistance is 80°C, heat deflection temperature is 98°C (1.82MPa), and decomposition temperature is 353°C. It has excellent mechanical properties and high rigidity. Has excellent mechanical properties, high rigidity, hardness, very small water absorption, good dimensional stability. Good toughness, impact resistance, friction resistance, creep resistance. Good chemical resistance, soluble in cresol, concentrated sulfuric acid, nitrobenzene, trichloroacetic acid, chlorophenol, insoluble in methanol, ethanol, acetone, alkane (Connor, 2021).

The life cycle and importance of PET recycling

The life cycle of PET products can be long, and if consumers dispose of it properly, very little plastic waste is generated. The material is easy to recycle, and recycled PET is a valuable commodity with closed-loop potential. Most PET bottles are clearly marked with the #1 resin code, indicating to consumers that it is a fully recyclable PET plastic. For example, some plastic containers are multi-layered and some people find it time consuming to sort them correctly (Wärenhed, 2023).

In general, the life cycle of PET packaging begins with its production and packaging, followed by its distribution and use by consumers. Once the products packaged in PET are consumed, the containers can be collected in recycling programs and processed for reuse in the production of new PET products. This can include the breakdown of PET into lower-quality materials and the subsequent reuse of those materials in lower-value products, or the direct reuse of recycled PET in the production of new PET packaging. Eventually, PET containers may end up as waste in landfills or through incineration, which can have a negative environmental impact. PET recycling can contribute to reducing environmental impact and become an important factor in the circular economy.

Image 12. Petcycle recyclable material cycle for PET bottles

Source: (PETCYCLE, 2020)

The growing demand for sustainable and eco-friendly packaging options provides an opportunity for PET products to be well-positioned in the market. Furthermore, the development of lightweight and biodegradable versions of PET may create new opportunities for PET products in various industries. However, PET production and disposal still have negative impacts on the environment, and growing concerns about plastic waste and pollution may threaten the market position of PET products. Strict regulations, taxes, or bans on single-use plastics can pose a threat to the use and popularity of PET products (Stadler, 2020).

- **High-density polyethylene (HDPE) and Low-density polyethylene (LDPE).**

HDPE and LDPE are polyethylene thermoplastics derived from petroleum through a polymerization process. As we all know, polyethylene is one of the most widely used and versatile plastic materials in the world. It has a simple molecular structure and can be found in everything from children's toys to shopping bags and water bottles.

This plastics have become the most valuable and reliable products to date, taking centre stage in their entry into the packaging and manufacturing industry. The main plastic bottles are manufactured in:

- Low-density polyethylene (LDPE):

  A clear or translucent plastic with chemical resistance, easy handling, and water drainage. The most common applications used in the manufacture of many products are flexible packaging, food bags, plastic bags and films, and molded pharmaceutical products.

- High-density polyethylene (HDPE):

A popular plastic material for high performance and durability. There are many different types available in the market, such as transparent and opaque, and they have excellent chemical resistance like LDPE. Popular HDPE applications include automotive parts, toys, kitchen appliances, pipes, outdoor furniture, and structures.

Although LDPE and HDPE are thermoplastic ethylene polymers, they show some differences in their properties, structures, and uses. The difference between them is that there are more branches in the structure of LDPE than the whole branch when compared with HDPE. Branching occurs during polymerization, where a polymer chain attaches itself to a second polymer chain by replacing an atom in the main chain with a monomeric group (Jindal, 2023).

- **Polypropylene (PP)**

Food-grade PP has very good heat resistance, so you can microwave heating. The lunch boxes with PP are also used in milk, tea, and coffee cup lids.

Regarding food-grade PP, it is a type of polypropylene plastic that is safe for contact with food and meets the regulatory requirements of the Food and Drug Administration (FDA). It is often used in the manufacturing of food containers, lunch boxes, and beverage cups due to its heat resistance, durability, and affordability. This plastic can withstand high temperatures and is microwave-safe, which makes it a popular choice for people looking for a convenient way to heat their food. It is important to note that while food-grade PP is considered safe and non-toxic for direct contact with food, it should not be reused extensively, as the plastic can break down and leach harmful chemicals into food over time (Gregersen, 2023).

- **Polyvinyl Chloride, (PCV)**

PVC (polyvinyl chloride) is a polymer material made by the polymerization of vinyl chloride monomers. The most common PVC products in daily life are plastic pipes. PVC is characterized by its versatility and durability, making it a popular material for a wide range of applications in construction and the medical industry. It is also known for its resistance to fire and chemicals. However, the manufacturing, use, and recycling of PVC can have negative impacts on the environment and human health. Regarding polystyrene, this material is known for its lightness and low cost, making it useful for the production of disposable products like cups, plates, and food containers. However, excessive use of these products can have a negative impact on the environment and human health.

On the other hand, polyvinyl is distinguished by its impact resistance and high optical transparency, making it ideal for products like security windows and lenses. However, polycarbonate may have some health risks, and caution should be taken in its use. In conclusion, it is important to consider both the benefits and risks of polymeric materials and their impact on health and the environment. By selecting appropriate materials, maximum safety and durability of products can be ensured while minimizing environmental impact.

4.5 New alternatives for plastic water bottles

With the improvement of people's living standards, technology is also progressing, the market of drinking water is also gradually stabilized, this plastic product, although to a certain extent to improve the quality of life, so that people's lives have been convenient at the same time, people's concern for the impact of this plastic products is also increasing between, especially for this plastic product used in drinking water, people's concern is particularly high (Enfoque, 2018)

Because water is closely related to human life activities, not only to ensure their own health, but also to minimize the impact of plastic on people's living environment, so in addition to the above-mentioned materials in widespread use, people are also developing or looking for some new materials to replace some existing plastic materials. Among them, biodegradable materials are gradually coming into people's view (UPB sustainable, 2020).

At present, environmental care has become a constant concern for many people, especially in the context of drinking water consumption. Although plastic products have made people's daily lives easier, their impact on the environment and health has become a growing concern. In order to minimize these impacts, more eco-friendly alternatives are being sought, such as biodegradable materials, which could play an important role in replacing current plastic materials. Additionally, technology is also focusing on new treatment and water purification systems, as well as the use of reusable or biodegradable packaging as an alternative to single-use plastic containers. All of this is aimed at providing a healthier and more sustainable life for both people and the planet (United Nations, 2019).

4.5.1 Biodegradable materials

Biodegradable materials are those that can be decomposed by biological agents such as bacteria, fungi, and other microorganisms into simpler elements that can be assimilated by nature. Biodegradable materials include bioplastics such as polylactic acid, thermoplastic starch, and polyglycolic acid polymer, as well as some natural materials such as wood, paper, and other materials derived from plants and animals. The biodegradation capacity depends on the material and the environmental conditions in which it is found. Biodegradable materials provide a less harmful alternative to the environment than non-biodegradable materials as they decompose over time and do not contaminate the environment with toxic and persistent waste (Etecé, 2022)

The process of degradation of biodegradable plastics is carried out by naturally occurring microorganisms in specific conditions such as anaerobic digestion or aqueous cultures in natural conditions such as soil or sand. The plastics break down into carbon dioxide (CO_2) and/or methane (CH_4), water (H_2O) and mineralized inorganic salts of the elements they contain, as well as new biomass. This process is different from traditional plastics, which can

take hundreds of years to degrade and can harm ecosystems. Biodegradable plastics represent a more sustainable and less harmful alternative to the environment (Mary Davis, 2019)

The characteristics of an ideal biodegradable plastic include excellent performance as a polymer material, the ability to be completely decomposed by environmental microorganisms after disposal and eventually become inorganic and a part of the carbon cycle in nature. In addition, an ideal biodegradable plastic is eco-friendly and sustainable, and has properties similar to those of paper and synthetic plastic (Mary Davis, 2019).

The two categories of biodegradable plastics are biology-based biodegradable plastics and petrochemical-based biodegradable plastics. Biology-based biodegradable plastics are derived from natural sources, such as plants and microorganisms, and decompose through biological processes in nature. Petrochemical-based biodegradable plastics are produced from materials derived from petroleum and decompose through chemical processes. In general, biology-based biodegradable plastics are considered more environmentally friendly and sustainable than petrochemical-based biodegradable plastics (Gibbens, S. 2018).

Bio-based biodegradable plastics can be divided into four main categories:

- Plastics obtained by direct processing of natural materials.
- Polymers obtained by the joint participation of microbial fermentation and chemical synthesis.
- Polymers directly synthesized by microorganisms.
- Biodegradable plastics obtained by co-blending these materials or co-blending these materials with other chemically synthesized biodegradable plastics.

Petrochemical-based biodegradable plastics are those obtained by polymerization of petrochemical monomers by chemical synthesis, such as PBAT, polybutylene succinate (PBS), carbon dioxide copolymer (PPC), etc…According to the classification of biodegradation process, biodegradable plastics can be divided into two types: completely biodegradable plastics and destructive biodegradable plastics (Rosenboom & Langer, 2022).

Destructive biodegradable plastics currently mainly include starch-modified (or filled) polyethylene PE, polypropylene PP, polyvinyl chloride PVC, polystyrene PS, etc.

Completely biodegradable plastics are mainly made from natural polymers (such as starch, cellulose, chitin) or agricultural by-products through microbial fermentation or synthesis of biodegradable polymers, such as thermoplastic starch plastics, aliphatic polyesters, starch/polyvinyl alcohol, etc. These plastics are all of this kind (Petrochemical-based biodegradable plastics are those obtained by polymerization of petrochemical monomers by chemical synthesis, such as PBAT, polybutylene succinate (PBS), carbon dioxide copolymer (PPC), etc…According to the classification of biodegradation process, biodegradable plastics

can be divided into two types: completely biodegradable plastics and destructive biodegradable plastics (Harvey Williams, 2018).

Biodegradable plastics based on natural substances such as starch include the following products:

- Polylactic acid (PLA)
- Polyhydroxyalkanoate (PHA)
- Polyvinyl alcohol (PVA)

- Polylactic acid (PLA)

Also known as poly-propylene glycol, is a polyester polymer obtained by polymerizing lactic acid as the main raw material, and PLA is a thermoplastic aliphatic polyester. The lactic acid or propylene glycol ester (Lactide) required for the production of PLA can be obtained by fermentation, dehydration and purification from renewable resources, and the resulting PLA generally has good mechanical and processing properties, while PLA products can be rapidly degraded by various means after disposal. The lactic acid used to produce PLA can be obtained by fermentation, dehydration, and purification from renewable resources, making it more environmentally friendly. Products made of PLA are biodegradable and can be quickly degraded by various means after disposal, making it ideal for use in single-use applications (Naser et al. 2021).

PLA is also widely used in the field of medicine, such as disposable infusion appliances, free surgical sutures, etc. Low-molecular PLA is used as a drug slow-release packaging agent, etc… PLA has similar basic properties to petrochemical synthetic plastics, which means that it can be used in a wide range of applications. PLA also has good gloss and transparency, comparable to films made from polystyrene, which are not available in other biodegradable products.

PLA is a new type of biodegradable material made from renewable raw materials such as corn starch. Glucose is obtained by saccharification of the starch, and then PLA with a certain molecular weight is synthesized by chemical methods. It is highly biodegradable and can be completely decomposed by natural microorganisms in the environment without contaminating it, making it an excellent option for protecting the environment. In addition, it does not produce greenhouse gases during disposal because it is buried instead of being incinerated like traditional plastics. These characteristics make PLA a globally recognized environmentally friendly material (Naser et al. 2021).

PLA has a good mechanical properties and physical properties. It is suitable for various processing methods such as blow moulding, thermoplastic, etc. It is easy to process and very widely used. It can be used to process various plastic products from industrial to civil, packaged food, fast food lunch box, non-woven fabric, industrial and civil cloth. In turn, it can

be processed into agricultural fabrics, health care fabrics, wipes, sanitary products, outdoor UV protection fabrics, tent fabrics, floor mats, etc. The market prospect is very promising (Serna, 2003). Its physical properties are:

- Density: 1.25-1.28g/cm3
- Melting point: 176 °C
- Characteristic viscosity IV: 0.2-8 dL/g
- Glass transition temperature: 60-65 °C.
- Heat transfer coefficient: 0.025 λ(w/m-k)

Mechanical properties:

- Tensile strength: 40-60 MPa
- Elongation at break: 4%-10%
- Modulus of elasticity: 3000-4000 MPa
- Bending modulus: 100-150 MPa
- Izod impact strength (without notch): 150-300 J/m
- Izod impact strength (with notch): 20-60 J/m
- Rockwell hardness: 88

PLA has good thermal stability, processing temperature 170-230℃, good solvent resistance, and can be processed in various ways, such as extrusion, spinning, biaxial stretching, and injection blow moulding. In addition to being biodegradable, products made from PLA have good biocompatibility, gloss, transparency, hand feel and heat resistance.

In addition to the basic characteristics of biodegradable plastics, PLA also has its own unique characteristics. The strength, transparency and resistance to climate change of traditional biodegradable plastics are not as good as those of ordinary plastics.

- Industry applications of PLA

The absolute harmlessness of PLA makes it unique in the field of disposable tableware, food packaging materials and other disposable products. Its ability to be completely biodegradable is also in line with the high environmental requirements of countries around the world, especially the European Union, the United States and Japan. However, the disposable tableware processed with PLA raw materials has defects such as non-temperature and oil resistance. This causes its functional role to be greatly reduced, as well as in transit tableware deformation, material brittle, resulting in a large number of inferior products. However, after technological development, the market has been modified by PLA material, can effectively

overcome the shortcomings of the original grain, and some even heat-resistant temperatures up to 120 ℃ or more, can be used as microwave oven utensils materials (Mexpolimeros, 2023).

Compared to other water bottles or packaging, PLA has certain advantages and disadvantages. Some advantages of PLA are that it is biodegradable and non-toxic, making it safe for consumers and reducing environmental impact. Additionally, it can be produced from renewable sources such as corn and sugarcane. To use PLA in the bottled water industry properly, it's important to consider the material's limitations. Although PLA is biodegradable, it's important to ensure that each country's environmental and recycling requirements are met. Additionally, it's important to use modified PLA to overcome the original material's deficiencies, such as lack of temperature and oil resistance (Mexpolimeros, 2023).

In the bottled water industry, bottles made of modified PLA that can withstand heat-resistant temperatures of up to 120℃ or more can be used. Additionally, PLA labels can be used instead of plastic labels to reduce environmental impact. Other disposable packaging and utensils made with PLA can also be used instead of non-biodegradable plastics. It's important to note that PLA is a more expensive material than conventional plastic. However, the environmental benefits it offers can outweigh the additional cost. It's also important to encourage recycling of PLA packaging to reduce the environmental impact of bottled water packaging (Mexpolimeros, 2023).

Image 13. PLA bottle made of bioplastic.

Source: (Naku, 2023)

- **ErcrosBio®:**

This thermoplastic material is also derived from polylactic acid (PLA) sourced from renewable natural materials, with its content of biological material exceeding 95%. Similar to the previously mentioned material, it meets the standard for producing food packaging (Prospector, 2021).

This thermoplastic material is made from polylactic acid (PLA), which is obtained from renewable natural sources, with a material content of biological origin exceeding 99%. It meets the criteria of Regulation (EU) No. 10/2011 for producing food packaging, and is compostable according to the EN 13432 1 standard. (Prospector 2021).

This material is specifically formulated for manufacturing sheets through extrusion-casting, injection, and injection-blowing processes. While it can be applied in various processes, it is particularly suitable for manufacturing thick-walled components via injection-blowing, thanks to its impressive impact properties. In fact, it is a highly recommended material for producing hollow objects through injection-blowing due to the same property. The material's crystallization speed is higher at temperatures ranging from 90°C to 110°C.

Properties of ErcrosBio® LL 650 Bioplastic:

Table 1. Properties of ErcrosBio LL 650 Bioplastic

Properties	Value	Units	Method
Flow index	17	g/10 min	ISO 1133-2 (195°C y 2,16kg)
Density	1,25	g/cm^3	UNE EN ISO 1183-1
Melting temperature	178	°C	ISO 11357
Glass transition temperature	61	°C	ISO 11357
Young's modulus	3,0	GPa	EN ISO 527
Elongation at break	3.7	%	EN ISO 527
Maximum effort in traction	65	N/mm^2	EN ISO 527

Source: Own elaboration, 2023

ErcrosBio LM 63101 bioplastic material, like the bottle body material, the recycling code for this material is 7, which corresponds to "Other" according to the SPI. The current market price of ErcrosBio LM 63101 Bioplastic is 6,5 €/kg.

Table 2. Properties of ErcrosBio LM 63101 Bioplastic.

Properties	Value	Units	Method
Flow index	4	g/10 min	ISO 1133-2 (195°C y 2,16kg)
Density	1,29	g/cm^3	UNE EN ISO 1183-1
Melting temperature	174	°C	ISO 11357
Glass transition temperature	60	°C	ISO 11357
Young's modulus	3,6	GPa	EN ISO 527
Elongation at break	4,2	%	EN ISO 527
Maximum effort in traction	60	N/mm^2	EN ISO 527

Source: Own elaboration, 2023

- **Polyhydroxyalkanoates, (PHA).**

PHA, which has been rapidly developed in the past 20 years, is an intracellular polyester synthesized by many microorganisms and is a natural polymeric biomaterial. PHA has good biocompatibility, biodegradability and plastic thermal processing properties, so it can be used as both biomedical materials and biodegradable packaging materials, so it has become the most active research hotspot in the field of biomaterials in recent years. PHA also has nonlinear optical properties, piezoelectricity, gas phase barrier many high value-added properties (Li & Yang, 2016).

Polyhydroxy fatty acid esters are intracellular polyesters synthesized by many bacteria and exist in living organisms mainly as a carbon source and energy reservoir. They have physical and chemical properties similar to synthetic plastics and many excellent properties such as biodegradability, biocompatibility, optical activity, piezoelectricity, and gas phase separation that synthetic plastics do not possess.

Polyhydroxy fatty acid esters have promising applications in biodegradable packaging materials, tissue engineering materials, slow-release materials, electrical materials, and medical materials, but large-scale applications are possible only when the production cost of PHAs is reduced (Li & Yang, 2016).

PHAs, have good gas barrier properties, making it possible to use them in fresh food preservation packaging for longer periods of time. Because water vapor permeability is an important indicator in fresh packaging, PHA's performance in this regard is fully comparable to PET, PP and other products, etc. On the other hand - PHA also has good hydrolytic stability, will be made of PHA cup with 75 ℃ automatic dishwasher total wash 20 cycles, its shape and molecular weight are not changed, indicating that PHA can be well used in the production of appliances (Li & Yang, 2016).

In addition, with other polyolefin and polyaromatic polymers than, PHA also has good UV stability. PHA can also be used as a source of biodegradable and environmentally friendly solvents, such as ethyl hydroxy-acid EHB (ethyl3-hydroxy-butyrate) which is water soluble It has low volatility and can be used as a solvent for cleaners, adhesives, dyes, and inks. Because PHA brings together these excellent properties, it can be used in packaging materials, adhesive materials, spraying materials and clothing, appliance materials, electronic products, consumer durables, agricultural products, automation products, chemical media and solvents.

Until 1998, more than 125 PHAs have been discovered. It can be expected that more PHA building blocks will be synthesized and discovered by using different strains, different fermentation substrates and metabolic modulation (Li and Loh, 2015).

Another feasible route for PHA production is to use transgenic plants for this purpose. the synthesis of PHA in plants can be a sustainable and renewable way of material production by using light energy to consume CO2. The synthesis of different PHAs, including PHB, PHBV

and medium and long chain PHAs, has been achieved in tobacco, potato, cotton, rape, maize and alfalfa plants (Poirier, 2001)

The price of PHA is still difficult to compete with petrochemical plastics, while the price of polypropylene is less than 1 USD/kg, and some of the cheapest biodegradable plastics are priced at 3-6 USD/Kg, while the production cost of today's ideal PHB is 4 USD/kg, which will be further reduced with the scale up, but it is difficult to reach 2-3 USD/kg. It is difficult to reach 2-3 USD/kg, which is mainly determined by the cost of bacterial fermentation substrate. However, PHA synthesis by transgenic plants is expected to reduce the cost of PHA significantly, because the cost of plants using CO2 and solar energy to produce vegetable oil and starch is 0.5-1 USD/kg and 0.25 USD/kg, respectively, and also the extraction process of PHA in plants has been better studied, and the extraction cost is not higher than that of PHA in bacteria. the production of PHA in plants will. The success of this project could lead to a fivefold increase in the use of renewable resources in the production of basic chemical raw materials and materials from plants by 2020 (Li & Yang, 2016).

Image 14. PHA water bottle

Source: (Bioplastics magazine, 2019)

PHA is a linear degradable polyester composed of optically active (R) 23HA monomers, and its physical properties are mainly determined by its monomer composition. The homopolymer P(3HB), composed of 3 (HB), has poor mechanical and processing properties, while the insertion of other monomers significantly improves the performance of PHA and brings some new properties, so the search for non-3 (HB) monomers has attracted the attention of science and industry. Its crystallinity is 55 to 80%. However, the polymer in bacteria is an amorphous form of water-insoluble inclusion bodies (Vibhuti Sharma, 2021)

PHA polymers are thermoplastic, can be processed on conventional processing equipment and are more or less elastic depending on their composition: ductile and more or less elastic. Their properties depend on their chemical composition (homopolyester or copolyester, etc.)

PHAs are soluble in halogenated solvents such as chloroform or methylene chloride. They are stable to UV radiation compared to other bioplastics made of other polymers such as PLA. They exhibit low water permeability (Zulfiqar Ali Raza, 2018).

PHA materials have good physical and chemical properties, thermal processing properties, optical isomorphism, piezoelectricity, gas barrier, biodegradability and biocompatibility are common excellent properties.

- Complete biodegradability: general biodegradable materials need to be composted to degrade, but PHA has spontaneous biodegradability and can be degraded in a natural environment without composting, and the degradation time can be controlled.
- Excellent biocompatibility: The degradation products of PHA in living organisms are mainly small-molecule oligomers or monomeric components, which are non-toxic and harmless to the human body and will not cause strong rejection reactions.

- Advantages

In relation to their monomeric structure, PHAs can be classified into several types based on the length of the hydroxyalkanoic acid chains they are composed of. Thus, short-chain PHAs (PHA-scl) are defined as polymers composed of monomeric units of 3 to 5 carbon atoms, while medium-chain PHAs (PHA-mcl) are made up of monomers of 6 to 14 carbon atoms. However, mixed PHAs also exist, meaning that they are composed of both short and medium-chain monomers. The type of PHA synthesized depends on the microorganism in question, with most only producing short or medium-chain PHAs, and only a small fraction capable of producing mixed PHAs. Additionally, PHAs can exist as homopolymers or copolymers, depending on the type of microorganism involved and the carbon sources used (Anderson and Dawes, 1990).

PHA production has gone through three generations, with PHB (polyhydroxybutyrate) being the first, followed by hydroxybutyrate copolyester (PHBV) and hydroxybutyrate-acid copolyester (PHBHHx), the latter of which was achieved by Tsinghua University and its cooperative enterprises. The fourth-generation product, P34HB (poly-3-hydroxybutyrate/4-hydroxybutyrate copolymer), is exclusively produced in China. The production of PHA is characterized by low energy consumption and CO2 emissions, making it an environmentally favorable choice. PHA is an eco-friendly bioplastic with excellent and adjustable properties, and its cost reduction and development of high value-added applications will make it a profitable biomaterial for multiple applications in the market. Compared to PLA, PHA has a shorter history of development, but it has great potential for development and a wider range of applications (Go PHA, 2022)

The improper and excessive use of plastic has caused serious environmental problems, such as air, land, and especially water pollution. In this context, the development of biodegradable materials has been promoted, which are capable of disintegrating and

decomposing naturally, without generating polluting waste. Biodegradable materials made of PHA, for example, can be applied in various fields, such as packaging, agriculture, medicine, industry, and others, to replace non-degradable plastic products. Here are some several applications of PHA that have managed to respect the environment and achieve sustainable management thanks to their properties of biodegradability, biocompatibility, and in some cases, non-toxicity:

- Environmental protection packaging materials: biodegradable plastic, biodegradable garbage bags, shopping bags, disposable lunch boxes, etc., using its good biodegradability, decomposition products can all be bioavailable.
- Agriculture: slow-release carrier for agricultural drugs, chemical fertilizers, herbicides, pesticides, etc.; utilizing the hydrolysis property of PHA; biodegradability.
- Medicine: sutures, repair devices, repair patches, bandages, cardiovascular patches, orthopedic needles, anti-adhesive films, scaffolds, guided tissue repair/regeneration devices, articular cartilage repair scaffolds, nerve conduits, tendon repair devices, spinal cord scaffolds, artificial esophagus and wound dressings; utilized for their biocompatibility; biodegradability; non-rejection, non-toxic.
- Industry: razors, utensils, diapers, feminine hygiene products, cosmetic containers, cups, medical device surgical gowns, home decoration materials, carpets, packaging bags, compost bags, etc.; utilizing their biodegradability; biocompatibility.
- Others: chemicals, industrial enzyme preparations, food, pharmaceuticals, energy, environmental management.

Image 15. Compostable paper bottle

Source: (Natural Vegan, 2019)

- **Polyvinyl alcohol (PVA)**

PVA is a colorless, generally non-toxic thermoplastic adhesive that is prepared by polymerizing vinyl acetate. PVA was discovered in 1912 by Dr. Fritz Klatte in Germany. It is one of the most widely used water dispersed adhesives. PVA is made up of a water-based emulsion of a widely used type of glue variously referred to as wood glue, white glue, carpenter's glue, school glue, or PVA glue. This is mainly used in glass fiber reinforced plastics to improve anti-stress and anti-drip properties. It is also used in car headlights to promote shine. The setting and curing of PVA is accomplished by the removal of water due to evaporation or absorption into a substrate. PVA adhesives produce tough, clear films that have good weatherability and resist water, grease, oil, and petroleum fuels. Additional properties are high initial tack, good resistance to biodegradation. PVA adhesives and copolymers are also used as hot melt adhesives, sealants, in fabric finishing, plastic wood, and inks (Mexpolimeros, 2023).

5. Running sporting events

5. Running sporting events

Organizing running sporting events is a popular pastime and an excellent way to promote health and fitness. This involves organizing races, marathons, and other running events that bring people together to achieve a common goal. These events take place all over the world, in cities and towns of various sizes, and can be organized by running enthusiasts, charitable organizations, businesses, and other groups. Running sporting events are competitions or exhibitions in the realm of athletics or track and field, which entail running as the primary physical activity. These events can include various types of distances, such as sprints, middle-distance runs, long-distance runs, and marathons. Competitors in running events typically try to achieve the fastest time over a given distance, or compete against others in head-to-head races. Running sporting events can take place in various formats, including track and field competitions, road races, cross-country events, or trail runs. Participation in these events can offer benefits, such as physical fitness, mental well-being, and the potential to compete at elite levels (Runners, 2023).

Running sporting events can bring many benefits to the communities where they take place, such as promoting physical activity and health, attracting tourism and visitors, increasing community visibility and reputation, and encouraging participation in social and recreational activities. In addition, these events can have a positive economic impact by generating income for local businesses, restaurants, shops, and hotels. In summary, running sporting events can have a significant and positive impact on the communities where they are held (United Nations, 2016).

5.1 Definition

The essence of sporting events is a competitive activity with human movement (using the competition to determine the winner), which is different from other activities (such as work, study and leisure). The components of the event include the event, the competitors, the referee, the organizer (or host), the spectators, the field, the mechanics and tactics, the capital, the time and the place; the purpose of this event is to show the magnitude of the competitive activity of human movement and to make it publicly known.

Sports events are organized activities within the sports industry that include public competitions or exhibitions in which the skill, ability or strength of the participants is tested in order to proclaim a winner or simply for fun and entertainment. These events can be of different types, such as football games, athletics competitions, car races, tennis matches, wrestling events, and many others. Sports events can take place at the local, regional, national or international level, and may involve the participation of amateurs, professional players and/or

sponsored teams. Sports events are very popular worldwide and can be an important source of entertainment and brand promotion (Polo, 2023).

5.2 Typology

Sports events can be classified in various ways. Here are some of the most common classifications.

- Based on organizational capacity: large, medium or small events.
- Based on the targeted audience: Sports, recreational, for profit, etc.
- Based on the type of sport or activity: Running, games, competitions, exhibitions, etc.
- Based on the sports discipline: Football, basketball, athletics, swimming, etc.
- Based on the geographic location: Local, regional, national, or international events.
- Based on the objective or purpose: Promotional, entertainment, competition, etc.

These are just some of the classifications that can be applied to sports events, and depending on the context, additional classifications can also be utilized.

The classification of sports events is important for both theoretical and practical studies related to its concept. Classification is usually subjective and utilitarian (based on the needs of the researcher), and the classification of sporting events is mainly based on the more authoritative and common international classifications that classify sporting events into the following categories (Parra, 2017).

5.2.1 Traditional events

Traditional events have two basic characteristics, first of all there is a competent body (organization, association or federation, etc.) that is responsible for developing and implementing a set of rules or by-laws on the basis of which the event organizers are approved and supervised in the operation of the event. The governing body of the modern Olympic Games is the International Olympic Committee (IOC) and the relevant statute, the Olympic Charter.
Other single sporting events such as the World Cup Soccer Tournament and intercontinental games such as the Asian Games are all part of this category (Martinez, 2012).

Secondly, as the name suggests, these events are required to be held on a regular basis, either at a fixed location or on a tour of different locations, but the content and protocols of the games usually require relatively strict standardization. It is important to note that traditional events often require adaptation and transformation due to factors such as the local culture,

new technologies and the characteristics of the participating population, but such changes cannot create a completely new event (Martinez, 2012).

Image 16. The Osaka Marathon is a growing annual running event

Source: (Nizar Grira, 2017)

In terms of how they are created, niche events can be formed by reforming or innovating from a traditional event, or by localizing a traditional event. The latter refers to the tournaments that are held in different places and are carefully crafted by the local government and the organizing organization, taking into account the local culture. This is the case of the 2008 Beijing Olympics, for example. The true sense of niche events refers to newly created events, which have three characteristics: firstly, they are highly targeted, usually facing special sports, leisure or tourism markets; secondly, they may present the content or characteristics of traditional events, but they can also be unconventional in form; thirdly, they are one-off events (Olimpics 2023).

Conceptually, any traditional tournament evolves from a niche tournament. A sports event can be produced as both traditional and niche, such as the Beijing Olympics, the Guangzhou Asian Games, and the Shenzhen World University Games, etc., which are traditional in terms of the event itself, but clearly niche in terms of the location where they are held. ", but is clearly niche in relation to the place where it is held.

5.1.2 Spectator-oriented and sports participation events

According to the purpose of holding and the main participants, sports events can be divided into two types: spectator-oriented and sports participation. Spectator-oriented events such as the World Cup, Olympic Games (summer and winter), Australian Masters Tennis Tournament, F1 Grand Prix, etc. These events are usually of a higher level, with more popular sports, high

spectatorship and a longer history. Therefore, these events can attract both local people and foreign tourists to watch the games.

Sports participation events such as international marathons are usually less popular and have fewer spectators. The purpose of holding these events is to encourage the public to participate in sports and enhance their physical fitness, which is obviously "public" or "public welfare" in nature (Alejandro, 2023).

Image 17. Mass participation sporting event, Australia

Source: (Corporate Sports Australia, 2023)

5.2 Major sporting events

It is that sporting activity that has a great impact at a social level that translates into a strong presence in the media and that generates great economic income. Not all competitive sporting events can be considered as major events, since in order to be considered as such, a series of conditions must be met that are mainly related to socio-economic factors. The first refers to the impact that the event has on public opinion and the second, to the capacity for economic generation and attraction of investment funds that the sporting event itself has.

5.2.1 Characteristics of a major sporting event

An important part of the characteristics of a great sporting event are the conditions that must be met. From a theoretical point of view, they can be classified into two large groups if we look at the degree of regularity they have within the sports calendar:

- **One-off events:** these are all those events that are organized sporadically once a year, such as marathons, cycling awards or athletics events.
- **Sports groups:** are all those events organized permanently or occasionally by sports associations. An example of this is the major football, basketball or handball leagues.

The conditions that a sporting event must meet to be considered a major event, according to sports management specialists, are closely related to each other and some are a consequence of the others, (Unisport, 2018).

:

- **Social impact:** major sporting events must have a great social impact, which translates into public opinion. Only in this way can an event be considered to be of sufficient magnitude to be classified in this way.
- **Level of public attendance:** this is a direct consequence of the previous condition, since thanks to the social repercussion and public attendance, the event will generate income on its own. In addition, it will be necessary for its realization to have adequate infrastructures, whose investment is expensive.
- **Presence of the media:** media attention contributes to generating public opinion, social impact and, above all, international attention. Thanks to the presence of the media, sponsorships can be more important, income from television rights improves, and the number of fans of a certain sport grows.
- **Sport typology:** the type of sport on which a sporting event focuses will also be closely related to its definition.
- **Difficulty of practicing sports:** the type of sport and its media coverage is important, but so is the difficulty of carrying it out to create fans.

5.3 Sports competitions for runners

Around the world there are many competitions for those who are passionate about running, one of the casual sports that has gained the most strength in recent years, thanks to its benefits and recognition in the sports field. Running is a sport that can be practiced by people of all ages, however, currently there are certain protocols for the professional practice of sport, such as body position, running style, and movements of the arms, legs, and legs. trunk. All this depends on the type of running that is practiced (Ospina, 2022).
Some of the benefits of practicing this sport are (Frey, 2021):

- **Stress reduction:** by practicing it, it improves mood and productivity during the day. It can be of great help for people suffering from depression and anxiety.
- **Improves physical condition:** allows you to work on resistance, do cardio and strengthen the different muscles of the body.

- **Release endorphins:** these substances, when secreted in the brain, generate a feeling of pleasure and well-being.
- **Easy and economical:** It is one of the sports in which you only need good tennis shoes and a lot of attitude. In addition, it is the complement for almost all sports, due to the resistance and physical conditioning that it allows.

The running disciplines that can be observed and practiced the most by all athletes are (Canata, 2022):

1. **Route:** it is the best known of running, it includes urban miles, 10 km, half marathons, marathons, 100 kilometres and 24 hours. The most popular is the half marathon, a demanding test but it does not reach the level of the marathon. The 100 kilometres or 24 hours are tests for people who have already mastered marathons and want a bigger challenge.
2. **Trail running:** it is a relatively new practice and one that continues to develop. This activity involves running in the mountains or trails with a variety of terrains, unevenness and distances that make it very attractive. This type of race obviously requires physical preparation that is very different from the rest of the running aspects, such as having a good physical condition, as well as mastering techniques to go up, down and know the terrain. In this type of running there is no defined distance limit so the runner can cover longer distances.
3. **Triathlon:** three tests are carried out, swimming, cycling and running; and in the duathlon, running, cycling and running are practiced. There are also other variants such as the aquathlon that consists of running, swimming, running and cross-country with a mountain bike.
4. **Barefoot running:** it consists of going for a run barefoot, its purpose is for the joints and feet to carry out their natural movement. It is called natural running and is practiced in parts of Africa and Latin America and is growing in popularity in others. For some specialists it is a risky practice, since they have not yet finished determining the injuries that running barefoot could have in the future. Although for many athletes, poor footwear is what causes the most injuries in their careers, since they ensure that running barefoot reduces the risk of suffering chronic injuries caused by hitting the heel with padded shoes.
5. **Running pool or aquarunning:** this type of training consists of running in the water to strengthen muscles and improve physical condition. This sport activates blood circulation, improves cardio-respiratory capacity, rehabilitates the back and develops muscle strength. It can be carried out in two different ways, with the feet in contact with the pool or without touching the ground. If the water reaches the waist, you work at a

higher speed, the resistance of the water reduces the impact on the joints. If the depth is greater, strength and power are developed but it is still a low-impact exercise on the joints.

6. **Chi running:** combines the strength and energy that characterize running with internal concentration and the movements of Tai Chi. Its objective is to promote a conscious technique and a more efficient running, taking advantage of the best of both types of activities. Chi running runners become aware of their body and all their movements to better channel energy avoiding injuries. One of the main factors in Chi running is the runner's body posture during training and the race. The technique seeks for the athlete to run with the body slightly leaning forward, reducing the impact on the joints.
7. **Cross running:** it is about running cross-country, covering distances in natural circuits such as mountains, hills with variety and difficulty of terrain. Cross running includes the crosstraining modality that encompasses disciplines such as swimming, cycling or running in water. These races take place in wooded areas with natural obstacles that present an interesting trajectory in a relatively short circuit. With cross running, the power of the muscle groups is improved and the risk of muscle injuries is reduced (Runners Chile, 2019).

Imagen 18: Runners cross the Verrazano-Narrows Bridge during the New York City Marathon

Source: (Craig Ruttle, 2017)

5.3.1 Marathon

It is a competition where the participants keep running constantly to complete the route of 42 kilometres and 195 meters, which is why this type of competition is called resistance, both physical and mental, and since it strengthens the spiritual power of each person.

It is a massive event, in which hundreds of people participate who are dedicated to doing a fairly long route (a little more than 42 kilometres), running at a constant pace, trying to be the first to cross the finish line in the shortest possible time. Marathons are internationally

recognized and there are more and more competitions at this level, they are even part of the disciplines that take place in the Olympic Games.

Marathons can be exclusive for men, exclusive for women, or mixed, for both men and women. An event of this nature is held in outdoor settings and the routes may vary according to the location in which it is held. The most popular marathons worldwide are:

- New York marathon.
- London marathon
- Zurich Barcelona marathon

- New York marathon

Second only to Boston in reputation, the New York City Marathon was founded in 1970 and is held every year in early November with a huge number of participants of up to 100,000. It is also one of the six largest marathons in the world. On November 5, 2017, the annual New York City Marathon took place under heavy police protection.

The 2017 New York Marathon was particularly notable due to some previous special events in New York. In June 2020, the New York Marathon organizers announced that the 2020 New York Marathon was cancelled due to health concerns caused by the spread of the New Coronavirus in the United States, (Chengcheng Wang, 2020)

- London marathon

The London Marathon was born in 1981, when it was inspired by the New York Marathon. The London Marathon is held every year in late April. The wide venue, scenic route, enthusiastic spectators, mountains of cheers, coupled with the effective management and almost perfect organization, all undoubtedly attract those veteran marathon runners, and it is definitely a festival belonging to every runner (World's Marathons, 2023).

The London Marathon is different from other races in that it is a charity marathon, with about two-thirds of the runners qualifying by way of charitable donations. The London Marathon used to be the city that produced the most men's and women's world best times in history, but that was in the early days. In the late 1980s, challenged by several high prize money American races, the London Marathon organizers had a stroke of genius and added a makeup team to the race to make it unique, and often had brides in wedding dresses and grooms in suits and ties running hand in hand over the 42km 195m distance (World's Marathons, 2023).

Imagen 19: The London Marathon

Source: (Isaac Williams, 2019)

The 2018 London Half Marathon UK is a race highlighting the environmental features of London's first commitment to be completely free of single-use plastic drinking bottles. To highlight the eco-friendly features of the competition, all participants will be prohibited from bringing their own bottles to drink from, but water and biodegradable cups will be provided to meet their needs in special circumstances (Phillips, 2017).

– Zurich Barcelona marathon

It is one of the most attractive races in Europe thanks to its flat and fast course, mild climate, beautiful location and all those enthusiastic spectators who take to the streets to support the runners. Your tour sees landmarks like Camp Nou, Sagrada Familia, and Casa Batlló from a whole new perspective. There are more than 50 animation points along the Zurich Marathon Barcelona route to encourage participants and spectators in the most difficult moments.

This annual marathon race is run over a classic distance of 42,195 km (26,219 m) usually held in March in Barcelona, Catalonia, Spain, and first held in 1978 in Palafrugell, Catalonia. The marathon is categorized as a Silver Label Road race by World Athletics (ShBarcelona, 2022).

5.4 Examples of similar products use and market analysis bottle drinking water for running sports

Whether they are professional athletes or running enthusiasts, in order to achieve good results during any type of competition, it is very important that the participants in this type of activity have the necessary sports equipment, from good shoes, socks, a visor, comfortable clothing, to a correct hydration before, during and after the race. This is quite important for the practice of this sport, since the body loses a lot of water during the exercise process, so it is necessary to maintain good hydration, not only to ensure that physical energy is abundant, but also to hydrate properly and avoid physical and health problems in runners.

For this reason, and regardless of the competition that takes place, the organization of the event must provide hydration points for these athletes who participate in competitions that

require such great physical effort. These hydration points are usually equipped with enough bottles of water. hydrating sports drinks and in some cases food.

Especially in major marathons and big running sport events, due to the long distance, many supply stations will be set up along the way at some distance, to provide athletes with drinking water to be put into disposable plastic water cups. , along with plastic water bottles. cups to provide athletes in need, and athletes can also put their own drinking water in plastic water bottles to protect their necessities. In addition, those attending the event, being an outdoor sporting activity, also bring their own bottles of water and soft drinks for their own hydration while watching the competition. Because of this, at the end of these massive competitions, it is common for too much plastic waste to remain on the streets, mainly single-use bottles and glasses.

Imagen 20: MWC and the Barcelona Marathon fill the city with plastic

Source: (Magnus Jern, 2022)

After a lively marathon and runner sports events, the garbage scattered along the course has become a difficult task for the event organizers. Especially in today's marathon fever, the issue of trash during the race has also sparked a lot of controversy. According to the BBC, nearly 920,000 plastic bottles were used in the 2018 London Marathon, and cleaning crews collected nearly 50,000 more that were left on the city's streets after the race (Nace, 2019).

Not only big sporting events, but all kinds of massive or multitudinous sales leave with them a large amount of solid waste and plastic packaging that is generally not managed correctly, that is, they are not recycled and end up in landfills causing serious damage to the environment. environment and natural resources. Due to this, the need arises to create new packaging from natural materials that can be compostable or biodegradable and do not have toxic components.

In this TFG, a selection of biodegradable bottles on the market with the potential to be used by runners during sporting events such as marathons is chosen. The main characteristic of the bottles presented below is their intention to reduce the impact on the environment, although they all have different characteristics, both in their composition and in their function,

the idea is to present the reader with some examples of biodegradable containers. existing ones or with an advanced process in its design and market launch to demonstrate the strengths, differences and opportunities that our particular product could have, since not all the bottles that will be presented below are for runners or to bottle water, it is intended Demonstrate the different materials and the importance of incorporating biodegradable materials in the different product consumption markets and the efforts that are made in different countries of the world, to achieve the implementation of non-polluting products in the economic markets.

The selection of bottle is:

- Maka™
- Biodegradable bottle of Bacardí™
- Choose™ bottle
- PLA???? bottles EU??'
- Ooho Water Sphere™

5.5.1 Maka™

Maka™ is a brand of water bottle whose packaging is capable of degrading 25 times faster than a conventional PET bottle, its bottles are made with an organic additive that reduces the oxidation time of the plastic to between two and six years, since a normal plastic bottle can take up to 150 years to disintegrate.

This water bottle, the brand and company was created by Fernando González and bears the trade name Maka™, which means "to give" in Nahuatl, a macrolanguage of Uoaztec origin in Mexico.

Imagen 21: Maka brand biodegradable water bottle created in Mexico

Source: (Gonzales 2021)

Maka™ is the only water brand in Mexico that uses this additive to reduce degradation time, due to the little information that exists about the product, it is not known which additive is used

by the brand. By adding this additive to the bottle, the PET molecules expand allowing bacteria to enter to speed up the decomposition process.

In 2019, Maka™ won two international awards for the design of its bottles: First place at the Dieline Awards, in the Best Water Bottle Design category; and second place for Best Packaging Design, at the Latin American Design Awards.

According to its creator, the most complex part was the packaging design, since the team decided to make a mold that would differentiate them from other brands. Currently, the Maka™ brand has managed to distribute its products in several cities in Mexico (Gonzales 2021).

This bottle is for general use, it is not exclusive for runners or athletes, however, it has helped to minimize waste generation in Mexico and to create environmental awareness among bottled water consumers.

5.5.2 Biodegradable bottle of Bacardí™

Bacardi, is a family-owned spirits company, one of the largest in the world, which currently has plans to bring the world's most sustainable spirits bottle to shelves by 2023. The new 100% biodegradable bottle seeks to replace 80 million plastic bottles (3,000 tons of plastic) that Bacardi currently produces in its portfolio of brands each year.

Imagen 22: Bacardi biodegradable liquor bottle

Source: (Reynolds, M. 2020).

This new bottle arises thanks to its collaboration with Danimer Scientific, developer and manufacturer of biodegradable products. Petroleum-based plastics currently used by Bacardi will be replaced by PHA Nodax™ from Danimer Scientific. This is a biopolymer that is derived from the natural seed oils of plants such as palm, canola, and soybean. Its main contribution to the environment is that while a traditional plastic bottle takes more than 400 years to decompose, the new liquor bottle made with Nodax™ PHA will biodegrade in a wide range of environments, including compost, soil, fresh water and water. of sea, and after only 18 months it will disappear without leaving harmful microplastics in the ecosystem.

Through the versatility of this innovative new material, Bacardi's packaging development

team aims to solve one of the beverage industry's oldest plastic problems, the plastic coating of bottle closures. According to Jean-Marc, vice president of the company, if you add that to the fact that in each bottle produced worldwide, we are talking about many tons of plastic every day. Once the problem has been fixed, it will open a new door to innovation for this industry.

Nodax™ PHA was verified as a truly biodegradable alternative to petrochemical plastics by the University of Georgia (UGA) and the UGA New Materials Institute in a 2018 study. Danimer Scientific uses Today the material for a wide range of applications, including thermoformed trays, straws/drinking straws, flexible and multi-layer film packaging, liners, disposable cutlery and more.

Nodax™ PHA is one of the most promising green materials in the world today because it offers the biodegradability consumers demand without losing the quality feel they get from traditional plastic, Scott Tuten, Director of Marketing and Sustainability at Danimer Scientific (Reynolds,2020).

This bottle is used in the liquor trade, it is taken into account for this research since the components that make it up make it an innovative idea for the beverage market and a sustainable and economical option for the development of new bottles. that can replace common plastic bottles.

5.2.3 Choose™ bottle

The founder of the company is James Longcroft, a Chemistry graduate, who previously sold plastic bottles, but upon discovering the footprint they left on the ecosystem, he stopped doing so. In addition to this, he helped the cause by creating his own biodegradable bottle.

Imagen 23: Choose water biodegradable bottle

Source: (Mollejo, V. 2018)

This young man, only 27 years old, made an alternative container capable of decomposing three weeks after its first use. A very short period of time compared to the 500 years that a conventional plastic bottle requires. The process takes a little longer for the stainless steel lid,

which takes around a year, but could still be recycled. The bottle is made from recycled paper and a waterproof lining that covers the interior.

According to its creator, these bottles do not leave toxic microparticles or filter heavy metals regardless of the environment in which they end up, it will not affect the environment.

For the important project that he leads, Longcroft is still seeking the necessary funding to commercialize the product. To do this, he has launched a crowdfunding campaign, with which he hopes to raise 25,000 pounds with which he intends to purchase the machinery that will produce the bottles on a large scale. For their part, these will have a much lower price, which will be around 90 pence, that is, around one euro.

The main hurdle you face is entering a saturated market and competing with an old and established industry. Changing an industry will be a big uphill battle, but with the support of the public he hopes to change the way we currently view bottled water (Mollejo, 2018).
This bottle is for everyday use, not only for sporting events or for the use of athletes.

5.5.4 PLA Compostable Bottles

These biodegradable bottles at the beginning did not have a biodegradable lid, however a few years later, a 100% plant-based compostable lid could be developed. It took about five years of trial and error to develop a compostable closure, but these biodegradable water bottles, caps, and labels are finally 100% plant-based. A product that can be processed in recycling, compost facilities, boilers, and possibly digested in a digester that has been in continuous research and development for nearly a decade. These compostable preforms are made with non-GMO plant resins like PLA and PHA, making them a sustainable option.

Imagen 24: biodegradable bottles plant-based

Source: (GS-Companies, 2023)

At the moment, the preform and closure is ready for mass production. This 23.5 gram preform with a 28mm neck is light blue in colour and is suitable for 500ml bottles. This company has chosen to only use the plant-based bottles in closed-loop locations, which would be a disadvantage for their large-scale trade. Well, your goal is to collect 90% of the bottles 90% of the time to process them correctly. Well, they have been able to observe that in normal retail it is difficult to create a good end-of-life for plant-based bottles. In normal retail,

PET bottles are generally recycled separately or sorted among household waste. A PLA recycling stream in normal household waste has not yet been developed in most countries of the world, because the amount of PLA waste is still too small to be a factor to deal with.

Within industrial composting, there is still a lot of uncertainty because there have been almost no bottles that have had a compostable closure, until now. There is a lot of miscommunications about how to deal with plant-based packaging in the waste stream and some people think that every plant-based packaging is simply composted in nature. This is incorrect, there are different plant-based packaging and they do not compost the same. There are those that can compost in nature and in water and some only compost in special circumstances, such as in an industrial composting facility. In the case of these compostable water bottles, they are composted in an industrial composting facility.

In 2004, this American company started with the first PLA milk bottle. In 2008, they switched to solve the problem of one of the most polluting products in the world, the petroleum plastic water bottle. PLA juice bottles and PLA milk bottles are the next logical products that will reduce single-use plastic waste problems.

Some advantages of this high-quality biopolymer is that it is a renewable, non-transgenic raw material. It is biodegradable, compostable and contributes to the reduction of microplastics on land and in the ocean. Compared to conventional plastics and paper, it has significantly lower CO^2 emissions when incinerated and does not produce toxic smoke. While other existing biomaterials exhibit one or more of these qualities, none of them combine all of them, making this high-quality biopolymer the most versatile biomaterial available: renewable, biodegradable, compostable, recyclable, and bioenergy convertible.

These plant-based resins are a very good candidate to replace conventional plastics currently on the market, including PP, PE, PET, and PS. It can be used in existing machinery and allows for more energy efficient production due to lower temperature needs (GS-Companies, 2023). These bottles are for general use, and their sale is made for any type of drink, although they prioritize the sale of water bottles.

5.5.5. Ooho Water Sphere™

Crazy Ooho Edible Water Spheres, or Ooho Water Sphere™ is an edible water sphere, a sphere-shaped container of water made from the gel of an algae plant. This type of water container was created by Skipping Rocks Lab to provide a more environmentally friendly alternative to single-use plastic bottles. Named Ooho after its designer, the container is made by sealing a small amount of water in a membrane made of algae and calcium chloride (Stewart, J. 2017).

Ooho is a container that holds water in a double membrane, using a technique to shape liquids into spheres called "spherification". A technique that encapsulates foods with gelatin

textures, so that they have a consistency similar to fish eggs. Its production cost is only 2 cents. It is made of algae and calcium chloride. To drink the water you just have to break the sphere and slurp the water inside or you can just eat it.

Materials: The spherical container is made of a membrane based on chlorine, algae and calcium, the content of which can hold up to 50 millilitres of water. It was designed by the Spanish Rodrigo García González, and the French Guillaume Couche and Pierre Paslier. Its main characteristics are: cheap, resistant, small, edible and biodegradable.

Uses: the design of the spherical container is intended to minimize the environmental impacts generated by plastic bottles, which is why they are ideal for use in large sporting events, such as the London marathon, where the use of plastic cups was prohibited. single use and banned runners from carrying plastic water bottles to highlight the green features of the race, thus providing Ooho water balloons instead of bottled water. Another use that its designers hope to give it is to carry water to countries with great difficulties in the water supply (Ooho water, 2019).

Imagen 25: Ooho! Edible water blob may replace plastic bottles

Source: (Nicole Tan, 2017)

The Ooho water sphere™ offers several benefits and advantages, including:

- Eco-friendly and sustainable alternative to plastic water bottles.
- Made from all-natural and biodegradable materials, such as seaweed and calcium chloride.
- Helps reduce plastic waste and carbon footprint.
- The edible membrane is a unique and innovative feature that offers a new way to consume water.
- The Ooho water sphere™ can be produced at a lower cost compared to traditional single-use plastic water bottles.

Some conclusions about the previous packaging water are:

- They are all designed from different natural materials, except Maka, which uses an organic additive to break down the plastic.
- The degradation time of all of them is very low compared to traditional plastic bottles.
- They can degrade in different scenarios such as compost, soil or water.
- Its production price is lower than traditional bottles both in its production and in its energy expenditure.
- During its decomposition, none of it emits heavy metals or toxic components that may affect the environment or natural resources.
- All are innovative products that contribute to improving the quality of the environment, reducing plastic waste.

From the point of view of running sports, the different examples of biodegradable bottles could be useful to reduce the environmental impact generated by traditional containers, however the most practical packaging for this type of competition is the Ooho Water Sphere™, since it Due to its shape and size, it guarantees zero waste and zero waste generation, it is easy to consume and it does not take much time for athletes during the competition to hydrate with this innovative packaging, from the point of view of consumers all the bottles mentioned above They would mean a good option compared to traditional bottles to initiate a more sustainable change of habits.

6. Target group

6. Target group

The target audience for the biodegradable water bottle is those runners who need good hydration during competitions, such as marathons, without leaving residues and pollution. It also targets people who are concerned about the environment and seek to consume low environmental impact products. This bottle aims to attract consumers who value sustainability and reducing their carbon footprint. The bottle is designed to be visually attractive and, at the same time, practical for use in major sporting events.

The design of the biodegradable bottle is intended to be easy and practical to carry, thin and with some details that allow a good grip and easy transport. It is ideal for the target audience of outdoor sports lovers who like to go to places where they can be in contact with nature without leaving waste or trash. This product can be consumed by any group of people of any age and in any place, although its sale seeks to ideally focus on places that generate a lot of waste due to their high consumption; For example, schools, universities, sports centres, mass events, amusement parks, music festivals, etc.

Bottled water, being a fresh and hydrating product, is within a very broad target audience, which is why for this new design the focus is on those people who are constantly on the move and require good hydration, a healthy product that satisfies your thirst and practical and easy to carry, in addition these people are modern and socially responsible, they are people who care about their physical health but also about the health of the environment. In general, the ideal target group has the following characteristics:

- Young people, who practice adventure sports, outdoor sports, hiking, running, mountaineering, cycling, etc.
- People who lead a busy and hectic life, such as students and workers with little free time.
- Very modern, educated, liberal, cosmopolitan people who highly value personal image. They are innovators in consumption and trend hunters.
- People who care about their image and take care of their physical health, go to the gym, play sports, consume "light" or low-calorie products.
- People who care about the environment, look for sustainable products, without generating waste, ecological, biodegradable, etc.
- People who are attracted to new, innovative, different products.

6.2 Market study relates to marathon population in China and their needs

The runners' sports events sport like marathon are popular all over the world, but in China it has only become popular in recent years. Participation in this sport has even become a fashion label for many Chinese people. The marathon craze has swept through China in recent years along with the growth in the number of people participating in marathons in China. (Schmitz, 2017)

According to surveys, sports events has become the new favourite of the increasingly affluent and health-conscious Chinese, and not only that, consumer investment in the sport is also climbing. Marathon is a mass sport and people come from different backgrounds. Only by studying different groups of runners can we better understand their specific needs and thus make practical suggestions for the further development of the sport and further promote people's passion for it (Fernández 2015).

The population that participates in marathons is very wide and diverse, as anyone who meets the registration requirements and is willing to train and compete can participate. Sports races are open to the public and often have different categories or divisions based on age, gender, and skill level. Therefore, participants of different ages, genders, and socioeconomic levels can participate in marathons, from amateurs to professional athletes. Those who enjoy running or jogging, physical exercise, competition, and personal challenge like to participate in marathons. Additionally, there are also participants who join marathons to raise funds for charities, to travel to new places, and to meet new people.

6.3 Marathon Population in China.

A large part of the growing number of marathoners is coming from the country's burgeoning middle class, young people and affluent population. People living in the northern, eastern and southern regions of China are the most enthusiastic about the sport. Highly developed megacities such as Beijing and Shanghai are the two cities with the highest number of marathon runners, accounting for 17.1% and 11.6% of the national total, respectively. In the less economically developed western and central regions, people's participation was the lowest with only 9.5% and 5.4%. (CGTN 2017)

In terms of runner's participation rates, those with higher education levels, higher social status and more assets are more enthusiastic about participating in marathons. 24% of core marathon runners have a master's degree or higher, 36% are in middle or senior management positions, 54% have a private car and 42% have a VIP bank card. (Athlinks, 2022)

Men are the backbone of the marathon, accounting for 86% of the total number of runners. But the number of female core runners is expected to grow, as the survey showed that 38% of potential athletes are women who have been running consistently for more than 3 months, run frequently once a week or more, and have completed any of the running events such as half marathon, 10K but not the full marathon event in the past three years.

Ninety-eight percent of those surveyed generally completed a full marathon in 2016, while 37% of them also considered participating in an ultra-marathon, trail run or mountain run. 86% of recreational runners planned to complete a half marathon, and 66% of them also planned to challenge a full marathon. About 55% of potential runners plan to challenge a half marathon within this year (Nielsen, 2016).

The purpose of participating in runner race young and middle-aged white-collar workers in first-tier cities to strengthen their bodies and relieve stress.

This part of the running crowd is mainly the young and middle-aged, high knowledge white-collar group in the developed coastal and high-tier areas, where the urban infrastructure conditions are relatively perfect, and the pressure of life and work is relatively high. In addition, the proportion of male runners is slightly higher than that of female, and the frequency of male running is also slightly higher than that of female; in terms of participation in running events, male performance is more positive than that of female; in terms of the purpose of running, male runners will sharpen their will through running, while female runners hope that running will help improve their sleep.

Nearly 90% of runners will run with some running applications, over 60% of runners said they will get professional course guidance such as running posture and warm-up preparation through such applications, over 80% of runners think that interesting running content is important to insist on running, and audio running content such as drama running and music running is becoming the new demand of runners. More than half of the runners think that running has social attributes. In addition to sharing in running applications, short video platforms are becoming the main social destination for runners after sports.

From 2021 to 2022, nearly 20% of runners have participated in running events. As offline activities are affected by force majeure factors, online events with higher flexibility and more fun are gradually gaining attention. For example, the KeepIP series of online marathons are the most popular among runners (Tong Dong, 2022).

6.3.1 Aspects to take into account in a traditional sport race.

When participating in a sport race like a marathon, it is crucial to be well hydrated. The general recommendation is to drink around 500 ml of water between 1 and 2 hours before running a marathon to stay hydrated. It's also recommended to drink fresh water in sips, around 50 to 100 ml, several hours before the race, and not to overindulge in alcoholic or caffeinated beverages. In addition, during the marathon, it's important to continue hydrating to regulate body temperature, facilitate the absorption of carbohydrates, and eliminate metabolic waste.

It's advisable to drink small amounts, approximately every 20 minutes, during the race, especially in warm or humid climates (Llorens, 2022).

The amount of water that should be consumed during a marathon varies depending on individual factors such as body weight, sweat rate, temperature, and humidity. This helps to maintain hydration levels and prevent dehydration, which can negatively impact performance and overall health.

Proper hydration is crucial during a marathon because of the fluid losses that occur during the race through sweating and respiration. Dehydration can lead to muscle cramps, heat exhaustion, and even heat stroke, which can be dangerous or life-threatening. Maintaining proper hydration levels helps to regulate body temperature, facilitate the absorption of carbohydrates, and eliminate metabolic waste products, all of which can help to optimize performance and prevent injury.

The number and location of competitor hydration stations can vary depending on the specific marathon, with some marathons having them approximately every half mile, while others have them every few miles. The type of fluid provided at these hydration stations may also vary, including water and/or sports drinks, as well as other items such as gels, fruits, or gummies. The exact number and location of hydration stations can usually be found in the race materials or on the marathon's website. It's important for runners to plan ahead and take advantage of the available hydration stations to maintain proper hydration levels and optimize performance during the race.

It's common for marathons to provide water in disposable cups, plastic bottles, or through hydration backpacks, and some races offer sports drinks in similar containers. Some marathons may also provide gels, fruits or other items to fuel and hydrate runners. The exact type or container used for hydration may vary depending on the specific marathon and organizer preferences.

To get an idea of the preparation for a marathon, we will provide the following example, for a total of 523 runners who need a personal hydration program, each runner must be given six bottles in the race, therefore, the organizers have to distribute 3,138 bottles of water, establishing hydration stations every 6.4 kilometres (Lorge 2020).

The amount of waste generated during a marathon can vary depending on a variety of factors, such as the number of participants, the duration of the race, and the availability of recycling and composting facilities. Typically, marathons generate a significant amount of waste, including disposable cups, bottles, and food packaging.

However, in recent years, sustainable practices such as reducing, reusing, and recycling waste have been increasingly adopted in marathons. Many events are working towards reducing waste by using compostable or reusable cups and containers, providing appropriate waste disposal bins for recycling, and encouraging runners and spectators to be mindful of their waste.

Exact data on the amount of waste generated in a marathon can vary depending on the event, but organizations such as the Council for Responsible Sport have developed standards and metrics to help quantify and reduce waste generated during running events.

6.4 Specifications for a bottle for drinking water for runners

To design a new bottle for drinking water through the use of biodegradable materials for runners, it is necessary to take into account the following aspects:
In general, the features to consider in a traditional a drinking bottle for human consumption will be:

- A bottle for drinking water must be contained in non-toxic containers that are suitable for not altering the flavour or colour of the product. The packaging must preserve the product's physicochemical, organoleptic, and microbiological characteristics, ensuring that it remains clear and fresh during transport and storage.
- The packaging must be manufactured with materials suitable for contact with food and beverages.
- The material used must be indicated on the label or on the container itself, in accordance with the Guide for Plastics coding system.
- The container must have a closure device designed to prevent any tampering. Once opened, the container must exhibit evident signs of opening.
- The expiration date must be clearly visible on the container.

In addition, the features to consider in a biodegradable drinking bottle for human consumption will be:

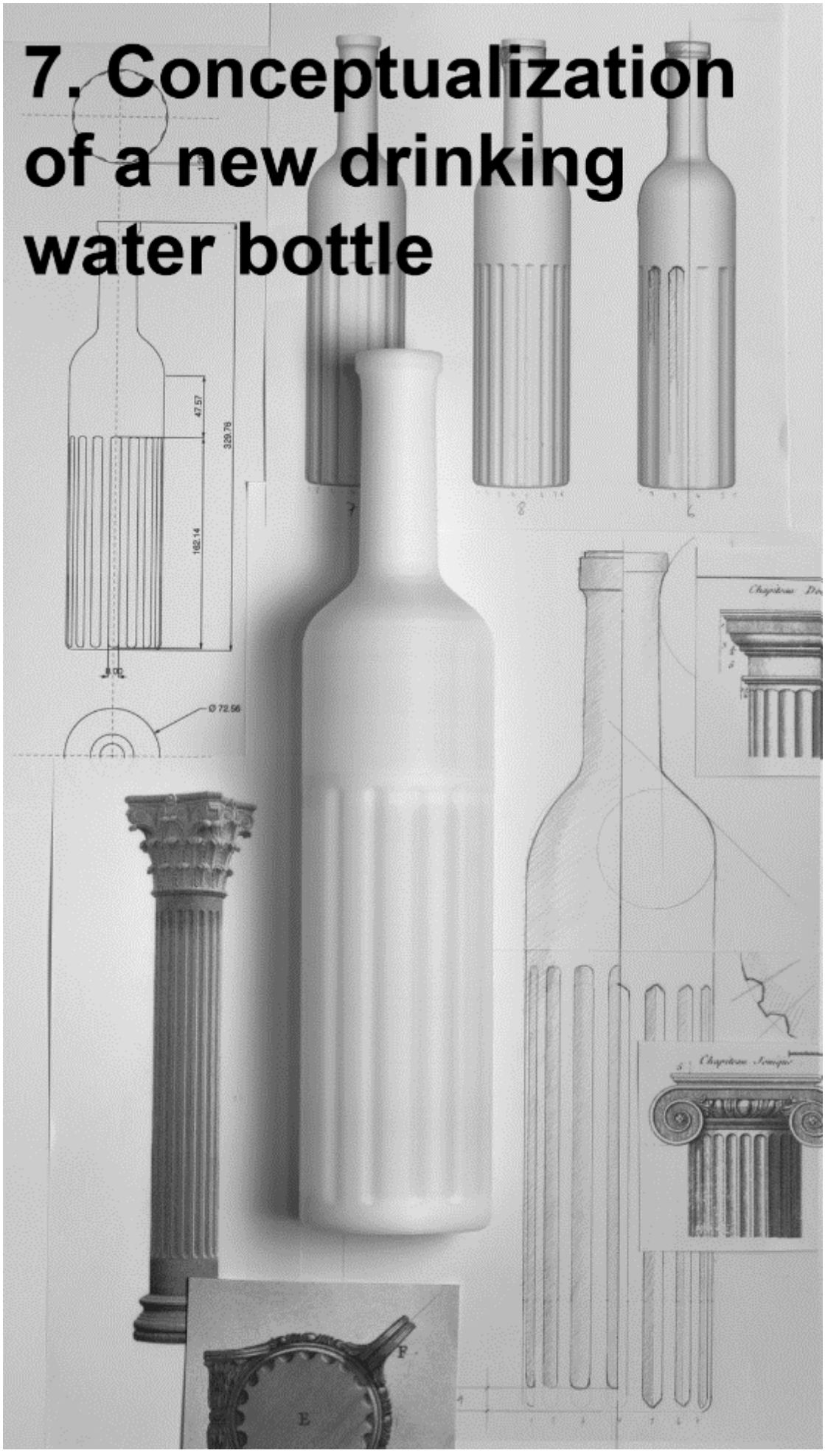
- Biodegradable food containers must guarantee a totally correct and safe handling, transport and conservation of food from purchase to consumption.
- The main characteristic of biodegradable food packaging is to degrade through the action of microorganisms that we find in the environment, without leaving residues that are harmful to nature, such as toxic residues or microplastics.
- They completely degrade in a short period of time compared to traditional containers and also become compost, water or CO2 for plants and soils.

The requirements for a material to be considered biodegradable, according to the European standard EN13432 are:

- Degrade at least 90% in 6 months, if subjected to an environment rich in carbon dioxide.
- In contact with organic materials, after 3 months the mass of the material must be made up of at least 90% of fragments smaller than 2mm.
- The material must not have negative effects on the composting process.

- Low concentration of heavy metals incorporated into the material.
- pH values within established limits.
- Saline content within established limits.
- Volatile solids concentration within established limits.
- Concentration of nitrogen, phosphorus, magnesium and potassium within the established limits.

7. Conceptualization of a new drinking water bottle



7. Conceptualization of a new drinking water bottle

The conceptualization and design process for a new biodegradable plastic bottle stems from the interest in designing a comfortable bottle, easy to carry and handle by runners during their training and competitions since the typical design of water bottles does not allow it to be comfortable. It is difficult to perform activities such as sports while drinking from them.

For the design of the bottle, some aspects were taken into account, such as its shape and elongated structure, so that it is easy to grasp by any type of person regardless of size, gender, or age. These details can help to prevent the slipping of the hands and a possible fall. A striking but simple shape and design, so that the consumer resembles the product that is to be represented, which is water.

7.1 Product definition

The design of the new high-quality pure water bottle, packaged in a biodegradable material, suggests the use of algae for its manufacture, due to the numerous existing investigations that demonstrate its quality and effectiveness for the development of plastics and PHAs. This packaging aims to be innovative both for the consumer and for the environment. One of the special characteristics and benefits of this container is that the consumer, after drinking the water, can eat, compost, bury or discard the bottle anywhere, since it, due to its easy degradation characteristics, can decompose naturally without damaging nature in any natural environment. The design of this packaging is simple, but practical, safe and easy to take everywhere. It is the perfect size for athletes and athletes of all kinds, making it very useful and safe for any type of competition or sporting event. Its compact size ensures that it can be taken anywhere, anytime and makes it easy to dispose of bottled water continues to be the most demanded drink worldwide, its high demand makes it an essential product for daily life, not to mention that it is the drink most used by athletes for hydration, before, during and after each workout. and competition, so it is necessary to create and design bottled water brands that not only provide high quality to the consumer due to the characteristics of the water, but are products designed with resistant materials and suitable for carrying the drink without generating toxic waste or negative impacts. to the environment, such as traditional water bottles.

This water bottle stands out from the rest for its comfortable and portable design, perfect capacity for proper hydration and ecological materials that make it ideal to take anywhere without worrying about where to throw it away or bring it back home to avoid contaminating places. what visits It is an ideal water bottle for outdoor outings, excursions in natural ecosystems or sports events such as marathons and more, since it does not generate

toxic waste and can be easily disposed of anywhere without negative consequences for the environment.

- For athletes and sporting events, it is recommended to use a small size that contains 300ml of pure water. This size is perfect for getting good hydration and is more comfortable and easier to carry, making it very useful for this type of activity.
- For daily use and other types of daily activities, the medium size with a capacity of 600ml is recommended.
- And finally, a larger size with a 1L capacity could be considered for home consumption.

On the other hand, material comes highly recommended for injection moulding applications where rigidity is required, and can be used as a substitute for opaque PP or PS. It is particularly well-suited for the production of thick-walled parts with small surface areas, such as horticultural items like fruit and vegetable boxes, as well as disposable household items, small containers, storage boxes, office materials, and food packaging vessels. The material is also suitable for the opaque injection-blowing process. (Prospector 2021).

The label will be made of recycled paper mainly composed of cellulose, which can be degraded and reabsorbed by nature. In addition, ecological ink made from vegetable-based ingredients will be used for printing on the label, with no mineral oils or volatile organic compounds included in the ink formula.

7.2 Conceptualisation

The idea of developing a new biodegradable primary packaging for bottled water that possesses the shape and quality of traditional bottles arises from the need to reduce waste generation or residues, since the majority of these are not recycled, reused, or properly disposed of after use, generating a serious environmental, economic, and social problem due to the pollution they generate in the long term and the deterioration they cause to natural resources and ecosystems in general.

To find a solution in line with the new global trends of sustainability and eco-design, the alternative of creating a new primary packaging for bottled water is proposed, being one of the most highly demanded drinks around the world, in addition to being necessary to maintain adequate hydration and to face the water shortage crisis that has been present for several years. In this way, with this new design, it is hoped to reduce waste generation, pollution caused by plastic and microplastics in oceans and other ecosystems, loss of biodiversity, and contribute to the reduction of the use and exploitation of natural resources, since the production of these new biodegradable containers represents less use of natural resources and the raw materials required are of natural origin, thus avoiding any type of environmental impact.

The design of these bottles makes them an ideal product to take anywhere, and their easy degradation allows for easy final disposal and avoids any negative consequences for the environment or society. The new packaging for bottled water promises to maintain the quality of the water, to ensure safe consumption of it, and has multiple benefits and characteristics that make it different from others, such as:

- In general, they are a combination of organic materials, such as starch and cellulose, and chemical additives that degrade into carbon dioxide, methane, biomass, water, and mineral salts.
- They are completely safe to use in the freezer, microwave, and can generally withstand heating temperatures of 120 to 200 degrees Fahrenheit.
- They do not contain allergens and are safe for atopic consumers.
- They are non-toxic.
- They do not contain chemicals that emit toxic and poisonous waste, as they are made from natural elements.
- The natural composition of biopolymers is completely absorbed by the earth.
- They require less energy to recycle since they are made of natural ingredients that easily decompose in the soil, providing faster and more efficient production.
- During production, half the energy required for ordinary plastic materials is needed.
- The same amount of energy can produce twice as many biodegradable bags, packaging or containers as non-degradable products.
- One major advantage of using biodegradable products is the reduced dependency on fossil fuels.
- This can benefit individuals involved in retail and manufacturing.
- The use and marketing of biodegradable products and packaging can improve the potential to increase sales and profits of businesses by attracting environmentally conscious consumers.

7.3 Sketches

The biodegradable bottle is designed to align with the global trend of environmental responsibility and sustainability. It aims to enter the market of sustainable products and biodegradable packaging, recognizing the lack of competition in this domain. The packaging's physical characteristics enable it to maintain product quality and freshness and protect the product during storage and transportation. It will be resistant, hermetic, suitable for storage conditions and flexible, to avoid spillages.

The bottle has an attractive design, with colours and shapes that relate to the product and capture the attention of the consumers. It is easy to use, store, transport, and dispose of, with a straightforward opening and closing mechanism.

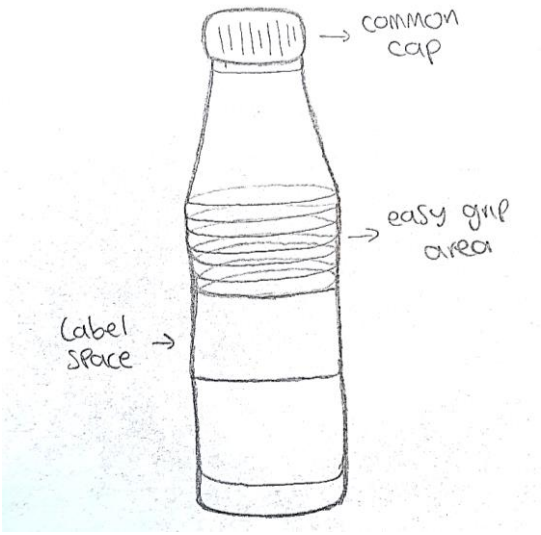
The bottle is highly practical and sustainable as it decomposes quickly in any medium, making it innovative and fitting for this new era of sustainability. Its distinctive feature lies in its ability to offer practicality while being environmentally friendly and not polluting.

The bottled water market is growing every day due to various factors. Firstly, people are becoming more concerned about their health, especially after the global pandemic, which has resulted in an increase in the consumption of bottled water as a way to improve their health habits. Secondly, the high level of contamination present in tap water makes people feel unsafe drinking it, hence the shift towards bottled water. Additionally, the ease of handling and mobility of water bottles also contributes to the growth of the market, as it is more convenient for people to carry water anywhere and dispose of the bottle afterwards. In Europe, for instance, the bottled water market has experienced significant growth in recent years due to concerns regarding tap water contamination and similar factors. However, the strong environmental impact caused by plastic waste has led to a preference for ecological packaging.

To tap into the thriving bottled water market, we are proposing a new primary packaging for biodegradable water bottles. Below are some container ideas, which we believe are the best alternatives due to their simplicity, consumer-friendly designs, and ease of grip. These designs are well-suited to compete in the existing bottled water market and offer consumers an eco-friendly option for their hydration needs.

Bottle 1: the original design of this bottle stands out from other common water bottles, it is basic but pleasing to the eye. Its design and shape convey the idea of containing purified water, making it easy for consumers to make a quick purchase without needing to know much about the product. Its ergonomic shape is easy to grip, which prevents it from slipping out of the hands of consumers. Initially, the bottle will be available in two sizes. The first is a 500 ml capacity, intended to be portable during daily routines, with a slightly longer shape than the competitor's containers, making it easier to transport. The second, smaller size contains 200 ml, making it ideal for public events since it offers easy handling and transport.

Imagen 26. Bottle 1 sketch.



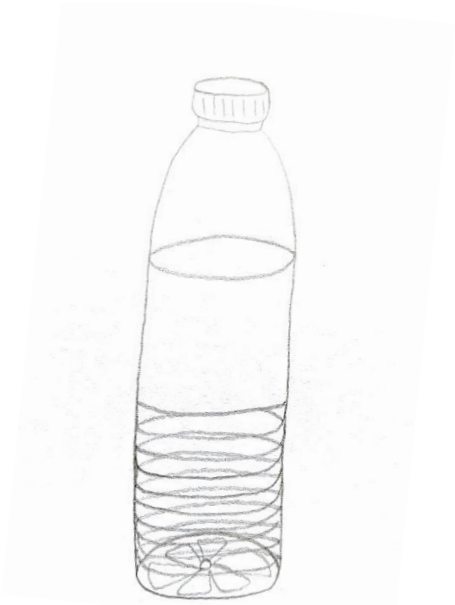
Source: (Own elaboration, 2023)

The bottle cap and label have a different green tone from the competition, which represents the purity of the water it contains and is easy for consumers to associate with the product. It has an elongated neck for easy grip and manipulation, followed by narrow horizontal stripes that prevent it from slipping and make it easy to transport. Later, a sleek design is presented with a label that includes specifications of the product's content, quality, and biodegradability. Finally, the background is similar to that of plastic soda bottles.

Bottle 2: The design of this bottle is slim and long with simple details and a straight cut. The upper part is smaller than the previous design and features a small neck, followed by a label on a flat surface. The middle section has small horizontal grooves that make it easy to grip and prevent slipping or falling. The bottom part of the bottle has a common plastic bottle design. This design reduces the cost of raw materials in manufacturing and helps to shorten the degradation time of the bottle. The base is designed to help the bottle stand, preventing falls and deterioration of the material. Despite the design at the bottom, the entire bottle maintains a cylindrical shape.

Its simple design makes it more affordable for consumers and competitive with other bottled water brands on the market, with a subtle distinction.

Image 27. Bottle 2 sketch.



Source: (Own elaboration, 2023)

Bottle 3: This design features a slim, long-necked bottle with details in the middle of the bottle that help make it easier to grip and the product label is featured. The lower part presents a design of vertical lines, it is a different and innovative design that is visually attractive and comfortable to take anywhere.

Image 27. Bottle 3 sketch.

Source: (Own elaboration, 2023)

Based on the previous bottle options and the choice of the best design option, it was determined that:

	Harmonious	Practical	Innovation	Easy to use	Total score
Bottle 1					

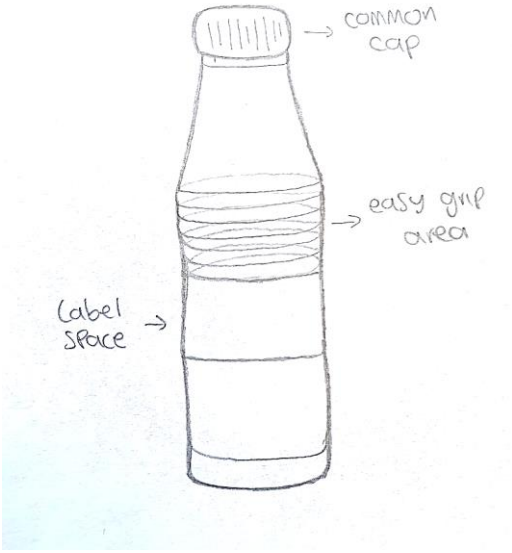
	10	10	8	10	38
Bottle 2 	4	6	5	6	21
Bottle 3 	9	8	9	8	34

As a conclusion and based on the score obtained, it can be deduced that:

- Bottle 1 is visually more harmonious, it looks practical and easy to hold, its size is ideal to quench thirst and to take anywhere, its design is simple, delicate and beautiful.
- Bottle 1 is more practical for use during events, competitions and race training, and its size and shape facilitate disposal, it is easy to compact if desired.
- Bottle 1 is more striking and different from the common water bottles on the current market, it could easily compete with the others.

The final bottle designed is a bottle 1, This is a beautiful bottle, the ideal size to carry anywhere, a perfect shape to carry in your hand for long periods of time, with the right amount of water to keep you hydrated and a different design from existing water bottles in the current market.

Image 28. Final sketch.



Sketcker of the final design created

7.4 3D design, CAD models and technical layouts of the final bottle prototype

The final bottle Bottle 1 was created in Solid Works Autodesk Tinkercad from the previously hand-drawn sketch, trying to be as similar to the sketched design as possible. It started from the upper part of the bottle, first making the mouthpiece with a thread, from there it was sought to give a thin and elongated shape to the neck of the bottle and then an irregularly shaped neck was added with horizontal engravings that resemble rings to give a better grip and avoid possible falls or slips of the bottle. After this, a smooth part was added to place the product label with all the information that is required. And finally, the base of the bottle was designed with some details that the common bottles have in the background that give it the perfect touch of design from start to finish. After this, the bottle cap was designed, which has a simple thread design that fits perfectly into the bottle's mouthpiece, thus avoiding spills or damage to it.
A possible name that will be given to the bottle is **BioHydrate,** a name that alludes to the biodegradable, ecological and environmentally safe packaging, and to the essential quality of bottled water for runners and athletes: hydration.

Figure 1: Bottle front, 3D transparency model	Figure 2: Bottle and cap 3D CAD

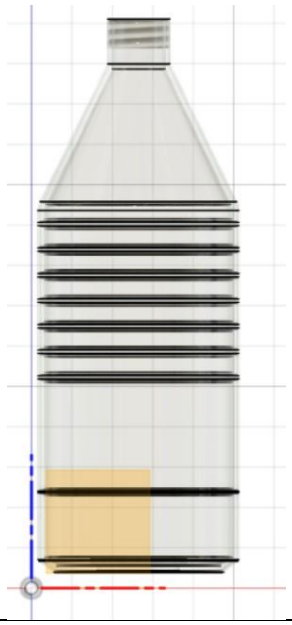
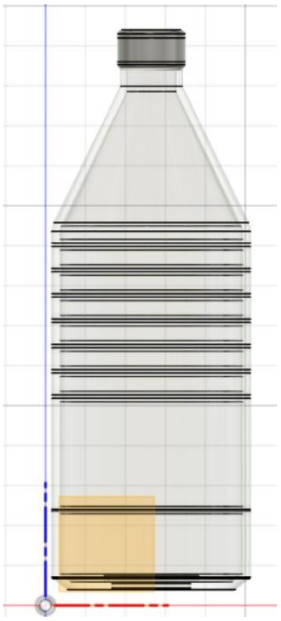
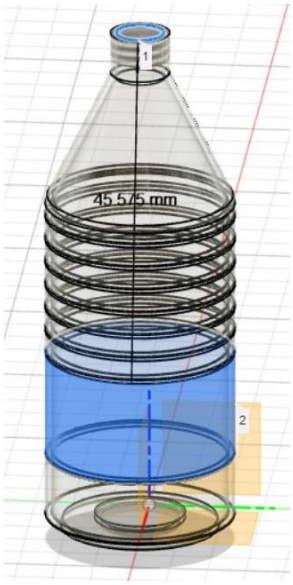
	
Source: (Own elaboration, 2023)	Source: (Own elaboration, 2023)

Figure 3: cap 3D CAD

Source: (Own elaboration, 2023)

Figure 4: 3D CAD bottle

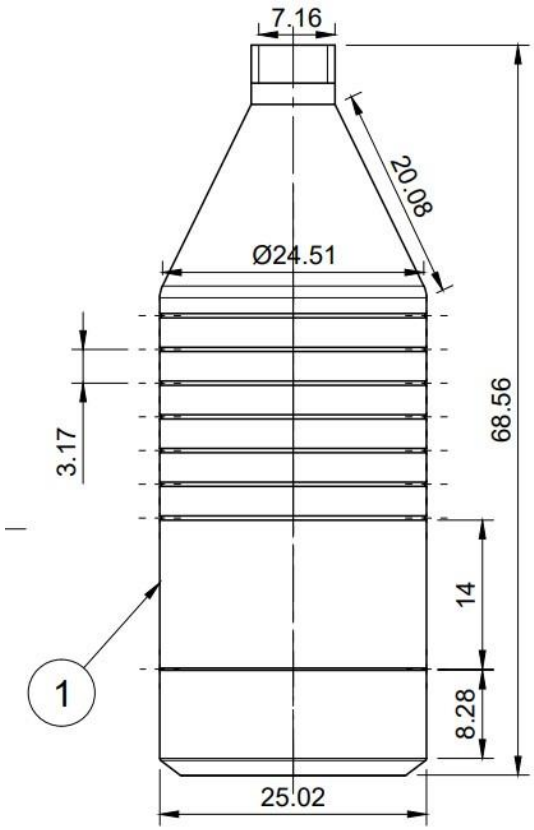


Source: (Own elaboration, 2023)

7.5 Technical layouts

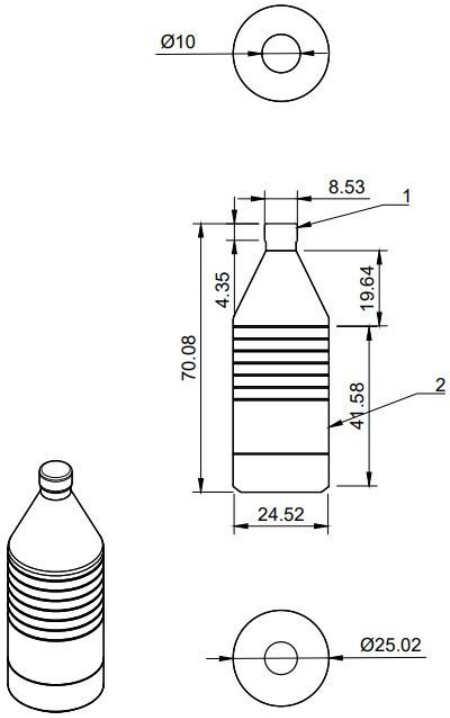
The design of the bottle was carried out in stages, designing each part separately, and then assembling all the pieces until the complete body of the bottle was obtained. Below are presented each of the parts individually developed until the final result is obtained. The final technical layouts will be in the annex I. The design of the base is intended to maintain the traditional shape of the bottles to ensure adequate stability and prevent the bottle from falling, this helps to have a safe and effective transportation of the bottles. The design of the traditional nozzle helps to have greater effectiveness in the closure of the bottle, avoiding waste or possible irrigation of the water, it is comfortable for the consumer and of a suitable size for anyone. The elongated design of the neck of the bottle adds elegance, it is easy and comfortable for anyone to grasp and manipulate.

Image 29. Technical layout created



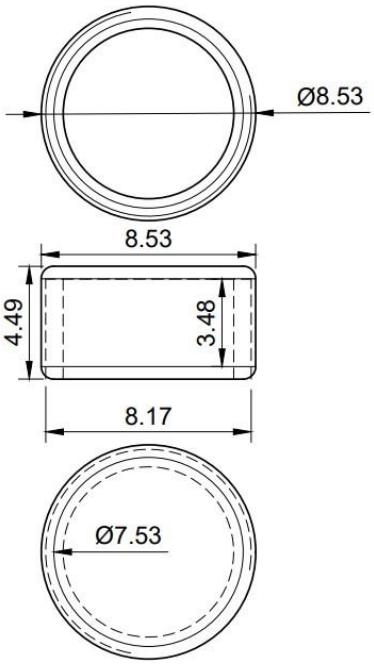
Source: (Own elaboration, 2023)

Image 30. Technical layout created



Source: (Own elaboration, 2023)

Image 31. Technical layout created



Source: (Own elaboration, 2023)

8. Budget

8. Budget

The ErcrosBio® LL 650 bioplastic material begins its biodegradation once dry, and in approximately 50 days the remains become compostable according to the criteria of the EN 13432 standard. This European standard describes the requirements for compostable and biodegradable packaging and provides a scheme for test and evaluation criteria for the final acceptance of the container.

The recycling code of the products obtained is 7, corresponding to "Others" according to the SPI (Plastic Industry Society) one of the main outlets once the useful life is over is composting. The current market price of ErcrosBio LL 650 is 4,6 €/kg

To convert the price per kilogram (€4.6/kg) to a price per gram, divide the price per kilogram by 1000. Therefore, the price per gram is: €4.6/kg ÷ 1000 = 0.0046 €/gram.

Multiply the amount of material needed by the cost per gram. In this case, the total amount of material needed is approximately 20 grams. Therefore, the total cost of the material needed to create a bottle is: 20 grams x 0.0046 €/gram. = €0,092.

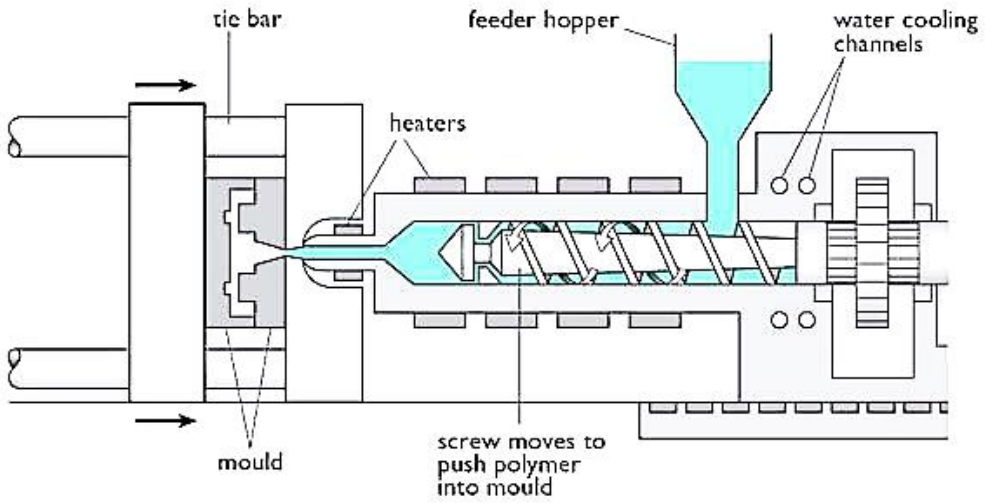
To calculate the factory cost of a conventional bottle cap that weighs around 2 grams, the material cost per kilogram (€6.5/kg) will be converted to cost per gram. To do this, divide the cost per kg by 1,000. Therefore, the cost per gram is: €6.5/kg ÷ 1,000 = €0.0065/gram.

The amount of material needed by the cost per gram. In this case, the amount of material needed to make a water bottle cap is approximately 2 grams. Therefore, the total cost of material to manufacture a conventional bottle cap is: 2 g x €0.0065/g = €0.013.

8.1 Product manufacture

The water bottle's simple design allows for a manufacturing process that involves very few steps. The bottle cap is produced through an injection moulding process, while the bottle body is shaped using an injection-stretch-blow moulding process.

Image 31. Plastic injection moulding process.

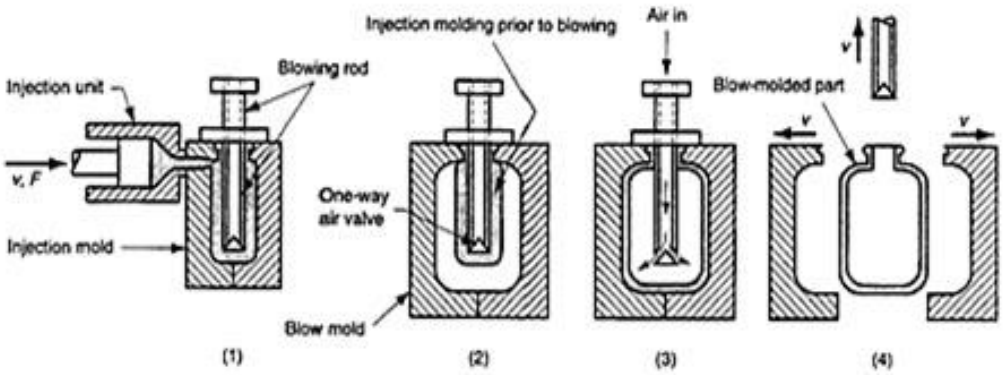


Source: (Senses 2020).

The manufacturing process for the bottle body begins by heating and melting the raw material in a machine that is equipped with an internal screw. The molten material is then injected into a high-pressure mould that forms a preform.

The preform is then heated by direct contact with the mould wall and inserted into the blowing mould. The stretching rod elongates the preform, and compressed air is quickly blown into it, pushing it towards the blowing moulds where it cools and solidifies into the bottle shape. Finally, the finished products are ejected from the machine and moved along a conveyor belt to be assembled with the cap.

Image 32. injection-stretch-blow moulding process.



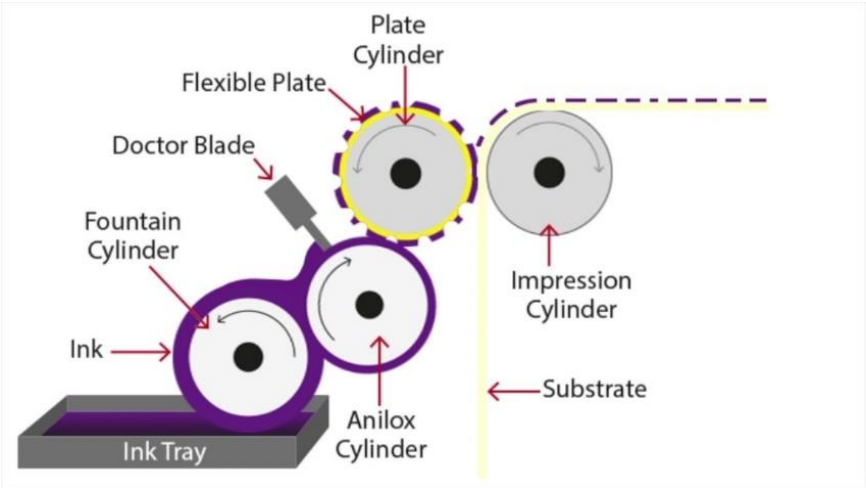
Source: (Alleycho 2020).

To create the bottle cap using injection moulding, the raw material is first introduced into the injection unit. The material is then heated, melted, dosed, homogenized and injected into the mould. Once the material has cooled in the mould, it is extracted.

Following the previous steps, the next stage involves labeling the product. Recycled paper is used for the label, which is compatible with all printing methods, and eco-friendly inks will be used. Flexographic printing is the preferred method due to its low environmental impact and superior compatibility with eco-friendly inks.

This printing method involves using raised plates affixed to metallic cylinders. The ink dozer roller applies ink to the plate, which is then printed on the product.

Image 33. Flexography printing process.



Source: (Percival R. 2019).

To start the process, a plate with the image printed in reverse is prepared so that the areas to be printed are in relief. The plate is then adjusted onto the platform cylinder so that the paper can begin to pass between the two larger cylinders. Next, a ceramic or anilox cylinder with small holes receives the ink and comes into direct contact with the plate, also housed on the platform cylinder, to provide ink only in the relief areas. The inked plate continues to rotate and comes into contact with the paper, which exits printed and dries quickly.

8.2 Cost of the product development

To determine the cost of product development, the following will be taken into account:
The cost of the bottle will be 0,092 €
The cots of the cap will be 0,013 €
Specialized machines are used for injection moulding, ranging from desktop injection moulding machines that businesses may use in their own facilities to large industrial injection moulding machines that are often used by service providers, manufacturers contract and large manufacturers.

Equipment costs are not included in the calculation of production costs, since the cost of these tools can be spread over several projects. Purchasing a desktop injection moulding machine and SLA 3D printer allows companies to start injection moulding for less than 9100,20 €.

On the other hand, the initial costs of blow moulding can be 30-50% lower compared to injection moulding. Injection stretch blow moulding machines can cost between € 22750,50 and € 40950,90. With the increase in price, production capacity and other features are also improved that can reduce labour costs and increase profits. The estimated price of Injection Blow is 0.73 €/ Piece.

Next, a budget will be made for the manufacture of 1500 units that will serve as an example to know the value of the manufacture of the bottles. of the bottle will be prepared taking into account the cost of the materials required for production, the cost of purchasing any necessary elements, and the cost of labour. This will include direct labour costs such as production operators, as well as indirect labour costs. Social expenses such as contributions to social security, work accidents, and professional training will also be considered, along with general expenses such as management, purchasing, and IT personnel. A profit percentage of 6% has been chosen.

To determine the total cost of materials for the bottle the cost of manufacturing the parts necessary for the design is first calculated, and then the cost of acquiring the products and materials required for the model. The necessary elements for the manufacture will be the body of the bottle, the cap and the label.

Table 4. Cost of purchased items

Cost of materials			
Material	**Quantity**	**Unit cost (€/Kg)**	**Amount (€)**
ErcrosBio LL 650 (kg)	50	4,6	230,00
ErcrosBio LM 63101 (kg)	50	6,5	325,00

Adhesive recycled paper	1500	0,1286	192,90
Ecopaks inks (kg)	1	10,9	10,90
		Total	**€ 750,8**

Source: Own elaboration, 2023

Next, the approximate cost of labor will be simulated, which includes the expenses generated by the operator involved in the product. The calculation includes operator fees and approximate social security payments as an example. The cost of direct labor represents the product of the time granted to carry out the process activities, both manufacturing and assembly, for their corresponding wages.

Table 5. Cost of operation

Cost of labour						
Operation	**Unit/time (dmh)**	**Units**	**Total (h)**	**Operator**	**€/h*operator**	**Total cost (€)**
Bottle body	10	1500	10	Employee 1	9,42	94,2
Bottle cap	10	1500	10	Employee 2	9,42	94,2
Label printing	10	1500	10	Employee 3	8,94	89,4
Assembly	15	1500	15	Employee 4	8,94	89,4
					Total	**367,2 €**

Source: Own elaboration, 2023

The cost of the label of the new bottle will be made of recycled paper composed of cellulose that is biodegradable and can be absorbed by nature. Eco-friendly ink made from vegetable-based compounds without mineral oils or volatile organic compounds will be used for printing the label. The Ecopack series has been certified by the FOGRA institute to meet the ISO 2846-1 standard and is suitable for printing according to the ISO 12647-2 standard.

The current market price of Adhesive recycled paper is 0,1286 €/kg.

The current market price of Ecopaks inks is 10,9 €/kg.

To calculate the price of adhesive recycled paper in euro per gram, we can use the following formula:

Price per gram = Price per kilogram / 1000

Substituting in the formula the price per kilogram indicated, 0.1286 €/kg, we obtain the

following result:
Price per gram = 0.1286 €/kg / 1000 = **0.0001286 €/g**

We apply the same formula to calculate the price €/g of Ecopaks inks obtaining as a result:
Price per gram = 10,9 €/kg / 1000 = **0,0109 €/g**

With the above information, we can know the final budget that will be presented in the following table:

Table 6: Final budget of the new bottle

Concept	Material	Specifications	Cost per unit
Bottle	ErcrosBio LL 650	20 gr x €0.0046/gr =	0,092 €
	Manufacturing	approximate manufacturing cost per bottle	0,73 €
	Mould of the bottle	aluminium (mould amortization value)	0,12 €
	Labour per person	bottle mount in man cost (time)	0,09 €
Cap	ErcrosBio LM 63101 Bioplastic	2 gr x €0.0065/gr =	0,013 €
Label	Adhesive recycled paper	recycled paper composed of biodegradable cellulose	0,0001286 €
	Ecopaks inks	Eco-friendly ink made from vegetable-based compounds	0,0109 €
		Total cost per bottle	**1,05 €**

In conclusion, the approximate price of a bottle is **€** 1.05 therefore, the price of 1500 units will be approximately **€** 1575

9. Bibliography

9. Bibliography

- AquaVita (2019). Essential Minerals Found in Drinking Water and Their Benefits http://aquavitallc.com/essential-minerals-found-in-drinking-water-and-their-benefits/ - (Consulted 17/04/2023)
- Alejandro, (2023). ¿Cuál es el objetivo de un evento deportivo? https://www.haciendaparaiso.com.mx/cual-es-el-objetivo-de-un-evento-deportivo/ (Consulted 17/04/2023)
- Alleycho (2020). Plastic Injection Stretch Blow Moulding Process. Alleycho International Ltd. https://alleycho.com/plastic-injection-stretch-blow-moulding-process/ (Consulted 17/04/2023)
- Asian Enviro Labs (2023). Laboratory water testing services Chennai | Asian Enviro Labs . https://www.asianenvirolabs.in/ (Consulted 17/04/2023)
- Athlinks, (2022). RUNNER DEMOGRAPHICS – Statistics and Research. https://5kevents.org/demographics.html (Consulted 19/04/2023)
- Anderson A.J.& Dawes E.A. (1990). Occurrence, metabolism, metabolic role, and industrial uses of bacterial polyhydroxyalkanoates. Microbiol. Rev. 54,450-472.
- Baidu, (2022). London Marathon, https://baike.baidu.com/item/londonmarathon (Consulted 19/04/2023)
- Baidu, (2022). Marathon, https://baike.baidu.com/item/marathon (Consulted 19/04/2023)
- Banco Mundial, (2020). Agua Residual: De Residuo a Recurso (bancomundial.org) (Consulted 17/04/2023)
- Benyathiar & Kumar, Carpenter, Brace & Mishra (2022). Polyethylene Terephthalate (PET) Bottle-to-Bottle Recycling for the Beverage Industry: A Review. Polymers. Vol14(12) pp. 2366. https://doi.org/10.3390/polym14122366
- Bioplastics magazine (2019). PHA water bottle coming soon - bioplastics MAGAZINE (Consulted 17/04/2023)
- Britannica. tereftalato de polietileno. *Enciclopedia Británica*, 20 de marzo de 2023, https://www.britannica.com/science/polyethylene-terephthalate. (Consulted 19/04/2023)
- Britannica, Enciclopedia Británica, 8 de diciembre de 2022, https://www.britannica.com/technology/glass. Consultado el 1 de mayo de 2023.
- Canata, G.L., Casale, V., Gaudino, C., Canova, R., Zanon, G. (2022). Disciplinas de atletismo para correr. En: Canata, G.L., Jones, H., Krutsch, W., Thoreux, P., Vascellari, A. (eds) The Running Athlete. Springer, Berlín, Heidelberg. https://doi.org/10.1007/978-3-662-65064-6_12

- Change.org (2023). Reduce the Environmental Impact of Plastic Bottles · Change.org . (Consulted 17/04/2023)
- Chengcheng Wang,(2020). New York City Marathon cancelled due to new crown epidemic, the world's largest marathon, https://sports.sina.com.cn/run/2020-06-26/doc-iircuyvk0475733.shtml (Consulted 19/04/2023)
- Centre for Disease Control and Prevention, CDC (2023). Types of Agricultural Water Use. https://www.cdc.gov/healthywater/other/agricultural/types.html Consulted 19/04/2023
- China Global Television Network CGTN, (2017). Beijing Marathon attracts over 30,000 runners (www.gov.cn) (Consulted 19/04/2023).
- City of Westminster (2023). Plastic waste complete guide. Westminster City Council Commercial Waste Services (CWS). https://cleanstreets.westminster.gov.uk/plastic-waste-complete-guide/ (Consulted 19/04/2023)
- Connor N, (2021). PET – Table of materials – Applications – Price. PET | Propiedades, precio y aplicación | Propiedades del material (material-properties.org) (Consulted 17/04/2023)
- Davis, M. (2019). Disposal Method Matters: The Truth Behind Biodegradable Plastics. El método de eliminación importa: la verdad detrás de los plásticos biodegradables – envirobites (Consulted 17/04/2023)
- Downey, R. (2017). Global Packaging Market in 2017: Emerging Markets and Pack Size Variation - Euromonitor.com (Consulted 17/04/2023)
- Gosling, E. (2019). Ever & Ever water bottles aim to create a solution to single-use plastics | Creative Boom . (Consulted 17/04/2023)
- Gonzales, E. (2021). Estas botellas son 25 veces más biodegradables que el PET - Energía Hoy (energiahoy.com) (Consulted 7/05/2023)
- Enfoque, (2018). El impacto ambiental del agua embotellada | Revista Enfoque (Consulted 17/04/2023)
- United States Environmental Protection Agency EPA, (2017). Water Recycling and Reuse: The Environmental Benefits. https://19january2017snapshot.epa.gov/www3/region9/water/recycling/pdf/brochure.pdf Consulted 17/04/2023.
- Etecé, (2022). Biodegradable materials. Concepto. Biodegradable materials - Materiales biodegradables - Qué son, importancia y ejemplos (Consulted 17/04/2023)
- European Commission (2015). Seaweed – A sustainable source of bioplastics | SEABIOPLAS Project | Results in brief | FP7 | CORDIS | European Commission (europa.eu) Consulted19 april 2023.

- Ecovidrio, (2022). The history of glass: origin and evolution of one of the oldest materials. Speaking in glass. https://hablandoenvidrio.com/historia-del-vidrio-i/ (Consulted 17/04/2023)
- Food and Drugs Administration FDA, (2023). Food Chemical Safety | FDA (Consulted 17/04/2023)
- Fernández Macías, M. Á., Godoy-Izquierdo, D., Jaenes Sánchez, J. C., Bohórquez Gómez-Millán, M. R., & Vélez Toral, M. (2015). Flow y rendimiento en corredores de maratón. *Revista de Psicología del Deporte, 24*(1), 9-19. https://www.redalyc.org/articulo.oa?id=235139639002 (Consulted 17/04/2023)
- Gregersen, (2023). Polipropileno | Propiedades, definición y usos | Britannica (Consulted 17/04/2023).
- Gregersen, (2023). Polypropylene. Encyclopedia Britannica. https://www.britannica.com/science/polypropylene (Consulted 17/04/2023)
- Georgiopoulou & Pappa, (2021). Recycling of post-consumer multilayer Tetra Pak® packaging with the Selective Dissolution-Precipitation process. https://doi.org/10.1016/j.resconrec.2020.105268
- Gibbens, S. (2018). Everything you need to know about bioplastics. Todo lo que necesitas saber sobre los bioplásticos | National Geographic (Consulted 17/04/2023).
- GS-Companies, (2023). Biodegradable water bottles are 100% plant-based. PLA bottles preforms https://www.plant-based-packaging.com/biodegradable-water-bottles/ (Consulted 07/05/2023)
- Go PHA, (2022). We want fish in our oceans, not waste. PHA. The biodegradable alternative to fossil plastics. Global Organization for PHA. https://static1.squarespace.com/static/5fb2575cf94ec942fe192fb3/t/6315db085c232e70b35a9345/1662376720244/GO%21PHA_Brochure+-+PHA+and+Policy+-+2022.pdf (Consulted 17/04/2023)
- HangZhou, (2017). Characteristics of PET plastic bottles. Características de las botellas de plástico PET - Introducción de nuevos materiales - Noticias - Unic Packaging Branch Branch de Hangzhou (unopackaging.es) Consulted 19 de april 2023.
- Honggfan,(2019) London Marathon uses capsule drinks to reduce plastic waste, ushering in a new era of marathon hydration https://sports.qq.com/a/20190508/000513.html (Consulted 19/04/2023).
- ISO, (2023). How standards benefit consumers. COPOLCO (iso.org) (Consulted 19/04/2023).
- International Olympic Committee, (2021), Marathon, https://olympics.com/ioc/olympic-games (Consulted 19/04/2023)

- Isaac, W. (2019). 26 tips to conquer the London Marathon route (Image). https://www.redbull.com/gb-en/london-marathon-course-tips (Consulted 17/04/2023)
- Jarvie, Michelle E.. (2016). Brundtland report publication by World Commission on Environment and Development https://www.britannica.com/topic/Brundtland-Report. Consulted el 31 de mayo de 2023.
- Jindal, (2023). LDPE Vs HDPE: una comparación completa - PlasticRanger (Consulted 17/04/2023).
- Johnson B. (2013) Zero Waste Home: The Ultimate Guide to Simplifying Your Life by Reducing Your Waste. Scribner Ed. ISBN 1451697686
- Juste, 2020. Types of plastics. https://www.ecologiaverde.com/tipos-de-plasticos-1732.html (Consulted 06/16/2023)
- ECHA, European Chemicals Agency, (2021). Categories of materials in SCIP. https://echa.europa.eu/documents/10162/28213971/material_categories_for_the_scip_database_en.pdf/47142a6a-2634-52ce-ced0-49670928c3c2 (Consulted 06/16/2023)
- Keith, L. (2016). City News. Ontario proposes new rules for bottled water companies CityNews Toronto https://toronto.citynews.ca/2016/10/17/ontario-proposes-new-rules-bottled-water-companies (Consulted 17/04/2023)
- Knight, G. (2012). Plastic Pollution, wikipedia. Baidu, Water resource, https://baike.baidu.com/item/waterresource (Consulted 19/04/2023)
- *Kevin Wandrei, (*2018). Cómo reducir el uso de recursos naturales | Ciencia (sciencing.com)
- Kumar, R.; Verma, A.; Shome, A.; Sinha, R.; Sinha, S.; Jha, P.K.; Kumar, R.; Kumar, P.; Shubham; Das, S.; Sharma, P.; Vara Prasad, P.V. (2021). Impacts of Plastic Pollution on Ecosystem Services, Sustainable Development Goals, and Need to Focus on Circular Economy and Policy Interventions. Sustainability Vol. 13 (17) pp.1-40 https://doi.org/10.3390/su13179963
- Lindwall, C. (2020). Single-use plastics 101. NEDC. Plásticos de un solo uso 101 (nrdc.org). https://www.nrdc.org/es/stories/plasticos-solo-uso-101#por-que (Consulted 17/04/2023)
- Li Z, Loh XJ. (2015) Polihidroxialcanoatos solubles en agua: materiales futuros para aplicaciones terapéuticas. Vol. 21;44 (10) pp. 2865-79. DOI: 10.1039/C5CS00089K. https://doi.org/10.1038/am.2016.48
- Li, Z., Yang, J. & Loh, X. (2016). Polyhydroxyalkanoates: opening doors for a sustainable future. *NPG Asia Mater* 8, e265. https://doi.org/10.1038/am.2016.48
- Llorens, D. (2022). How do you have to hydrate if you do a race or marathon?. Saber vivir tve. https://www.sabervivirtv.com/ejercicios/como-hidratar-corredor-carrera-maraton_7084 Consulted 19 de april 2023.

- Lorge, S. (2020). How to put more than 3,000 bottles in the right hands?. Runner's World UK: the UK's largest running website (runnersworld.com) Consulted19 april 2023.
- Material-Properties, (2023). PET – Material Table – Applications – Price. PET | Properties, Price & Application | Material Properties (material-properties.org) Consulted 17/04/2023)
- Davis, M. (2019). Disposal Method Matters: The Truth Behind Biodegradable Plastics. El método de eliminación importa: la verdad detrás de los plásticos biodegradables – envirobites (Consulted 17/04/2023)
- Martinez, J. (2012). Los eventos deportivos: concepto, historia, características, implicaciones y tipos (efdeportes.com) (Consulted 17/04/2023)
- McGrane, Kelli. (2019). Does Mineral Water Have Health Benefits? (healthline.com) (Consulted 17/04/2023).
- Mexpolimeros, (2023). PLA | Polylactic Acid - Thermoplastic polymers, elastomers and additives (mexpolimeros.com) (Consulted 17/04/2023).
- Mexpolimeros, (2023). Polyvinyl acetate (PVA) - Thermoplastic polymers, elastomers and additives (mexpolimeros.com) (Consulted 17/04/2023).
- Mollejo, V. (2018). La botella de agua que se desintegra en tres semanas (redbull.com) (Consulted 07/05/2023).
- Motion Elements (2023). Manufacturing process of bottles in glass factory. Manufacturing Process Of Bottles In Glass Factory Live Action | 11495373 (motionelements.com) . (Consulted 17/04/2023)
- Mordor Intelligence (2022). Informe sobre la industria del embalaje en China | Tamaño, participación, crecimiento y tendencias (2023-28) (mordorintelligence.com) (Consulted 17/06/2023)
- Naser, DeiaB, & Darras (2021). Poly(lactic acid) (PLA) and polyhydroxyalkanoates (PHAs), green alternatives to petroleum-based plastics: a review - RSC Advances (RSC Publishing) DOI:10.1039/D1RA02390J (Consulted 17/06/2023)
- Natural Vegan, (2019). 23-year-old develops 100% compostable paper bottle - Canadian Biomass Magazine . (Consulted 17/04/2023)
- Naku, (2023). Not Plastic Water - gut für dich und die Umwelt (naku.at) . (Consulted 17/04/2023)
- Nace, T. (2019). Los corredores del maratón de Londres recibieron bolsas de algas en lugar de botellas de plástico (forbes.com) (Consulted 17/04/2023)
- Nielsen, (2016). Marathon boom brings huge business opportunities https://www.nielsen.com/zh/insights/2016/business-opportunity-looms-as-marathon-mania-sweeps-across-china/ (Consulted 28/04/2023)

- Nizar Grira, (2017). Osaka Marathon 2017 (Image). Osaka Marathon 2017 | SPORTS ENTRY -Find and register for sports events in Japan- (Consulted 17/04/2023)
- Ocean Conservancy. (2019). The Beach and Beyond: 2019 Report. Final-2019-ICC-Report.pdf (oceanconservancy.org) (Consulted 17/04/2023)
- Ooho water, (2019). The revolution of the water bottle market or the future of hydration? - Oohowater (Consulted 07/05/2023)
- Olimpics Games (2023). Juegos Olímpicos de Beijing 2008 - Atletas, medallas y resultados (olympics.com) (Consulted 17/04/2023)
- Ospina, K. (2022). ¿Qué es el Running? – El Deportista (Consulted 17/04/2023)
- Parra, D. (2017). Percepción de los residentes sobre los impactos de un gran evento deportivo: Desarrollo y validación de una escala (1library.co) (Consulted 17/04/2023)
- Palmer P. (2005). Getting to Zero Waste. Purple Sky Press. ISBN 0976057107
- Phillips, M. (2017). London Marathon unveils new half-distance mass race for 2018 | Reuters (Consulted 17/04/2023).
- Peters, A. (2020) The Edible Water Bottle Is How You Will Drink In The Future.Fast Company. Fast Company. https://www.fastcompany.com/40403025/this-edible-water-bottle-is-how-youll-drink-in-the-future (Consulted 17/04/2023)
- PETCYCLE, (2020). System for sustaintable PET circular economy (Image). Intelligent combination of reusable crates and disposable PET bottles (petcycle.de) . (Consulted 17/04/2023)
- Pierre, (2017). THE BEGINNING OF SOMETHING EXTRAORDINAIRE. Perrier® Expands | Perrier® Carbonated Mineral Water
- Poirier Y. (2001). Producción de poliésteres en plantas transgénicas. Adv Biochem Eng Biotechnol; 71:209-40. DOI: 10.1007/3-540-40021-4_7
- Polo, C. (2023). ORGANIZACIÓN DE UN EVENTO DEPORTIVO | Web Oficial EUROINNOVA (Consulted 17/04/2023)
- Prospector (2021). ErcrosBio® Renewable-based Thermoplastic for Ercros, S.A. | UL Prospector Consulted 30/05/2023.
- Trinidad Alfonso, (2019). The Valencia Marathon and Ecoembes recycle 99.99% of the bottles used. El Maratón Valencia y Ecoembes reciclan el 99,99% de las botellas utilizadas (valenciaciudaddelrunning.com) Consulted19 april 2023.
- Reynolds, M. (2020). Bacardí apuesta por botellas 100% biodegradables | mundo PMMI (Consulted 07/05/2023)
- Rui, (2005). The history and ideology of a bottle of mineral water. http://old.lifeweek.com.cn//2005/0317/11367.shtml (Consulted 17/04/2023)
- Rosenboom & Langer & Traverso, (2022). Bioplastics for a circular economy | Nature Reviews Materials (Consulted 17/04/2023)

- Roetell, (2021). When Were Glass Bottles Invented – Roetell When Were Glass Bottles Invented
- Runners, (2023). Running. Todo sobre el Running | Runners (Consulted 17/04/2023)
- Runners Chile, (2019). ¿Cuántas disciplinas de running existen? - Runners Chile (Consulted 17/04/2023)
- Serna, L. and Rodriguez, A. and Alban, F. (2003). Polylactic Acid (PLA): Properties and Applications. Vol 5. 11. Vista de Ácido Poliláctico (PLA): Propiedades y Aplicaciones (univalle.edu.co) (Consulted 17/04/2023)
- SMF (2023). Plastic injection recycling SMF injector . (Consulted 17/04/2023)
- Sierra & Plazas, Guillén & Rodríguez (2010). Quality control guide of the packing employed in the pharmaceutical, cosmetics and food industry. Protocolo para el control de calidad de envases de plástico, utilizados en la industria farmacéutica, de cosméticos y de alimentos (scielo.org.co)
- Sintac, (2022). Polietileno de Tereftalato: Usos y Características ♻ SINTAC (Consulted 17/04/2023)
- Souhu (2020). Concept and classification of sports events. https://www.sohu.com/a/399552747_120582168 (Consulted 17/04/2023)
- Schmitz, R. (2017). In Fast-Paced China, Marathon Craze Is Off And Running (Despite A Clumsy Start) : Parallels : NPR (Consulted 17/04/2023)
- Stadler, (2020). PET recycling: towards a circular economy - RECYCLING magazine (recycling-magazine.com) Consulted 30/05/2023.
- Statista, (2023). Global plastics industry - statistics & facts | Statista (Consulted 17/04/2023)
- saporti & robins**,** (2021). scaling up water reuse: why recycling our wastewater makes sense.https://blogs.worldbank.org/climatechange/scaling-water-reuse-why-recycling-our-wastewater-makes-sense
- Stewart, J. (2017). Ooho! is an Edible Water Bottle Made from Seaweed (mymodernmet.com) (Consulted 17/04/2023)
- ShBarcelona, (2022). All you need to know for the Barcelona Marathon 2022 (shbarcelona.com) Consulted 30/05/2023.
- Stuart, M. (2018). Tetra Pak and Veolia partner to get all beverage carton components recycled Tetra Pak and Veolia partner to get all beverage carton components recycled Ethical Marketing News (Consulted 17/04/2023)
- Tan, N. (2017). Ooho! Edible water blob may replace plastic bottles (Image). Ooho! Edible water blob may replace plastic bottles | The Petri Dish (Consulted 17/04/2023)
- Tong, D. and Li Y. (2022). 2022 China running sports industry report: running crowd accounted for 26% of the total users of the sports and fitness industry http://ent.people.com.cn/n1/2022/1128/c1012-32576064.html (Consulted 17/04/2023)

- The food tech, (2018). Materiales multicapa - THE FOOD TECH - Medio de noticias líder en la Industria de Alimentos y Bebidas
- Uamerica, 2019. Budget Type. https://www.uamerica.edu.co/ppto/tipos_presupuestos/pres_prod.htm (Consulted 16/6/2023).
- United Nations, International Decade for Action, Water for Life https://www.un.org/zh/waterforlifedecade/scarcity.shtml (Consulted 17/04/2023)
- United Nations, (2019). Global commitment to reduce single-use plastics. Compromiso mundial para reducir los plásticos de un solo uso | Noticias ONU (Consulted 17/04/2023)
- United Nations, (2023) Worldwaterday: Accelerating change. https://www.worldwaterday.org/ Consulted 17/04/2023
- United Nations, (2016). Sport Promoting Human Development and Well-Being: Psychological Components of Sustainability | United Nations (Consulted 17/04/2023)
- Unisport, (2018). Características más importantes de un evento deportivo (unisport.es) (Consulted 17/04/2023)
- Urbanore.com (2023). Zero Waste Resources https://urbanore.com/ Consulted 17/04/2023
- United Nations, (2021). El plástico, que ya ha atragantado nuestros océanos, terminará por asfixiarnos a todos si no actuamos rápidamente | Noticias ONU (un.org) (Consulted 31/05/2023)
- UPB sostenible, (2020). Descubre como reducir el plástico de un solo uso | UPB (Consulted 17/04/2023)
- Vibhuti Sharma, Rutika Sehgal, Reena Gupta, (2021) Polyhydroxyalkanoate (PHA): Properties and Modifications, Polymer, Vol 212 https://doi.org/10.1016/j.polymer.2020.123161.
- Wärenhed, S. (2023). The Importance of PET Recycling: Saving the Environment One Bottle at a Time - Orwakbalers (Consulted 17/04/2023)
- Williams, H. and Kelly, P. (2018). Polihydroxyalcanoates biosynthesis, chemical structures and applications. New York. Chapter 1 (unesp.br) (Consulted 17/04/2023)
- World Economic Forum (2023). Zero waste guide. What is zero waste? | World Economic Forum (weforum.org) . (Consulted 17/04/2023)
- WHO (2011). Guidelines for drinking-water quality, 4th edition Guidelines for drinking-water quality, 4th edition (who.int) (Consulted 17/04/2023)
- WHO, (2017). Diarrheal diseases. Enfermedades diarreicas (who.int) (Consulted 17/04/2023)
- World's Marathons, (2023). London Marathon, 23 Apr 2023 | World's Marathons (worldsmarathons.com) Consulted 30/05/2023.

- Zero Waste Action Plan (2020). Zero Waste Action Plan. Turning the vision of the circular economy into a reality for Europe. Masterplan_Castellano_2020_07_07_zwe_zero_waste_cities.pdf (Consulted 17/04/2023)
- Zulfiqar Ali Raza, Sharjeel Abid, Ibrahim M. Banat, (2018) Polyhydroxyalkanoates: Characteristics, production, recent developments and applications, International Biodeterioration & Biodegradation, Vol 126, 45-56, ISSN 0964-8305, https://doi.org/10.1016/j.ibiod.2017.10.001.