POLITÉCNICO DE LEIRIA | ESCOLA SUPERIOR DE TURISMO E TECNOLOGIA DO MAR

Production of packaged mineral water: current sustainability and environmental resilience practices in Portugal.

Jonathan Andrés Chérrez Vega

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Production of packaged mineral water: current sustainability and environmental resilience practices in Portugal.

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Dissertation for obtaining the Master's Degree in Food Quality and Safety Management

Master's Dissertation under the supervision of Susana Filipa de Jesus Silva (PhD) and Alexandra Augusta Ramos Lopes da Cruz (PhD)

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"Desventurado o povo onde a juventude é humilde com o tirano, onde os estudantes não fazem tremer o mundo".

Juan Montalvo

Title: Production of packaged mineral water: current sustainability and environmental resilience practices in Portugal.

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ABSTRACT

Portugal has abundant nascent mineral water, but the extraction, bottling, transport, and disposal of bottled water have significant environmental impacts due to plastic use. The research aims to determine if the Portuguese bottled water industry implements sustainability and environmental resilience practices on it chain value. The methodology includes bibliographic research and interviews with industry technicians, focusing on 19 leading brands to formulate variables and indicators based on hypotheses. The identified problem is the potential noncompliance of the Portuguese bottled water industry with SDG goals, which could result in reduced competitiveness among environmentally conscious consumers.

The sales and production of natural mineral and spring water in Portugal, reached 224 million euros and over 1,490 million liters respectively in 2019. The bottled water sector in Portugal is strictly regulated for product safety and quality, but there are initiatives promoting tap water consumption and reducing packaging waste. The importance of analyzing the industry's practices is emphasized to identify strengths and weaknesses in terms of sustainability and environmental resilience, leading to targeted solutions to enhance environmental performance and promote long-term sustainability.

Mineral water companies can contribute to the SDGs by promoting sustainable production, reducing water and energy consumption, and implementing low-carbon mobility plans, among other activities. It is crucial to prioritize prevention over recovery to reinforce resilience and manage risks effectively. Regulations and laws must be examined to identify relevant environmental issues and assess how they integrate sustainability and resilience. Companies should invest in infrastructure, collect real-time data, and implement action plans and protocols to prevent new risks. The dissemination of sustainability guides and self-monitoring of water quality are essential, and stakeholder involvement is necessary for resilience. Complementary studies are suggested, including a consumer survey and a comparative study between mineral water companies in Portugal and other countries.

Keywords: mineral water, bottling, environmental impacts, SDG goals, sustainability, resilience.

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LIST OF ACRONYMS

APIAM: Associação Portuguesa dos Industriais de Águas Minerais Naturais e de Nascente

PVC: Polyvinyl chloride

PET: Polyethylene terephthalate

RPET: Recycle Polyethylene terephthalate

LDPET: Low Density Poliethylene

MDGS: Millennium Development Goals

SDG: Sustainable Development Goals

DECO: Defesa do Consumidor

HACCP: Hazard Analysis and Critical Control Point

CCP: Critical Control Points

CHAPTER I - INTRODUCTION

Water is essential for life; all living beings, including humans, depend on water for their livelihoods. Currently, two thirds of the planet is covered by water and only the remaining third corresponds to dry land. In nature, water is found in three physical states: solid, gas and liquid (as in seas, lakes, lagoons, aquifers, etc.). (Associação Portuguesa dos Industriais de Águas Minerais Naturais e de Nascente [APIAM], 2015).

Indeed, water is used on a daily basis by people and in addition to its recognized role in health, it has a function in the modern economy, therefore, sustainable water management is one of the biggest challenges today, lack of water or water without quality decrease the life quality of the populations.(Sezinando, 2013).

One of the most important properties of water is its ability to dissolve different substances in greater quantities than any other liquid, considering it as a universal solvent, water serves as a vehicle for essential nutrients for the survival of plants and animals, it also degrades rocks incorporating and transporting soluble salts and minerals.(Sezinando, 2013).

The overall amount of water on the planet remains stable, it is constantly renewed. This closed system constitutes the hydrologic cycle or water cycle and is a consequence of the principle of water conservation in its three phases. The hydrological cycle (Figure 1) describes a sequence of natural phenomena where water is released into the atmosphere through evaporation at the surface and returns to the surface by solid or liquid precipitation. Along the way, water may be retained on the surface, infiltrate, form part of rivers, or evaporate back into the atmosphere. (Kuchment, 2012).

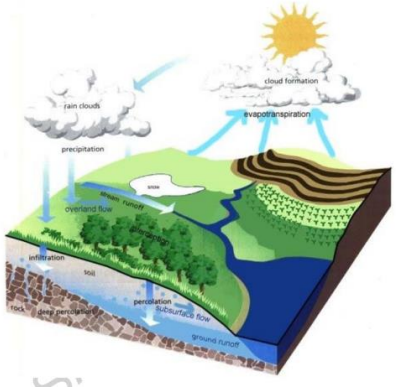


Figure 1. Terrestrial hydrological cycle. Source: (NASA, n.d.)

Throughout the twentieth century, due to the increase in population and therefore the increase in waste and residues of society itself, led to an increase in the pollution of water sources, all these events led international organizations such as UNESCO to declare water as a strategic resource of the XXI century. (APIAM, 2015).

1.1 Mineral water

As part of the water cycle (Figure 1), an important part of the water that reaches the earth's surface in the form of rain or snow runs off in torrents or rivers. Part of this water infiltrates into the ground, another part returns to the atmosphere in the form of water vapor as a result of the heating of water in rivers and lakes or plant transpiration. That small amount that infiltrates is known as groundwater. It is this small fraction that generates natural mineral and spring water; as it is so limited, it is necessary to protect it, preserve it and enhance its value. (APIAM, 2015).

During water infiltration, a slow and complex process of natural filtration takes place, which eliminates microorganisms as well as suspended substances and enriches the water with salts and minerals. (Sezinando, 2013).

According to Associação Portuguesa dos Industriais de Águas Minerais Naturais e de Nascente [APIAM], there are three aspects that influence the water mineralization result:

1. The rock type in which the water circulates through, by dissolving minerals, the water absorbs the corresponding salts that will later make it have unique characteristics.
2. The time of permanence and contact of the water with the subsoil can be from a few hours to several thousand years. Usually the longer the contact time, the higher the degree of mineralization.
3. Aquifer temperature and depth. The greater the depth of subway circulation, the higher the temperature and consequently the greater the quantity of salts and minerals.

The five elements that constitute this "subway laboratory" are therefore: water, rocks, space, time and temperature. A sixth, somewhat more punctual and less important element can be included, which refers to regions where there is significant volcanic and seismic activity. In these areas there may be the presence of carbon dioxide, fluorine or lithium.(APIAM, 2015).

(Sílvia Cristina Feliciano Guerreiro Sezinando, 2013) adds that Portugal is one of the richest countries in the world in terms of variety and quantity of mineral water nascent, many of these waters are used and valorized both in the thermalism and bottling aspects. According to APIAM data, Portugal is the third country in Europe after France and Italy regarding the exportation of natural mineral and spring waters, taking into consideration the volume of national production, there are no two groundwaters identical, each natural mineral water and spring water are identified by their origin and unique path, as well as the history of the subsoil, so to identify them should not be considered only the major components (sodium, calcium, bicarbonates, etc.).

Natural and spring waters are the only ones that maintain their original purity after bottling, which means that no physical-chemical treatments or additives are allowed. Natural mineral waters are considered to be in the public domain while spring waters are privately owned. (Sezinando, 2013).

Worldwide, there are more than three thousand brands of bottled water, and the market growth trend has led to the appearance of new companies and brands. Although the production industry is experiencing transformations with the arrival of new trends and competitors. (Cristine et al., 2010).

1.1.1 Historical context

Historically, European culture has been rooted in a special dedication towards water and an attention to its richness and diversity. The cult of water as a natural and specific product dates back to the early Roman Empire. This civilization associated the preservation of the original quality of water with multiple properties related to health and well-being. As part of this tradition, the natural mineral and spring water sector has developed into an economic activity of great economic, social and environmental value. (APIAM, 2015).

In the 18th century, the healing properties of natural mineral waters became a subject of interest. At a time when disease prevention was limited, natural mineral waters were increasingly seen as an important health care resource. By the 19th century, thermal resorts had become popular destinations for the wealthy, who visited them to bathe and enjoy the therapeutic benefits of mineral water. At that time the water was not always safe to drink. Waterborne diseases, such as cholera and typhoid fever, encouraged people to seek natural, uncontaminated drinking water from springs. (Natural Mineral Waters Europe, 2022).

Nevertheless, the bottling and marketing of natural mineral waters began in a rudimentary form in Europe in the mid-16th century, with the mineral waters of Spa in Belgium, Vichy in France, Ferrarelle in Italy and Apollinaris in Germany.(Maraver, 2019).

The first mechanical capping machine was invented in France in 1840, while bottling plants appeared throughout the continent at the end of the 19th century. Other European countries also adopted the trend of bottling waters at source, and these waters were sold as medicines in pharmacies until the beginning of the 20th century. (Maraver, 2019).

1.1.2 Mineral water classification

Lourenço & Ribeiro, 2004 proposes three different types of bottled drinking water: natural mineral waters, spring waters and other water typologies for human consumption. In Portugal, the bottling industry only extracts, conditions and markets natural mineral waters and spring waters. Table 1 presents the main characteristics of each type and their differences can be observed.

Table 1.

Bottled water and its characteristics. Summarize from (Lourenço & Ribeiro, 2004).

	NATURAL MINERAL WATER	SPRING WATER	OTHER BOTTLED WATER
GROUND CIRCULATION	YES	YES	NO
NATURAL CONDITION AND ORIGINAL PURITY	YES	YES	NO
CAPTATION IDENTIFICATION	YES	YES	NO

IDENTIFICATION OF CHARACTERISTIC COMPONENTS	YES	NO	NO
BOTTLING AT THE SOURCE LOCATION	YES	YES	NO
STABLE AND PERMANENT CHARACTERISTICS	YES	NO	NO
PROHIBITION OF CHEMICAL TREATMENTS AND/OR ADDITIVES	YES	YES	NO
PROTECTION OF AQUIFERS	YES	YES	NO
FOOD PRODUCT	YES	YES	YES
SUITABLE FOR CONSUMPTION	YES	YES	YES

Natural mineral waters have characteristics that distinguish them from others, such as the stability of physical-chemical parameters, for example, which have no recommended or admissible limits, only some trace ions have concentration limits in accordance with (EU DIRECTIVA 2003/40/CE DE LA COMISIÓN, 2003) from May 16th.

In the case of nascent waters (as well as other waters for human consumption), the concentration limits of the parameters are defined in the "Decreto Lei (243/2001,) from 5th of September".

Mineral waters specifically can be subclassified according to the (Decreto-Lei n.o 156/98, 2008) from 6th June:

a) **Natural mineral water. -** circulating groundwater, considered bacteriologically suitable, with stable physicochemical characteristics at the origin within the margins of natural fluctuations, which may eventually have beneficial effects on health and which is distinguished from ordinary drinking water by its original purity and nature.
b) **Sparkling natural mineral water. -** water that releases carbon dioxide spontaneously and perceptibly under normal conditions of temperature and pressure, either at the spring or after bottling, and is classified into three categories:

    Carbonated natural mineral water. - water whose carbon dioxide content from the aquifer after decanting, if any, and bottling is the same as at the origin,

taking into account, if applicable, the reintroduction of a quantity of gas from the same aquifer equivalent to that released during these operations and subject to the usual technical tolerances.

Natural mineral water fortified with natural carbon dioxide gas. - water whose carbon dioxide content from the aquifer itself, after decanting and bottling, is higher than that found in the spring.

Natural mineral water with added carbon dioxide. - water to which carbon dioxide has been added from a source other than the aquifer from which it originates.

c) **Spring water. -** groundwater, considered bacteriologically suitable, with physical and chemical characteristics that make it suitable for human consumption in its natural state.

1.1.3 Mineral water and health

Water, in general, is essential for the functionality of the human body, representing 50 to 60% of its weight. It is the solvent for biochemical reactions, the medium for transporting nutrients and other materials to tissues and organs, the vehicle for excretion of metabolic products and the agent for regulating body temperature. Inadequate hydration implies an insufficient amount of water for the functioning of the organism and is related to the development of different diseases, mainly at the renal, cardiovascular and digestive levels. (Paedez, Padrão and Macedo, 2009).

The human organism can produce most of the vitamins it needs, but all minerals are essential and must be supplied through diet or food supplements, natural waters hydrate and satiate thirst without calories and have a specific chemical composition that includes mineral salts and trace elements. (Sezinando, 2013).

To maintain the body's cellular function, it is essential to regulate the amount of water in the organism. A complex mechanism is responsible for stabilizing total body water and the relationship between the volume of water inside and outside the cells. Sodium, which is the

main extracellular ion, and potassium are the main chemicals involved in this process.(APIAM, 2015).

Depending on circumstances such as age, gender, weather conditions or physical activity, among others, specialists recommend drinking an average daily amount that can vary between 1.5 and 3 liters. It is better to drink water several times a day at regular intervals, rather than drinking large quantities at once. (APIAM, 2015).

It is necessary to consider that the excessive consumption of mineral water, especially in people with a genetic tendency to form kidney stones as well as people with a predisposition to or latent hypertension, can be detrimental to the development of these diseases, especially water with a high content of sodium ions and carbonates. (Machete, 2015).

1.2 Bottled mineral water in Portugal

With the fall of the Roman Empire and the arrival of the barbarian peoples of northern Europe, the tradition of mineral waters associated with cures was not lost. The Arabs also made profuse use of mineral and thermal waters and, in the Middle Ages, Christians and Jews adopted similar behaviors.(Maraver, 2019).

In ancient Lusitania, the Romans were undoubtedly the pioneers of hydrology, which later, during the reign of King Afonso Henriques, began to gain importance with the founding of health care establishments.(APIAM, 2015).

1.2.1 The history of mineral water in Portugal

The use of natural mineral water has accompanied the history of Portugal since its foundation. In 1207, King Afonso Henriques stayed at the bathing resort of S. Pedro do Sul (ancient Alafões) to recover from a leg fracture suffered during the siege of Badajoz. D. João I was in the waters of Taipas. D. Leonor de Lencastre, wife of D. João II, had a bathing hospital built in 1485, in the district of Óbidos, made of "caldas", which came to be called Caldas da Rainha. The king, then, would have used the waters of Caldas de Monchique.(APIAM, 2015).

These historical facts do not necessarily mean that, in those times, bathing resorts were very popular, since the majority of the population did not have the necessary living conditions to do so. However, it does mean, that there has always been the conviction that water has curative properties. It is especially from the 16th century that the use of water for curative purposes intensified in Portugal, as it did all over the world.(Sezinando, 2013).

Gradually, what was empirical observation yielded to science, and advances in analytical chemistry were reflected in a greater knowledge of mineral waters. The first historically significant scientific studies on water date back to the 18th century.

In 1726, Francisco da Fonseca Rodrigues, physician to Dom João V, published a book entitled Aquilégio Medicinal. Subsequently, the analysis of some works and lessons given by professors from Coimbra allows us to deduce that the analysis of water marked the scientific activity of chemistry in that university city. The book Elementos de Química, by Vicente Coelho de Seabra, contains a chapter dedicated to the analysis of mineral waters. The author offers a classification of water based on the dissolved substances and the recommended analytical methods.(APIAM, 2015).

During the 19th century, the study of water was extended to the Escola Politécnica de Lisboa and the Academia Politécnica do Porto. Following the interest of scientists and populations, the government tried to protect the medicinal waters, taking actions and ordering laboratory studies, stocktaking and the collection of analytical data. (APIAM, 2015).

1.2.2 Geological diversity in Portugal and association with mineral water sources

Analyzing the Portuguese territory reveals variety and diversity, reflected in its fountains and springs, which gives the country a leading role in the hydrological domain.

Geographically located at latitudes 37-42º north and with the characteristics of moderate climates, Portugal has identified over 400 natural mineral springs and spring waters. (APIAM, 2015).

Regarding the chemical composition of natural mineral waters and spring water, it is possible to identify different regions according to the predominance of the rocks. Granite is the predominant rock in the north and center, up to the Iberian Plateau, which is the oldest relief unit of the Iberian Peninsula and occupies most of the surface of the Portuguese

mainland (including, among others, Serra da Estrela, Lousã, Serra da Gardunha and Alentejo).(Sezinando, 2013).

Trás-os-Montes e Alto Douro

In the Trás-os-Montes region, the slopes of Vidago stand out, with the waters of the same name, the waters of Campilho and the popular Pedras Salgadas. Located in the Alto Tâmega, these waters have circulated for years through the granitic rock and have thus been enriched with mineral salts.(APIAM, 2015).

The exploitation of the springs of Pedras Salgadas, already known since Roman times, did not begin until 1871. Here, for example, Água das Pedras was born. Still in the Trás-os-Montes region, in Sampaio, Vila Flor, a place with a secular and rich history, the waters of Bem-Saúde, marketed under the name of Frize, are found at an altitude of over 500 meters above sea level. These are carbonated, bicarbonated and sodic waters. Figure 2.

Figure 2. Tras-os-Montes and Alto Douro regions. Source: (In-libris, 2023)

Entre Douro e Minho

The waters of Melgaço are located in the Alto Minho region Figure 3, and have been known since Roman times. The first record of the existence of these waters dates back to 1884, but it was not until 1885 that they began to be bottled.(Sezinando, 2013).

In the foothills of the Serra do Gerês, the water of Fastio stands out, known since the beginning of the 20th century for its diuretic and digestive properties, due to its hyposalinity (low mineral salt content), high silica content and slightly sweet and sour taste. These unique

characteristics of Fastio's water are due to the fact that it flows deep into the granite called Terras do Bouro, before emerging naturally. This type of granite is exclusive to this rainy and very mountainous region of northwest Portugal, recognized for the fact that it is home to the country's only national park: the Peneda - Gerês National Park. (APIAM, 2015).

Figure 3. Old Entre Douro e Minho region of Portugal. Source: (In-libris, 2023).

Beiras

On the slopes of one of Portugal's mountain ranges, the Serra do Caramulo, the Caramulo water is born. The Caramulo water spring is located in a vast and protected granitic area of the mountain, where nature is especially preserved.(APIAM, 2015).

From the center of the country comes the famous Luso water, whose origin is in the rainwater that infiltrates the Serra do Buçaco, in rocks formed almost exclusively by quartz, i.e. quartzites. The fact that the quartzites are located at high altitude allows them to benefit from the high rainfall characteristic of these areas. When these rocks were formed more than 400 million years ago, circumstances left them very compact. In the meantime, a dense network of fractures developed that allowed the storage and circulation of water. These two circumstances-a virtually impermeable rock and a thick grid-explain the remarkable concentrated flow of groundwater.(Sezinando, 2013).

Figure 4. Old Beira province in Portugal. Source: (Cutuga, 2021).

Estremadura e Ribatejo

In the western region, some records from 1845 show the existence of two baths by the Alcabrichel river, in the town of Maceira, only 50 km from Lisbon. The first official analysis of the waters of the Vimeiro was carried out in 1868 by Charles Lepierre. The waters of the Vimeiro have been developing and with them the whole region to the point of becoming the main source of income of the nearest villages. (Sezinando, 2013).

The region of Caldas da Rainha is strongly associated with thermalism; it was here that the world's first thermal hospital built in 1482, a hospital in which thermal waters were used to treat illnesses. It is in this region that the water of the Arieiro spring comes out.(Sezinando, 2013).

Alentejo e Algarve

In the Alto Alentejo, Castelo de Vide has always been known for its water. The Água da Fonte da Mealhada (formerly known as Água de Mesa de Castelo de Vide), classified as bicarbonated, calcium and magnesium, and the Águas Fontes do Ribeirinho and do Arco, classified as hyposaline, have been bottled for dozens of years. (APIAM, 2015).

In the Algarve, numerous important archaeological finds in areas adjacent to the springs of Monchique have led specialists to affirm that the baths were used by the Romans from the 1st century on. Analyzed for the first time in 1789 by Dr. Dimas Tadeu, the Água de

Monchique has since been the subject of several medical and chemical studies.(Sezinando, 2013).

Figure 5. Old provinces division of Portugal. Source: (Cutuga, 2021).

1.2.3 Bottled mineral water industry in Portugal

In the 19th century, in Portugal, as in the rest of Europe, baths were frequented mainly by the aristocracy and the bourgeoisie. However, mineral water was everywhere believed to have curative properties. Indeed, it is in the context of thermalism that the market for natural mineral water emerged, reflecting the awareness of health benefits, as well as the concern to ward off the diseases and contaminations.(APIAM, 2015).

This idea was at the origin of the success of the mineral water bottling industry. Analyzed, studied, filtered, protected and subjected to filling processes close to the springs, in industrial plants. (Machete, 2015).

In Portugal, the benefits of thermal waters, in the treatment of diseases such as skin, rheumatism, respiratory tract and digestive system, naturally led to the idea that it would be beneficial to drink these waters and sell them in bottles and containers.(Sezinando, 2013).

This activity began in the transition period between the 19th and 20th centuries. Then, as today, the idea was to bring water to consumers in the most complete state of purity. Several documents remain from that period that attest to the concern for ensuring the conservation and sanitation of the bottling establishments.(APIAM, 2015).

In the sixties, there was already a group of companies dedicated to the bottling of natural mineral water and total sales already reached fifteen million liters. At this time, more

precisely in 1963, the Industrial Association was formed, which is at the origin of the current APIAM.

In the 1970s, the sector experienced a strong commercial impulse. In 1970, total sales reached twenty million liters, and by 1975, they had exceeded sixty million liters. New boreholes and drillings were carried out, new manufacturing facilities were built and the first modern laboratories appeared. In the early 1980s, traditional glass found an alternative: PVC (polyvinyl carbonate) plastic containers. Sales increase significantly, exceeding 200 million liters in Portugal.(Merketeer, 2021).

Since then, the activity, which has been framed in specific European legislation since Portugal's accession to the EU, has continued to grow, evolve, innovate, invest and mature. As a result, it has reached the 21st century with brands of enormous prestige and water of exceptional quality that are available to the consumer, both on the domestic and international markets.(APIAM, 2015).

1.3 Packaged mineral water industry and production process

Natural mineral water has its own history, with a geological journey that begins after precipitation and infiltration into the subsoil. This gives it a unique and stable mineral composition over the years, which depends essentially on climatic factors and the geology of the terrain, meaning that there are no two mineral waters identical. Therefore, natural mineral water remains pure and unaltered until the moment it is collected. (Nestlé, 2020).

The main stages are as follows (Figure 6):

a) **Collection and filtration. -** Following the natural water cycle, after evaporation, condensation and precipitation, the water infiltrates through the ground, feeding the springs through a completely natural filtration and mineralization process. The collection works involve the isolation of the spring in order to avoid contamination of the water to be bottled. This water then goes through a filtration pretreatment. The purpose of these pretreatments is to maintain the purity and richness levels characteristic of the water at the collection point and to protect it from possible risks of contamination by dust, bacteria and algae.(Garcia, 2008).

b) **Tanks and pipelines. -** These tanks are reserve water reservoirs that allow the operation of the filling installations; they are hermetically sealed, allowing periodical unloading and cleaning, and also have sampling valves. The pipes are made of unalterable materials that do not modify the characteristics of the water, i.e. PVC, stainless steel, ceramics, etc. The pumps are also made of stainless steel. In order not to alter the characteristics of the water, the valves and gaskets should not have contact with the water, and if this is not possible, they should be made of materials with special texture and composition, such as Teflon. The entire piping system must be able to be stabilized and purged at any time. In addition, the piping system must have sampling valves, in order to be able to take water samples to detect specific contamination.(Garcia, 2008).

c) **Bottling, labeling and coding. -** The water then goes to the bottling lines in different presentation formats (plastic bottles, glass bottles, gallons, etc. of different capacities). In some companies, the plastic containers are manufactured "in situ", but they are usually purchased from an external distributor. The filling and capping area is isolated from the rest of the installations, so that the area is aseptic (air filtration and renewal, impermeable floors and walls, etc.). The automatic filling machines that are inside this area are a risk point, and therefore, exhaustive sterilizations are carried out. (Garcia, 2008).

   The importance of washing and disinfecting the containers before filling is also emphasized. For this purpose, the composition and temperature of the washing water, as well as the detergents, bactericides and additives used are monitored and controlled. The caps must also be sterile, either because this operation is carried out after their manufacture or before their use. After packaging, an inspection of the filling of the containers is carried out, labeling and coding those that comply with the quality parameters.(Garcia, 2008).

d) **Wrapping, boxing, palletizing and storing.-** Depending on the type of container, they pass to the low-density polyethylene film (LDPE) wrapping stage or to the case packing stage, after which they are palletized and stored.(Garcia, 2008).

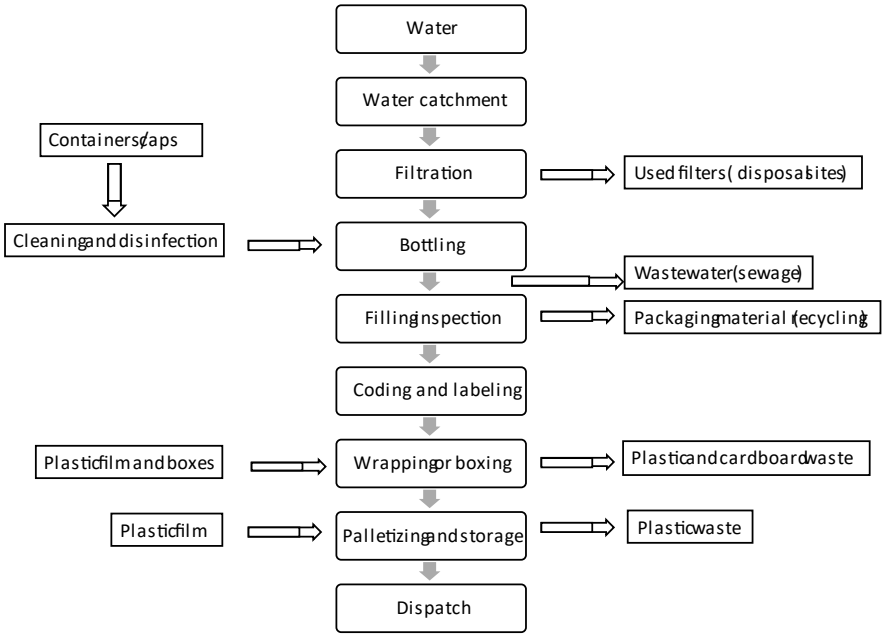


Figure 6. General diagram of the mineral water production process.

1.4 Environmental impact of bottled water

The consumption of bottled water has grown in recent years, even in places where the public water supply guarantees quality drinking water. The extraction, bottling, transport and subsequent disposal of this product causes various environmental impacts. (Fundación EROSKI, 2017).

The industrial extraction of water from its places of origin can cause serious environmental and economic imbalances, especially in developing countries with drought problems. The bottled water then has to be transported to its place of consumption, sometimes for several kilometers. Bottled water also uses non-renewable fuels. Most bottles are made of polyethylene terephthalate (PET), a plastic derived from petroleum. Every year, some 2.7 million tons of plastic are used worldwide to bottle water. In addition, this type of plastic releases certain substances such as antimony or bisphenol A overtime.(Fundación EROSKI, 2017).

1.5 Environmental sustainability

In 1980, the United Nations introduced the term sustainable development into the international debate in the document "The Conservation Strategy", subtitled "Conservation of present resources for sustainable development". Just a few years later, in 1987, former Norwegian Prime Minister Gro Harlem Brundtland raised the warning in the report "Our Common Future", which gave birth to and institutionalized the concept of sustainable development, which was subsequently incorporated into all the UN's programs and served as a central theme for major international meetings such as the Earth Summit held in Rio de Janeiro in 1992. (Santiso, 2004)

Sustainable development, as defined in that document, is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development focuses on the concept of needs, in particular the essential needs of the world's poorest people, which must be given priority, and on the idea of establishing certain criteria and limitations so that economic growth does not further degrade our environment, the defense of which is no longer a national or local task, but a global issue. (Santiso, 2004).

The former Prime Minister of Norway, member of the United Nations Panel of Experts on Global Sustainability, explained at a conference organized by the Agbar Foundation on the occasion of World Water Day 2015, that the traditional separation between the public and private sectors is becoming increasingly irrelevant, so that collective actions will be crucial to face the dangers of climate change and promote a green and circular economy, which allows the preservation of resources and their reuse. (Santiso, 2004).

Not only the public service system and society as a whole have to be globally responsible, but also the corporate community. Companies are also obliged to show an example, because society demands behavior that fully incorporates a new virtuous circle based on the green economy and the reuse of waste. Citizens are the shareholders of the common good, particularly water. We must therefore be able to reflect the full environmental and human costs of economic decisions and establish signals, warnings and criteria that make clear the consequences and costs of both action and inaction.

At the end of September 2015, the UN approved in New York the 17 Sustainable Development Goals (SDGs). Their purpose is to set the post-2015 agenda, which means they constitute a new action plan to continue and complete the work of the former MDGs (Millennium Development Goals) up to 2030. The great innovation they present is their special emphasis on the involvement of companies of all sizes and sectors to achieve a sustainable and inclusive economy. (Santiso, 2004)

Regarding water, three of the new goals for 2030 are closely related to its use and enjoyment: ensuring its availability and sustainable management, as well as sanitation; conserving oceans and marine resources; and ensuring access to sustainable energy.(Santiso, 2004).

1.6 Environmental Resilience

Related to these concepts, there has been much debate about the definition, application and evaluation of the term resilience since the work of Hashimoto et al. (1982). Resilience has many subtly different definitions and has been elaborated in different social, technical and socio-technical frameworks, for example (Butler et al., 2017) considers the concept of resilience as "the degree to which the natural system minimizes the magnitude and duration of disturbances over exceptional conditions"; essentially, it is a measure of how the system behaves when subjected to unexpected threats.

Resilience is a broad concept that measures the propensity of ecosystems to maintain their main traits after disturbance and is related to systemic diversity, complexity and interconnectedness, suggesting that human impacts that reduce these properties should be avoided.

If we refer to Sustainable Development, we necessarily incorporate the three dimensions of interaction: in the economic, social and environmental fields. Therefore, the concept of resilience understood in the environmental and social field is key as an indicator of the possibilities of greater understanding in the diagnostic processes and, therefore, in the systemic characterization of the dynamics of ecosystems at the spatial-territorial level, the possible interactions and exchanges between social and natural systems (their criticalities and potentialities).(EcuRed, 2010).

1.7 Sustainability and environmental resilience variables and indicators in the value chain of production companies.

The sustainability and environmental resilience of production companies in the value chain are critical aspects that require careful assessment and monitoring. A range of variables and indicators can be examined to evaluate their sustainability practices comprehensively.

(Godínez et.al., 2010) states that policy, mission, and vision statements serve as the foundation for sustainable operations, providing a strategic direction and long-term goals towards sustainability. Corporate values associated with the environment signify the company's commitment to ecological responsibility and can guide decision-making processes at all levels, this relates to higher education institutions, but can basically be extrapolated to all companies as well.

(Torres and López, 2021) in the considerations of environmental resilience indicators for the city of Valencia under a sustainable development sustainable development approach, it names a series of environmental practices encompass a wide array of initiatives, including waste management and recycling programs, energy efficiency measures, adoption of clean technologies, and the promotion of circular economy principles. These practices demonstrate the company's tangible efforts to reduce its environmental footprint and promote sustainable resource utilization, Water and energy consumption are vital indicators to assess resource efficiency and conservation efforts within the production process. Monitoring and minimizing water usage and implementing energy-saving measures contribute to sustainable operations while reducing environmental impact. As well as the adoption of advanced technology and techniques can significantly influence the sustainability and environmental resilience of production companies. This includes the implementation of eco-design principles, the use of renewable energy sources, the optimization of production processes, and the integration of digital solutions for more efficient resource management.

(Joumard and Gudmundsson, 2010) repeatedly states that compliance with environmental legislation is an essential factor, as it ensures that production companies adhere to regulatory requirements and contribute to environmental protection. By complying with relevant laws and regulations, companies demonstrate their commitment to responsible practices and sustainable operations. Also refers constantly that aligning company practices

with the Sustainable Development Goals (SDGs) is another crucial indicator of sustainability efforts. By identifying relevant SDGs and setting targets that contribute to their achievement, production companies demonstrate their commitment to addressing global sustainability challenges, such as climate action, responsible consumption and production, and the protection of ecosystems.

(Joint UNECE/Eurostat/OECD Task Force on Development, 2013) refers that measuring and reducing environmental footprints, such as carbon footprint and water footprint, allow production companies to quantify and manage their environmental impact. These footprints provide valuable insights into the greenhouse gas emissions, water consumption, and other environmental indicators associated with the company's operations, enabling targeted improvements and informed decision-making. By considering these variables and indicators, production companies can holistically assess and enhance their sustainability and environmental resilience within the value chain. This comprehensive approach ensures that environmental considerations are integrated into all aspects of their operations, leading to more sustainable practices and a positive contribution to the wider sustainability agenda.

CHAPTER II - SUBJECT SETTING, OBJECTIVES, AND STRUCTURE.

2.1 Problem Statement and Research Goals

The natural mineral and spring water of subterranean origin can be considered as a food whose properties, mainly mineral, differentiate it from public water supply. As mentioned above, the chemical composition that characterizes it is the mineral content (a result of a slow interaction of rainwater infiltrated into the subsoil and rock minerals).

As referred previously, natural mineral and spring water are resources that the legislation classifies as geological resources, at the same time that it establishes the rules for their use or licensing and springs protection and preservation mainly. The demand for bottled water in Portugal has been growing over the last few years and has conquered a prominent place in the beverage industry. The per capita consumption figures in 2014 were close to 112 liters, within the average values of the European Union. (APIAM, 2022).

In Portugal, the bottling industry extracts or collects, conditions and markets these waters. The process of bottling mineral and spring water is an industrial process that involves several practices that begin with the protection, preservation and valorization of the aquifer where the water is collected and ends when the package product, properly sealed and labeled, reaches the consumer, and the consumer, based on his knowledge and habits, gives the packaging a “final destination”.

The practices of mineral and spring water companies are by nature associated with environmental concerns, because it is an activity that depends on environmental protection. In fact, this is essential to guarantee the natural renewal in quantity and quality of water. It is also controlled by local and international legislation.

The mineral water bottling industry is theoretically aware of the need to preserve nature, defining as a primary objective the balance between environmental interests, consumer requirements and business goals. By assuming this commitment, it has taken measures, carried out a set of activities whose main objective was the minimization of the environmental impact of its activities in the production process and of the residues (mainly packaging) that reach the consumer.

In 1980, the United Nations introduced the concepts of sustainability, sustainable development and later environmental resilience into the international debate, pushing for the implementation of plans and laws designed in favor of these concepts. In order to seek a better quality of life and the universal common good, in 2015 the Sustainable Development Goals were presented, which set goals for all countries to be achieved ideally by 2030. (Ávila, 2018).

The mineral water industry, far from being exempt from these concepts, is impacted and has the obligation to evolve its practices to be in accordance with the parameters of good living based on these values. The sustainable development of the companies implies an adequate management of the water source (aquifer) that implies the action of environmental practices where there is a rational use of the resource so that over time, the water always remains with the same volume and composition, in addition to the preservation of the environment surrounding the source. Therefore, the mineral water bottling industry must

implement conservation plans, cleaning, care, etc. supported by new techniques, technologies and policies imbued with the concepts of sustainability and resilience. (Butler et al., 2017).

The issue at hand pertains to the potential failure of bottled mineral water companies to incorporate the fundamental principles of sustainability and environmental resilience into their industrial operations. This problematic situation arises from the inadequate implementation or complete absence of these concepts within the companies' manufacturing processes. The failure to embrace sustainability and environmental resilience not only highlights a significant shortcoming in these entities' approach to responsible resource management, but also raises concerns about their overall commitment to minimizing ecological impacts and preserving natural resources. This non-application of essential principles compromises the potential for these companies to operate in a manner that is both environmentally conscious and socially responsible. Addressing this problem necessitates a comprehensive evaluation of current practices, coupled with the implementation of robust sustainability strategies, in order to rectify the lack of alignment between the operations of bottled mineral water companies and the imperatives of a sustainable and resilient future.

The objective of the present study is to examine the extent to which the Portuguese mineral water industry has embraced and implemented sustainability and environmental resilience practices. This investigation seeks to describe and analyze the specific measures that have been adopted within this. By scrutinizing the existing indicators and frameworks employed by Portuguese mineral water companies. Furthermore, if deemed necessary, the research will propose additional activities and strategies that can further enhance the industry's commitment to sustainability and environmental resilience, with a particular focus on aligning these efforts with the United Nations' Sustainable Development Goals (SDGs). The outcomes of this work will provide valuable insights into the progress made by the Portuguese mineral water industry and offer recommendations for advancing its sustainability practices in a manner that contributes to the attainment of the SDGs.

To solve the problem, the following operational objectives were defined:

a) Conduct a bibliographic search of bottled mineral water companies in continental Portugal and their environmental practices.

b) To clarify the concepts of sustainability and environmental resilience and how they can be included in the practices of bottled mineral water companies.
c) Systematically list the current regulations and laws that influence bottled mineral water companies, analyzing how the concepts of environmental sustainability and resilience are integrated in it.
d) Detail the SDGs in which packaged mineral water companies may be involved, detailing objectives and proposed activities or, alternatively, propose some of them.
e) Assess awareness of Portuguese water industry professionals about the importance and knowledge of the concepts of environmental sustainability and resilience and the environmental practices of the companies through interview.
f) To investigate the technology and technique of the process of production of packaged mineral water in Portugal and to create a portfolio of innovative technologies that are being developed worldwide to improve environmental performance of bottled water industry.

2.2 Dissertation structure

The Figure 7 outlines the structured process that was carried out for the development of the dissertation:

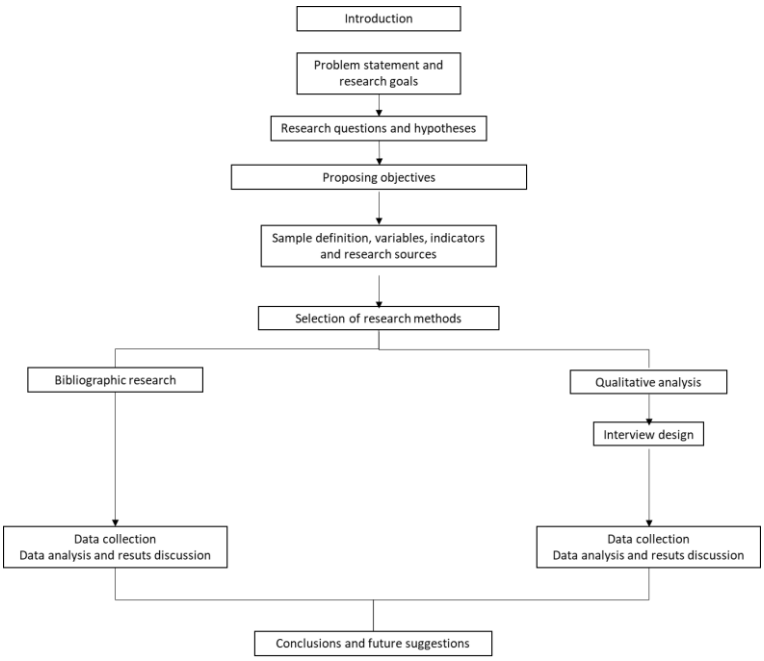


Figure 7. Structure presented on the dissertation

CHAPTER III – INVESTIGATION METHODOLOGY.

3.1 Research question and hypotheses

Based on the literature review, the problem statement, the definition of the objectives and the selection of the research method, the research question and the research hypotheses are established. This is followed by data collection and analysis, and the results are presented. These will confirm or deny the research hypotheses, which will lead to the conclusions and recommendations of the research.(Guimarães & Cabral, 2007).

The research question generated from the present problem is:

Research question

Has Portuguese bottled mineral water industry implemented, in their production process, environmental practices aligned with current concepts of environmental resilience and sustainability contributing towards its competitivity and, population life quality?

The following **research hypotheses** were formulated:

H1: Bottled mineral water companies in Portugal have adopted in their policies, mission and vision the concepts of environmental sustainability and resilience, developing activities and setting goals.

H2: The current legislation under which the bottled mineral water companies in Portugal are governed is in line with the trends of environmental protection and care, mainly aiming at the sustainability of resources and environmental resilience.

H3: The technology and techniques used by the bottled mineral water companies in Portugal are sufficient to develop their activities under the premise of environmental sustainability and resilience.

H4: The communication strategy of both the bottled mineral water companies in Portugal and the government have managed to involve the final customers in the process to close the cycle of resource use in a sustainable and resilient way.

H5: The bottled mineral water companies in Portugal consider sustainable development objectives in their processes and activities, mainly those directly related to water, and set goals to achieve these objectives.

3.2 Sample definition, variables, indicators and research sources

According to data provided by APIAM, the mineral water bottling industry in mainland Portugal consists of 31 units. In order to conduct this research, a sample of 19 companies representing prominent brands of bottled mineral water in the country was selected. It is important to note that this sample was chosen using a "convenience sample" approach. In other words, the selection of companies was based on their accessibility and willingness to participate in the study rather than through a random or systematic sampling method. Although this convenience sample may limit the generalizability of the findings, it nonetheless provides valuable insights into the sustainability and environmental resilience practices implemented by a subset of key players in the Portuguese mineral water industry.

Based on the literature review, the identified problem, and the formulated research question, the crucial variables pertaining to the study were identified. These variables were carefully selected to encompass the key aspects of the research topic. Furthermore, indicators were formulated to measure and assess these variables effectively. These indicators served as quantitative or qualitative measures that provided meaningful insights into the phenomenon under investigation. Additionally, the resources employed to address the identified variables and indicators were thoroughly detailed. This information is described in the following

Table 2.

Table 2.

Variables, indicators and resources used.

Variables	Indicators	Source
Policy, mission and vision of bottled mineral water companies	Corporate values	Bibliographic research including network, press, etc./Interviews with company personnel
	Interest in environmental care	Bibliographic research including network, press, etc./Interviews with company personnel
	Environmental complaints from stakeholders and/or clients	Bibliographic research including network, press, etc./Interviews with company personnel
Environmental practices of the manufacturing plants in	Aquifer management	Bibliographic research including network, press, etc.

Variables	Indicators	Source
the bottled mineral water value chain.	Bottling and bottling waste	Bibliographic research including network, press, etc.
	Water consumption	Bibliographic research including network, press, etc.
	Energy consumption	Bibliographic research including network, press, etc.
Environmental legislation and control to mineral water companies	International Environmental Management Systems Legislation	Bibliographic research including network, press, etc.
	Water classification	Bibliographic research including network, press, etc.
	Executive orders on quality of bottled mineral water	Bibliographic research including network, press, etc.
	National mineral water legislation	Bibliographic research including network, press, etc.
	Control institutions	Bibliographic research including network, press, etc.
Technology and technique associated to the production process of mineral water	Research areas	Bibliographic research including network, press, etc./Interviews with company personnel
	Investigation	Bibliographic research including network, press, etc./Interviews with company personnel
	Extraction technologies	Bibliographic research including network, press, etc.
	Packaging and labeling	Bibliographic research including network, press, etc.
	Distribution systems and processes	Bibliographic research including network, press, etc.
	Waste management	Bibliographic research including network, press, etc.
Environmental communication strategy associated	Communication campaigns	Bibliographic research including network, press, etc./Interviews with company personnel
	Communication networks	Bibliographic research including network, press, etc./Interviews with company personnel
	Media and communication networks	Bibliographic research including network, press, etc./Interviews with company personnel
Environmental sustainability	Knowledge of and compliance with the Sustainable Development Goals (SDGs)	Bibliographic research including network, press, etc./Interviews with company personnel

Variables	Indicators	Source
	Carbon, energy and water footprints	Bibliographic research including network, press, etc./Interviews with company personnel
Environmental resilience	Responsiveness	Bibliographic research including network, press, etc./Interviews with company personnel
	Quality measurement parameters Sustainable Development Goals (SDGs)	Bibliographic research including network, press, etc./Interviews with company personnel

3.3 Bibliographic research

The bibliographic search was done from a structured and professional perspective. At the beginning of the bibliographic search process, it was not clear what was going to be pertinent or relevant; however, as the process progressed, the perspective improved and the topics of real interest began to be defined. Therefore, it became necessary to delimit the search and know when to stop, even if there are a number of questions to be answered before addressing the main topic of the project. (Luna et al., 2014).

The material used can be considered as "recognized", meaning that it is carefully reviewed by experts before being published. Theses, reports, journal articles, technical reports, etc. are detailed. In these documents useful information can be found. Sometimes it is difficult to access these because the publication policy depends on the entity that makes them, in some cases the technical reports provide information for a particular application and promote a certain brand or product.

The Internet appears as a valuable source of information, but should be treated with extreme caution, because it can take hours of searching without finding anything of value and the material found can be unreliable. In order to define the research domain, search equations (expressions consisting of keywords and logical operators) that include specific terms of the topic to be investigated should be used, in addition, semantic and citation patterns should be studied and the cognitive structure should be identified in the first instance in order to determine the main lines of research developed worldwide for the study of the topic.(Luna et al., 2014).

For instance, statistical data and other general information was obtained from sources such as INE, DECO and the "Associação Portuguesa dos Industriais de Águas Minerais Naturais e de Nascente" (Portuguese Association of Natural and Natural Mineral Waters Industry). In terms of regulations and legal aspects, the information was consulted from the respective national and international decrees and laws available on official websites. The information of the companies to be studied was obtained from their official websites as well as from online news and other sources.

In addition, thesis and dissertations, as well as books and journal articles, also form part of the bibliographic support of the research. All this information, complemented with the data obtained from the representatives of the companies interviewed.

3.4 Interviews

Interviews are distinguished by the application of the fundamental processes of communication and human interaction. These processes allow the researcher to extract from interviews information and elements of reflection that are more complex and detailed than those that can be included in a survey. The interview method is always associated with a content analysis method. During the interviews, the objective is, in fact, to bring out as many elements of information and reflection as possible, which will serve as material for the analysis.(Guimarães & Cabral, 2007).

This study faced certain limitations regarding data collection, resulting in the conduct of just two interviews with technical personnel, specifically production and quality managers, representing the most prominent mineral water companies in Portugal. These companies were part of the sample selected for data collection in section 3.2. The restricted number of interviews can be attributed to challenges encountered in accessing these individuals and their reluctance to share information.

The interviews were conducted via Zoom during the months of July and August 2022, each lasting approximately 40 minutes. It is important to note that recording of the interviews was prohibited, and both the interviewees and their respective companies requested anonymity. Consequently, the analysis and discussion of the study's findings will exclude personal names and any identifiable information derived from the interviews. The interview templates utilized in these discussions are provided in Annex 1. Despite the limitations

imposed by the restricted number of interviews, their insights make valuable contributions to the overall conclusions and outcomes of this research endeavor.

CHAPTER IV – RESULTS AND DISCUSSION.

4.1 The bottled mineral water industry in Portugal

In Portugal there is a great diversity of recognized waters as Natural Mineral Waters, to which, since ancient times, unique capacities are attributed for the treatment and prevention of certain diseases, as well as for the promotion of health and well-being.

Natural mineral waters are geological resources formed under specific geological conditions, defined according to Law 54/2015, of June 22, as "bacteriologically suitable waters, of subterranean circulation, with stable physico-chemical particularities in origin within the range of natural fluctuations, from which possible therapeutic properties or favorable health effects may result".

The distribution of water in mainland Portugal is uneven, with a greater presence of this kind of water in the north and center of the country, which is mainly due to the geological and structural features that characterize the territory. These water bodies are part of the national heritage and represent a considerable economic and social added value for the region in which they are found, given that the type of use they provide (thermal spas, bottling and geothermal energy) has an impact on the areas of health and wellness, environment, tourism and energy, depending on their respective particularities. (Direção Geral de Energia e Geologia, 2023).

The following Table 3 is a list and general description of the main brands of the most important mineral water companies in mainland Portugal. It should be noted that within these brands, Sociedade Central de Cervejas e Bebidas SCC, Compal Sumol and Superbock Group have two and three brands in the market, respectively:

Table 3. General information about the main brands and companies of mineral water in Portugal.

Brand/Company of bottled mineral water	General Information	Data source
NATURAL MINERAL WATER		
ALARDO	**Location:** Castelo Novo, Fundão, Castelo Novo district**.** **Type of water:** low mineralized, low in sodium**.** **Description:** the exploration of the area was granted in 1922, from 2011 it was attributed to the Water Bunkers group, which with an investment of more than two million euros updated the brand and modernized the manufacturing unit.	(Água Alardo, 2023) official web Page https://www.aguadoalardo.pt/ Acceded 01-2023.
CALDAS DE PENACOVA	**Location:** Pecanova, Coimbra district**.** **Type of water:** low mineralized, low in sodium**.** **Description:** The company currently has more than 50 employees and has had a significant increase in the domestic market and in exports, with growth in Africa, Macao, USA and, especially, in Europe, a sales performance that has encouraged the company to invest more in factory modernization and in quality. The company is certified in accordance with food safety references NP EN ISO 22000:2005 and IFS (International Food Standard).	(Água das Caldas de Penacova, 2023) official web Page https://www.caldasdepenacova.pt/ Acceded 01-2023.
CARVALHELHOS	**Location:** Boticas, district of Vila Real **Type of water:** low mineralized **Description:** The Carvalhelhos brand is associated with the village of the same name, located in Barroso, in the municipality of Boticas, in the heart of Trás-os-Montes. In 2011, a new technological evolution took place with the implementation of an ERP in the PHC Enterprise range, replacing the existing technological platform, with architecture and genesis from 1989.	(CARVALHELHOS, 2023) official web Page. https://carvalhelhos.pt/ Acceded 01-2023.
FASTIO	**Location:** Serra do Gerês, Terras de Bouro, district of Braga. **Type of water**: low mineralized, low in sodium**.** **Description:** Água do Fastio was acquired in 1972 by what is now Empresa das Águas do Areeiro, and in 1979 it was commercialized for the first time. The EAA Group currently has 330 employees and plays a relevant role in terms of employment of the local population in some geographical areas of the interior (Serra do Gerês and Vidago).	(Fastio, 2023) official web Page. https://www.fastio.pt/ Acceded 01-2023.
LUSO	**Location:** Vila do Luso, Serra do Buçaco, Mealhada, Aveiro district. **Type of water:** low mineralized, low in sodium**.** **Description:** It has its origin in the rainwater that infiltrates in the Serra do Buçaco, in rocks called quartzite, which allows them to benefit from a high orographic rainfall. In these rocks, which were very compact when they were formed, a dense network of intercommunicating fractures has developed, allowing the storage and circulation of water.	(Sociedade Central Cervejas e Bebidas, 2023) official web Page. https://www.aguadeluso.pt/pt/ Acceded 01-2023.

Brand/Company of bottled mineral water	General Information	Data source
MONCHIQUE	**Location:** Monchique, Faro district. **Type of water:** low mineralized, fluoridated. **Description:** The water of Monchique has been known since the time of the Roman presence in the Iberian Peninsula. The geology of volcanic origin is composed of two distinct formations of schist and a syenite massif that rises to 902 meters. The mineral water springs are related to the circulation of water at depth within the subvolcanic eruptive massif.	(Água Monchique, 2023) official web Page. https://aguamonchique.pt/ Acceded 01-2023.
SALUTIS	**Location:** Grichões, Paredes de Coura, Viana do Castelo district. **Type of water:** low mineralized, low in sodium. **Description:** The recognition report for this water dates back to 1920, the bottling workshop was built in 1933, and it is collected and bottled in an environmentally preserved site within a protective perimeter, using modern equipment and internal and official quality control.	(Água Salutis, 2023) official web Page. https://aguasalutis.pt/page/salutis_gourmet_1l Acceded 01-2023
SÃO SILVESTRE	**Location:** Pernes, district of Santarém **Characteristics of the water:** mineralized spring **Description:** The São Silvestre water is a mineral water, which is captured in a hole at great depth in the mountains of Pernes and subject to strict quality controls. It is a light mineralized water, rich in Sodium and Calcium.	(Água São Silvestre, 2023) official web Page. https://www.aguasaosilvestre.pt/ Acceded 01-2023
VIMEIRO	**Location:** Vimeiro, Lourinhã, Lisbon district. **Water characteristics:** Vimeiro lisa.- little mineralized / Vimeiro Original.- messosaline and chlorinated. **Description:** The Natural Mineral Water of Vimeiro has its origin in the Karstic Plateau of Cezaredas, where it infiltrates the carified limestones. It flows at a depth of 2000 meters and emerges in Vimeiro in an environment of rare natural beauty where the impermeability of the evaporites prevents its migration and causes its ascent.	(Águas do Vimeiro, 2023) official web Page. https://www.aguadovimeiro.pt/ Acceded 01-2023
VITALIS	**Location:** Serra de São Mamede, Castelo de Vide, district of Portalegre. **Characteristics of the water:** Low mineralization **Description:** part of the Superbock Group, this natural mineral water arises in quartzite massifs, crystalline rock, composed mainly of silica, where, coming from the rain, it penetrated and circulated in the past, through an intricate network of fractures of capillary thickness, being collected, intact and enriched by some mineral salts.	(Super Bock Group, 2023b) official web Page. https://www.vitalis.pt/agua-mineral-natural/ Acceded 01-2023
GAS-CARBONATED MINERAL WATER		
FRIZE	**Location:** Vila Flôr, Bragança district. **Water characteristics:** Rich in mineral salts, bicarbonated, sodium and fluoridated.	(Frize, 2023) official web Page. https://frize.pt/ Acceded 01-2023

Brand/Company of bottled mineral water	General Information	Data source
FRIZE	**Description:** Marketing began in September 1994 through the company Águas de Bem Saúde. In 1999 it was acquired by Compal and has been growing at 40% per year until then.	
MELGAÇO 	**Location:** Melgaço, district of Viana do Castelo. **Water characteristics:** mesosaline, bicarbonated. **Description:** Part of the SuperBock Group. The first registration of Águas de Melgaço was in 1884, but the first bottling took place in 1885. The two Melgaço basins are located in a protected park, crossed by two bucolic rivulets, in a region that is also home to a unique water with its own special properties.	(Super Bock Group, 2023c) official web Page. https://www.superbockgroup.com/produto/melgaco/ Acceded 01-2023
PEDRAS SALGADAS PEDRAS	**Location**: Pedras Salgadas, Vila Pouca de Aguiar, Vila Real district**.** **Water characteristics**: rich in bicarbonate and sodium mineral salts. **Description:** The discovery of Pedras Salgadas dates back to the Roman Empire. In 1871, the famous doctor from Trás-os-Montes, Júlio Rodrigues, proclaimed the excellence of the qualities of the thermal water of Pedras Salgadas and two years later, in 1873, it was recognized worldwide. The Companhia Águas de Pedras Salgadas was created in 1874. In 1893, the infrastructures for bottling and distribution began to be created.	(Super Bock Group, 2023a) official web Page. https://www.aguadaspedras.com/ Acceded 01-2023
CARBONATED MINERAL WATER		
CASTELLO ÁGUA CASTELLO	**Location:** Pisões, Moura, Beja district. **Characteristics of the water:** slightly mineralized**.** **Description:** Água Castello is one of the oldest Portuguese brands of bottling and distribution of mineral water, founded in 1899. Created by the company Águas de Moura, belonging to Assis e Companhia, it launched the brand of natural carbonated mineral water. In 1937, it inaugurated its factory in Pisões. In 1949, it installed in its factory the first existing automatic line in Portugal for bottling mineral water. In the early 1980s, Nestlé acquired the capital of Águas de Pisões Moura. In 2007, Água de Castello was acquired by a group of investors created by Libarache SL and Moka Investments SARL.	(Água Castello, 2023) official web Page. https://www.aguacastello.com/ Acceded 01-2023
SPRING WATER		
SÃO MARTINHO	**Location:** Ulme, Chamusca, district of Santarém. **Water characteristics:** low mineralized. **Description:** In the heart of the Serra de Fafe, Outeirinho is located. The main characteristics of its water are its lightness, purity and transparency, meaning that it is naturally pure water. Since 1999, the company has	(OUTEIRINHO TURISMO E INDUSTRIA, S.A., 2023) official web Page. http://outeirinho.co

Brand/Company of bottled mineral water	General Information	Data source
SÃO MARTINHO NATUREZA SAGRADA	invested in both facilities and production equipment. Outeirinho is dedicated solely and exclusively to bottling water.	m.pt/contactos/ Acceded 01-2023
CARAMULO caramulo® A pureza da montanha	**Location:** Lugar de Varzielas, freguesia de Varzielas, concelho de Oliveira de Frades, district of Viseu. **Water characteristics**: low mineralized **Description:** In 1982, the construction of the factory began and in 1984, production started and the company was acquired by VMPS - Vidago, Melgaço and Pedras Salgadas. In 1997, the company was acquired by Jerónimo Martins, SGPS. Research was carried out to increase the flow and in 2002 the company was acquired by UNICER. It undergoes certification processes, changes of image renewal in its respective labels and packaging and in 2009 reaches a record production volume of 70.1 million liters.	(Mountain Water SA, 2023) official web Page. https://www.aguasdocaramulo.pt/ Acceded 01-2023
GLACIAR GLACIAR uma das melhores águas do mundo	**Location:** S. Pedro, freguesia de S. Pedro, concelho de Manteigas, distrito da Guarda. **Water characteristics:** low mineralized **Description:** Glacier water springs from an ancient spring source at a temperature of 7°C, located on one of the slopes of the Zêzere glacial valley, the largest glacial valley valley in Europe. The first award for água Glaciar was the ITQI 2008 (International Taste and Quality Institute of Brussels). Obtained FDA certification in 2009 in the United States of America.	(Glaciar, 2023) official web Page https://aguaglaciar.pt/ . Acceded 01-2023
SERRA DA ESTRELA SERRA DA estrela ÁGUA DE NASCENTE SPRING WATER | EAU DE SOURCE	**Location:** Lugar de Castro Verde, freguesia de Paços da Serra, concelho de Gouveia, distrito da Guarda. **Water characteristics:** low mineralized **Description:** The water of Serra da Estrela rises at an altitude of 1200 m, emerging from the granitic rock. It rises in the Fonte da Vidoeira, in Cabeça do Velho, in the protected area of the Serra da Estrela Natural Park. This origin gives it balanced characteristics and composition. Its neutral pH and low mineral content are crucial for the lightness of the water.	(SUMOL+COMPAL Marcas, 2023) official web Page. https://aguaserradaestrela.pt/ Acceded 01-2023
SERRANA SERRANA ÁGUA DE NASCENTE	**Location:** Lugar de Cabril, freguesia de Agadão, concelho de Águeda, district of Aveiro. **Water characteristics**: low mineralized **Description:** In 1971 the company Central Serrana de Águas, S.A. was founded, which built the bottling plant and acquired several hectares of land around the springs. The food safety management system has been certified by APCER since 2007. La Serrana's water springs from the rock on the western slope of the Caramulo mountain range.	(Serrana, 2023) official web Page. https://www.aguaserrana.pt/ Acceded 01-2023

The Table 3 above shows general information on the bottled mineral water enterprises under investigation. It provides details of the company's location, particular characteristics of the water commercialized and a brief historical synopsis of the corresponding company. the information was mostly obtained from the sources listed in the chart, i.e., public information and official websites, whether of the group and/or association itself or of the brand in particular.

4.1.1 The corporate values associated with the environment of bottled mineral water companies

The corporate values associated with the environment in bottled mineral water companies serve as a significant indicator to gain insights into the sustainability and resilience practices adopted within these companies. These values, when explicitly articulated and embedded in the company's mission, vision, and overall organizational culture, reflect a strong commitment towards environmental responsibility. Such corporate values often encompass principles like conservation of natural resources, reduction of ecological footprint, promotion of biodiversity, and mitigating environmental impacts.

By examining and evaluating these corporate values, it becomes possible to gauge the extent to which mineral water companies prioritize and integrate sustainability and resilience practices into their operations. The presence of strong environmental values indicates a higher likelihood of implementing initiatives and strategies aimed at resource efficiency, renewable energy adoption, waste reduction, and the use of eco-friendly packaging materials. Thus, exploring the corporate values associated with the environment provides valuable insights into the overall sustainability and resilience practices of bottled mineral water companies.

Corporate values are elements of the company's culture, specific to each, given its competitive characteristics, the conditions of its environment, its competition and the expectations of its customers and owners. Specifically, we are talking about concepts, customs, actions, attitudes, behaviors or thoughts that the company assumes as standards or principles of conduct or that it intends to have or achieve as a distinctive feature of its positioning and/or its competitive variables.(Mejia, 2014).

Among these values, the ecological, environmental and sustainability values tend to be mainly: Durability, Efficiency, Renewability, Separability, Recycling and Reuse, Safety and Sufficiency. The transitory abundance of natural resources, in this case mineral water, brings with it a social perspective that is not very conscious of the value that these non-renewable natural resources have for the present and for the future of the country.(Ortega, 2013).

Portugal has great opportunities to achieve sustainable development by taking advantage of non-renewable energies, optimizing resources and changing public policies to make them more suitable for their development. This scale of values proposed here, in besides creating awareness, gives meaning to the fact of imagining, projecting and building a more environmentally sustainable world.

In Table 4 The values and goals of the main brands of bottled mineral water in Portugal are listed, these data were obtained through a bibliographic search on official websites, social networks and/or television interviews or digital news. It was found that almost all the brands investigated have specific sections that show, at least, the predisposition to consider the environmental component in their policies, values and/or goals.

Table 4. List of brands of mineral water companies, description of their values and goals.

Brand/Company of bottled mineral water	Goals and corporate values	Related to environmental responsibility?
ALARDO	The company directs its efforts towards the continuous improvement of competitiveness sustained by customer loyalty, competent, dynamic, and motivated employees, real leadership, and a spirit of continuously improving all factors that influence productivity, quality, and customer satisfaction. Alardo is committed to exploit this resource in the most sustainable way, they believe they can grow economically by adopting a green thinking..	YES
CALDAS DE PENACOVA	Quality and Professionalism: To ensure the quality and food safety of your product. Humanism:Continuous training of employees. Credibility: Translated into the fulfillment of duties to employees, suppliers and other stakeholders. Sustainability: Contribution to the development of the region in its various aspects.	YES
CARVALHELHOS	The Carvalhelhos is governed by a set of ethical values, enhancing the relationships between all stakeholders: Respect for the environment, ethics in relationships with social partners, seriousness and transparency in trade relations, order and planning of the structures of the company, commitment and involvement of employees, reputation of Carvalhelhos brand, quality image of the company's products.	YES
FASTIO	Continuous learning, learning from the people who make up the company, from current events, from challenges and from all those who appreciate water, accept	YES

Brand/Company of bottled mineral water	Goals and corporate values	Related to environmental responsibility?
	mistakes and are ready for constant evolution. Bringing a little bit of Gerês nature at home and along the way forming the promise of wanting to be a completely circular brand.	
LUSO	**Sociedad Central de Cervejas e Bebidas SCC:** PASSION for consumers and customers, CARING about people and the planet, JOY to live, BOLDNESS to dream and to be pioneers. Its mission is to contribute to the advancement of knowledge and information related to water and human health, to the preservation of the water and natural heritage of Luso, as well as to the sustainable development of the Community.	YES
MONCHIQUE	Sociedade da Água de Monchique directs its efforts towards the continuous improvement of competitiveness sustained by loyal customers, competent, mobilized and motivated employees, effective leadership and a will to continuously improve all factors that may affect productivity, quality and customer satisfaction.	YES
SALUTIS	Not founded	N/A
SÃO SILVESTRE	To be reliable and quick in action and response, to have transparent internal and external relationships based on responsibility and trust, to value and respect people and the environment, to communicate clearly and accurately, to maintain consistent and focused leadership, to have economic, social, and environmental sustainability.	YES
VIMEIRO	The Água do Vimeiro is totally committed to guarantee a quality product and service with special relevance to the satisfaction and overcoming of requirements, namely, the protection of the hydric resource, clients, guarantee of food safety as well as legal and normative requirements. The Água do Vimeiro has as a constant practice and concern the guarantee of health and safety conditions of its collaborators, as well as the protection and conservation of installations and equipments, the prevention of any source of pollution from its activities and the promotion of sustainable environmental practices and framed in Circular Economy Systems.	YES
VITALIS	**Superbock Group:** we excel with ambition: we lead with pride and entrepreneurship, we trust in people: people are the engine and soul of the company, we do with excellence: we deliver the best in the simplest, most agile and innovative way to generate positive impact, in the medium and long term, in society, contributing to sustainable development, obtaining the appropriate recognition and appreciation from the community and shareholders.	YES
FRIZE	**Sumol compal group:** To nourish, hydrate and provide well-being through fruits, vegetables and water. Satisfy consumers and customers with unique, innovative and great-tasting brands developed with science and art. To contribute to a more sustainable world, creating value with balance and satisfaction.	YES
MELGAÇO	**Superbock Group:** same as Vitalis and Pedras Salgadas	YES

Brand/Company of bottled mineral water	Goals and corporate values	Related to environmental responsibility?
PEDRAS SALGADAS	**Superbock Group:** same as Vitalis and Pedras Salgadas	YES
CASTELLO	**Sociedade Central de Cervejas e Bebidas SCC**: PASSION for consumers and customers, CARING about people and the planet, JOY to live, BOLDNESS to dream and to be pioneers.	YES
SÃO MARTINHO	**Outeirinho Group: Food** safety, profitability, focus on consumers and customers, continuous improvement, communication, partnership with suppliers, investment in employees, social responsibility, environmental responsibility. The Outeirinho Group assumes an environmentally responsible attitude, especially in the context of rational and sustainable use of raw materials / consumables, natural resources and energy.	YES
CARAMULO	It is not specifically stated, its goals are named in a general way.	YES
GLACIAR	Concern for the well-being of our consumers and collaborators, reflected in the quality and food safety of the products and services we offer. Continuous innovation in search of the best to captivate and surprise customers and consumers. Investing in the growth and appreciation of our people and our brands; Sustainability - evident in all its projects.	YES
SERRA DA ESTRELA	**Sumol Compal group:** Same as FRIZE.	YES
SERRANA	It is not specifically stated, its goals are named in a general way.	YES

The data were corroborated as far as possible by the technical staff of the bottled mineral water companies that were interviewed; they stated that "prioritizing the quality of the final product, they always have a section on environmental care within the company policy", besides being a subject that is internalized in the technical and administrative workforce.

4.1.2 Activities and goals related to environmental sustainability and resilience

The presence of specific activities and goals related to environmental sustainability and resilience within mineral water companies serves as a crucial indicator for gaining insights into their overall sustainability practices. When companies establish and pursue concrete activities and goals aligned with environmental sustainability and resilience, it demonstrates their proactive approach and commitment to addressing ecological concerns. These activities

may include initiatives such as water source protection, energy-efficient production processes, waste management strategies, carbon footprint reduction, and biodiversity conservation efforts. Additionally, setting clear goals related to sustainability, such as achieving specific emissions reductions or attaining certifications for sustainable practices, provides a measurable framework for assessing a company's progress in integrating sustainability principles.

By examining and evaluating the specific activities and goals undertaken by mineral water companies, it becomes possible to gauge the extent of their commitment to environmental sustainability and resilience practices. These indicators offer valuable insights into the effectiveness and impact of their efforts towards building a sustainable and resilient future.

The information disclosed by the Association of Natural Mineral and Nasciente Water of Portugal, indicates that the industry is committed to the preservation of the environment around the aquifers, the industry has implemented plans for the conservation of trees, cleaning of rivers and care of flora and fauna. Reforestation plans have also been implemented to protect aquifers from contamination from agriculture and animal husbandry.

But preserving the environment also implies the control of the influence of the activity on the environment and the adoption of initiatives that lead to the improvement / control of environmental performance indicators, such as:

Aquifer management

The natural mineral water and spring water industry is a responsible business that has the privilege of marketing a product whose purity and quality must be preserved through a policy of protecting resources and limiting the impact of the activity on the environment.

The sustainable development of companies dedicated to the extraction and commercialization of natural mineral or spring water requires a correct management of the subterranean aquifer, which implies a rational use of the resource, to ensure that over time the water remaining in the subsoil always maintains the same volume and composition.

As a result, each of the natural mineral water and spring water companies has, respectively, a "protection perimeter" and an "exploitation flow". Protection perimeters are

granted by the competent administrative authorities once the authorization to use the water has been granted and are inspected annually, after having been previously approved.

With the protection perimeters, the natural mineral and spring water industry is also responsible for protecting the natural areas surrounding the aquifers, ensuring their conservation and avoiding any possible accidental contamination.

Bottling and bottling waste

Mineral water packaging is essential to guarantee the purity and quality of natural water, mobility and convenience of use, as well as to transmit information on the geographical origin and chemical composition of the product we consume. Industry uses plastic (PET) and glass containers, suitable for contact with food.

REDUCTION

The industry is firmly committed to prevention by reducing the weight of packaging at origin. Reducing the weight of containers while preserving water quality and user convenience is a constant challenge for the industry.

In 1996, the average weight of a 1.5-liter PET bottle was over 50 grams. Today, the weight of the same bottle is around 30 grams, and there has been a significant reduction in the weight of the bottle at source, which translates into significant environmental benefits, especially in terms of production and transport.(Sociedade Ponto Verde, 2022).

RECYCLING

Both PET and glass are recyclable, so the industry has assumed full responsibility for the disposal of the packaging waste it uses (about 0.03% of the total waste produced in Portugal) and has agreed to manage and finance the packaging waste recovery and recycling system.

For this purpose, the industry was, from the beginning, among the founding sectors of the Sociedade Ponto Verde (Green Dot Company), created in 1996 by the productive sector and financed entirely by it. With the Sociedade Ponto Verde, the industry in this sector assumes full responsibility for the destination of the packaging waste it places on the market and undertakes to manage a packaging waste collection and recycling system.

Water

REDUCING THE WATER CONSUMPTION RATE

The water usage rate is defined as the amount of water used in relation to the volume of beverage produced. It is a key indicator of the environmental performance of the beverage industry.

Innovations in bottling lines, bottling plant operator awareness, investments in new production lines and bottle washers, along with the continuous search for improvements, are all part of the industry's commitment to increase the efficiency of production units.

WASTEWATER - RECYCLING

The water resulting from production processes, such as the final bottle rinsing, is reused for internal cleaning of truck crates and floors, or for irrigating green areas.

The sector's industry is committed to treating wastewater and ensuring that all water used in manufacturing processes is returned to the environment with a quality that guarantees the care of nature, meaning the survival of living beings.

In relation to this last point, the companies interviewed did not have a water recirculation process in their processes. Although it is true that in both cases they did not wash their containers, the water used in the other production processes could still be recirculated in a more efficient way. They limit their action for this type of water by controlling compliance with the quality parameters to be able to discharge the water to the pit.

Energy

Energy is critical in production and distribution. It is used from the production of packaging to the manufacture, distribution and sale of products. The industry is constantly improving energy efficiency and reducing the rate of CO2 emissions in production and distribution, while looking for new and innovative ways to trade more sustainably.

REDUCING ENERGY CONSUMPTION

The industry has long been working to reduce its energy dependence, through changes in lighting, improvements in bottling processes and investments in energy-saving devices and technologies.

REDUCING EMISSIONS

The natural mineral water industry, like most food industries, is dependent on energy in all its production equipment, sales processes and distribution systems. It therefore systematically reduces energy consumption per liter produced.

The industry believes that a significant reduction in energy consumption can be achieved by adopting the technological and environmental innovations that are constantly being developed and by considering and implementing new logistics and transportation options.

The following Table 5 shows the specific actions carried out by companies and/or bottled mineral water brands, which were communicated in press releases, social networks and mainly on their official websites described on Table 3, doing a deep search on it.

Table 5.

Mineral water companies and brands in Portugal and their specific activities related to environmental sustainability.

Brand/Company of bottled mineral water	Actions, activities and/or goals
ALARDO	- Modernizing the production lines making them more energy efficient, reducing raw material waste. - Reducing the weight of PET used. - For the future, Alardo intends the use of recycled PET in its packaging.
CALDAS DE PENACOVA	- Increased production capacity with a 20% reduction in energy consumption. - Initiated an awareness campaign "o Ciclo Lógico do Plástico apanha boleia do Ciclo Hidrológico".
CARVALHELHOS	- Investment for clean technologies, stimulating savings, recycling and fighting losses. - Expanded the wastewater treatment unit in 2008.
FASTIO	- They handle 100% recyclable PET or glass bottles. - They have a range of returnable glass in various presentations. - Developed an "eco-cup", the Fastio "eco-cup" is an innovation designed never to separate from the bottle
LUSO Sociedad Central de Cervejas e Bebidas SCC	- Reduced 30% of PET packaging. The new handle of the Água do Luso bottle has less plastic. - Partner of the Mata do Bussaco Foundation with several projects over the years. - Stablished a protocol with Quercus, intervening in 24 hectares during three seasons (from 2014 to 2016), to plant and/or care for a total of 24,000 native trees and shrubs. - Use of exclusively returnable glass bottles.

Brand/Company of bottled mineral water	Actions, activities and/or goals
	- Contribution to the progress of knowledge and information related to water and human health, to the preservation of water and natural heritage.
MONCHIQUE	- Awarding of the Green Energy Certificate. This important green seal certifies that the energy consumed in the production unit comes exclusively from renewable sources. - Already meets the commitment with APIAM, having all its new PET bottles, recently launched, 30% RPET in its composition. The company's ambition is to reach 100% recycled plastic. - Installation of 23 collection machines for non-reusable PET plastic beverage bottles throughout the country as part of the pilot project "When old becomes new, everyone wins. The planet wins".
SALUTIS	No data found
SÃO SILVESTRE	No data found
VIMEIRO	- The new Vimeiro Gas bottles are transparent and 100% recyclable. This substitution of the traditional green bottles represents a sustainable action of the Empresa das Águas do Vimeiro (EAV) which is concerned with the environmental impact caused by colored PET plastic.
VITALIS **Superbock Group**	- In 2009, Vitalis challenged itself to have the lightest bottle on the market in order to actively reduce its environmental impact. - As part of the superbock group, based its sustainable development objectives on 3 pillars: People: Promoting a Zero Accident Culture, Attracting, Retaining and Enhancing the Talent of People, Educating to Support the Development of Communities, Smart Consumption. Prosperity: Enhance the Value of Brands and Increase Reputation, Innovate, Ensure Product Quality and Safety, Manage the Value Chain in a Sustainable Way. Planet: Less Water, Less Carbon, More Circular Packaging.
FRIZE **Sumol compal group**	- Increasing the percentage of recycled material in packaging and investing in ecodesign. - ÁGUA SERRA DA ESTRELA's plastic packaging incorporates recycled PET. - They seek to reduce greenhouse gas emissions in the value chain and invest in renewable energy to reduce the carbon footprint.
MELGAÇO **Superbock Group**	Part of SuperBock group politics and activities.
PEDRAS SALGADAS **Superbock Group**	Part of SuperBock group politics and activities.
CASTELLO **Sociedad Central de Cervejas e Bebidas SCC**	**Carbon Neutrality** Zero emissions in Production by 2030 Carbon neutrality in the entire value chain by 2040 100% ingredients from sustainable sources **Maximize circularity** Zero waste going to landfill globally by 2025 Turning waste into value and closing the loop of materials throughout the value chain **Healthy Water Resources** Balancing water used in products in water-constrained areas by 2030 Maximize water reuse and recycling in water-constrained areas by 2030 Treating 100% of wastewater from all breweries by 2023 Reducing average water consumption to 2.6 hectoliters per hectoliter (hl/hl) in water-stressed areas and to 2.9 hl/hl worldwide, by 2030 **Associated Initiatives** Photovoltaic panels, More efficient vehicles, Ecodesign and packaging optimization, Labels produced on FSC paper, Water resource protection, More efficient packaging.

Brand/Company of bottled mineral water	Actions, activities and/or goals
SÃO MARTINHO	The Outeirinho Group assumes an environmentally responsible attitude, especially in the context of rational and sustainable use of raw materials / consumables, natural resources and energy. But within concrete activities undertaken by the company no information was found on this subject
CARAMULO	- Águas do Caramulo invests in 25% RPET bottles, in the 0,50 L format. - They have adopted an Ecogreen concept, promoting the "Always Recycle" campaign. - For the Horeca Channel (Hotels, Restaurants and Cafes) the Premium Bottle is made of 100% Recycled plastic. - They foresee that in 3 years, and with a growing concern to live in a circular and sustainable economy, the bottles will be 100% RPET.
GLACIAR	- Use of recycled plastic in its bottles. - Applies the 5R policy: Recycle, Reuse, Rethink, Refuse. Reduse. - In addition, Glaciar is committed to ensuring that its activity actively contributes to the Sustainable Development Goals defined by the United Nations. No specific activities were found in relation to this.
SERRA DA ESTRELA Sumol compal group	Part of the activities of SumolCompal Group. Established a partnership with ICNF and IKEA in 2002 to plant trees in Portugal. With the help of its headquarters, more than 1.5 million trees have already been planted.
SERRANA	Packaging is produced using recycled raw materials, and is 100% recyclable.

4.1.3 Complaints to companies related to environmental conservation, legality and/or sustainability

Any citizen can (and should) report environmental crimes, filing a complaint about environmental occurrences in areas such as waste or noise, but also related to water and rivers, or air quality. In 2020, the GNR's Environment and Territory SOS Line (808 200 520) received more than 12 thousand complaints, mainly related to the mistreatment of domestic animals and forest fires, or waste.(Direção Geral do Consumidor, 2022).

The interviewees stated that their respective companies have never had formal complaints regarding the quality of their products or practices in the production process. In digital news and portals such as DECO Proteste, there are no records of formal complaints against bottled mineral water companies.

However, there are some negative reviews of the companies in social networks and search engines, but since there is no formality, these complaints can only be taken as simple observations of the population. The most notable and frequent ones were collected in Table 6.

Table 6.

List of some non-formal complaints made to mineral water companies.

Company of bottled mineral water	Complaint / negative review	Notes
ALARDO	The label does not show the water analysis, nor does it say whether the water is obtained directly from the source.	The labels on the bottles comply with legal regulations.
CALDAS DE PENACOVA	N/A	N/A
CARVALHELHOS	N/A	N/A
FASTIO	Better than water, just the fantastic location in front of the factory, shame about the noise produced by the machines.	No environmental noise sanction was found.
LUSO	N/A	N/A
MONCHIQUE	The level of fluoride and sodium is very high, I don't drink it safely.	Sodium and fluoride levels are within permitted levels, but it would be advisable to limit consumption.
SALUTIS	N/A	N/A
SÃO SILVESTRE	N/A	N/A
VIMEIRO	N/A	N/A
VITALIS	N/A	N/A
FRIZE	N/A	N/A
MELGAÇO	N/A	N/A
PEDRAS SALGADAS	N/A	N/A
CASTELLO	N/A	N/A
SÃO MARTINHO	N/A	N/A
CARAMULO	N/A	N/A
GLACIAR	N/A	N/A
SERRA DA ESTRELA	N/A	N/A
SERRANA	N/A	N/A

4.1.4 Economic situation of bottled mineral water companies in Portugal

Generating wealth

According to official data in 2019, the sales of the natural mineral and spring water sector were approximately 224 million euros, with a production of more than 1,490 million liters. The sector ensures more than 10,000 jobs, between those generated directly (between 1,400 and 1,600 workers considering seasonal variations) and indirectly, downstream and upstream of the activity (suppliers, services, distributors).

A significant part of this employment has contributed to attenuating regional asymmetries by being in interior regions of the country, since bottling plants cannot relocate because they must be located near the water sources.(APIAM, 2015).

Stable market

The consumption of bottled water in Portugal has experienced sustained growth in recent years, gaining a prominent place in the beverage sector. This fact reflects an evolution in consumer behavior, marked by growing and relevant concerns related to a healthier and more balanced diet.(APIAM, 2015)

Today, Portuguese people drink more bottled water than in the past, which is mainly because they are more concerned about nutrition, health and balanced lifestyles. In Portugal, natural and spring mineral water consumption per capita in 2014 was about 112 liters, in 2019 it was 146.4 liters (Figure 8), within the average consumption figures for the European Union.(Sezinando, 2013).

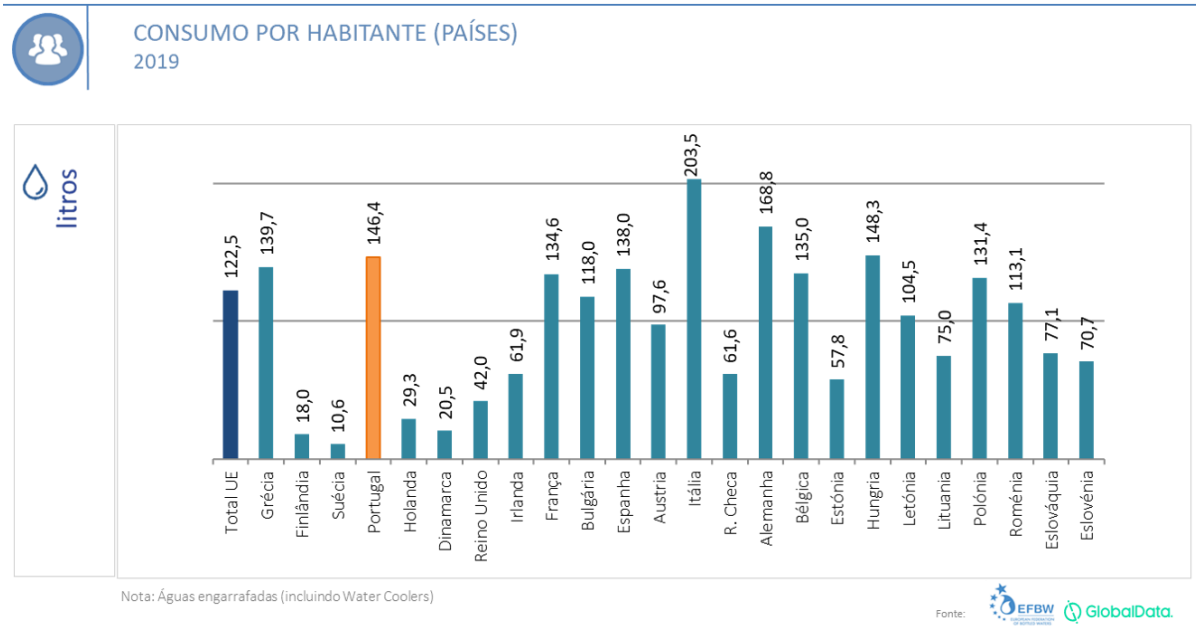


Figure 8. Water consuption on Europe per peson. Source (APIAM, 2015)

4.2 Legislation applied to the management of water resources and practices of bottled mineral water companies

The legal framework governing water resource management sets the foundation for responsible and sustainable practices within the industry. Compliance with relevant laws and regulations indicates a company's adherence to environmental standards and their commitment to mitigating potential negative impacts on water resources. Additionally, legislation often promotes the sustainable use of water, encourages efficient water management practices, and emphasizes the protection of water quality and ecosystems.

By examining the extent to which bottled mineral water companies align their operations with these legal requirements, it becomes possible to assess their level of commitment to sustainability and resilience. Companies that proactively go beyond compliance, adopting additional measures and initiatives to conserve and protect water resources, demonstrate a higher dedication to sustainability. Thus, analyzing the relationship between legislation and the practices of bottled mineral water companies offers valuable insights into their overall sustainability and resilience efforts.

Legislation should regulate all phases of the water cycle to promote efficient, fair and sustainable use of water resources and minimize the impact on the environment. Regulations must be enforced and control agencies must be consolidated, while innovative approaches must be facilitated and encouraged. Given their knowledge of local contexts, autonomy for water management should be assigned to the level of government closest to the final users, the governments closest to the final users should have autonomy to manage water resources and should be consulted on legislation and decision-making. (Conselho Mundial da Água, 2018).

Cities and their inhabitants are changing consumption patterns, demographic changes and resource scarcity, among many other challenges, require legislation to keep pace with the current trends in today's world. The quality of urban life affects people's well-being, and laws can have positive or negative effects on social justice, good governance, democratic decision-making, economic development, and the defense of fundamental rights and transparency. (Conselho Mundial da Água, 2018).

Regulation must cover land use and water bodies to ensure long-term sustainability and equity for all and for future generations, protecting the human right to water and sanitation for all. The safe return of used water to the environment so that it can replenish - and not pollute - water sources must become common practice through the application of rules and regulations along with the implementation of best practices and training programs.(EU DIRECTIVA 2003/40/CE DE LA COMISIÓN, 2003).

Legal frameworks, whether fiscal, administrative or political, can ensure effective decentralization of responsibilities and resources. Legislation should also promote citizen participation and accountability in decision-making and oversight. The enforcement of accountability standards can provide valuable data that can inform national standards and benchmarks. (Conselho Mundial da Água, 2018)

Participatory and transparent processes should be adopted to ensure inclusiveness, responsibility and transparency. These characteristics of good governance should be applied to water management, including the development, adoption, and enforcement of laws that promote more active ownership and participation.

4.2.1 Introduction of regulation in Portugal

At the beginning of the 19th century, in Portugal, the already established idea that the various species of mineral water are invaluable assets, whether from the therapeutic and sanitary point of view, or from the ecological or economic-heritage point of view, led to the concern to regulate the sector. In 1894, the first regulations on mineral waters were published in Portugal, much later than in Spain, where the corresponding legislation dated back to 1816, and in France, where it had existed since 1589.

Already at that time it was understood that all natural mineral water springs should be protected, to ensure that extraction was carried out without danger of depletion or deterioration. In Portugal, these measures are especially necessary given the natural environment surrounding the mineral water springs.

Today, the current legislation, without losing this important significance, considers natural mineral water as an element of a much broader complex, in which concerns for the protection of nature, the environment and the quality of life of the citizen and the reordering

of the territorial space in ecologically balanced areas also acquire fundamental importance. In synthesis, the current legislation refers to the delimitation and protection of the natural reserves that normally surround natural mineral water springs.

It is clear that this objective, which is a priority in contemporary societies, is not achieved by simply protecting the purity of the water and its flow, nor by simple prohibitions (of negative content), as has been the usual practice. Instead, protection must be extended to the farthest territorial limits of the natural "parks" or green areas surrounding the springs, and must include aspects that go beyond the defense of the flow and purity of the water.

Moreover, since most of the springs are located in the most disadvantaged areas of the interior, it is a good idea to take advantage of these poles to promote the material and cultural well-being of the population. In fact, the complexes in which the element of natural mineral water and spring water predominates are undoubtedly one of the pillars of regional development.

4.2.2 Natural and spring mineral waters as a geological resource

The purpose of the natural mineral water and spring water bottling industry is the management of hydrogeological resources. Natural mineral water belongs to the public domain of the government, is used under concession and, if it has certain proven therapeutic properties, can be used in thermal resorts and prescribed by doctors for the treatment of certain types of illnesses. Some of these waters can also be used for bottling.

Spring waters, which are also geological resources subject to strict authorization and protection rules, belong to the private domain and are used under license.

These resources are regulated, from their qualification to their extraction, by Decree-Law 54/2015, of June 22nd.(Assembleia da República, 2015), regulating the disclosure and exploitation of geological resources, as well as Decree-Laws 86/90 and 84/90, of March 16, 1990, (Assembleia da República, 1990) regulating respectively the extraction of natural mineral waters and spring waters.

4.2.3 Access to hydrogeological resource development activities

La The procedural sequence of an application for prospecting and research, as well as for the exploitation of resources included in the public domain of the Nation, as is the case of **natural mineral waters**, entails a request, properly instructed, that must include among other elements

a) A hydrogeological study of the area, with the description of the drilled holes, the existing water catchments, with the physical-chemical and bacteriological characterization of the water, the indication of the flow and temperature obtained, as well as the evaluation of the environment from the point of view of the vulnerability to contamination;

b) 12 physicochemical and bacteriological analyses, including the essential indicators for testing water quality, carried out on samples taken at regular one-month intervals.

c) Complete chemical analysis;

d) Radioactive study of the water;

e) Report of the General Direction of Sanitation;

f) Project for the definitive abstraction;

g) Descriptive report on the economic exploitation of the mineral water.

The process of granting licenses for the exploitation of **spring water** is accompanied, among others, by the following elements

a) Hydrogeological study of the area of emergence and circulation of the water, including a description of the catchments; physicochemical and bacteriological characterization of the water; indication, for each collection, of the respective flow rates and temperature; as well as an evaluation of the vulnerability of the surrounding area to contamination and a proposal for the creation of a protected area;

b) 12 physicochemical and bacteriological analyses, including the essential indicators proving water quality, carried out on samples taken at regular one-month intervals;

c) Complete chemical analysis and radioactive study of the water;

d) Project for the definitive abstraction;

e) Report of the General Direction of Sanitation.

The qualification of water as spring water is the responsibility of the Directorate General of Energy and Geology. This Directorate General checks whether the characteristics of the water meet certain criteria, after obtaining the approval of the Directorate General for Health. In the positive case, after duly safeguarding the protection of the respective aquifer, it will submit its opinion to the Minister of Economy and Innovation, who will take the final decision. The effectiveness of the establishment license is conditional upon the authorization of the activity of the industrial bottling plant.

4.2.4 Protection perimeters

Given the high patrimonial and ecological value of natural water, Portuguese legislation has provided since 1928 for the establishment of protection perimeters for abstractions. This guarantees the purity and quality of these geological resources, which fall under the competence of the Directorate General of Energy and Geology. Article 46 of Decree-Law 54/2015, of 22 June, regulates the protection of resources and imposes the necessary restrictions on activities, establishing the principle that the adequate protection of geological resources must be guaranteed, with a view to their exploitation.

In development of this principle, it was established that, in cases of exploitation of hydromineral resources, a protection perimeter capable of guaranteeing the availability and characteristics of the water and ensuring the conditions for good exploitation will be established, based on a hydrogeological study. In the case of natural mineral water, the establishment of a protection perimeter is imperative, while for spring water it will only take place if the adequate protection of the aquifer so requires.

The protection perimeter comprises the immediate zone, the intermediate zone and the extended zone. The restrictions and limitations established or which may be established in each of these areas are set out in articles 47, 48 and 49 of the same law. (Figure 9).

In the immediate zone (article 47) there are prohibitions and restrictions that differ according to the type of activity involved:

a) Absolutely prohibited activities: the use of organic or chemical fertilizers, pesticides, insecticides and other chemical products, as well as the dumping of trash, waste or the creation of landfills;

b) Relatively prohibited activities: those which, being beneficial for the conservation and exploitation of water, require authorization from the competent authorities; these prohibitions include construction, drilling, subway works, landfills and other operations involving alterations of the land, as well as the conduction, treatment and collection of wastewaters;

c) Activities subject to prior authorization by the competent administrative entities, namely: felling of trees and bushes, destruction of plantations and demolition of buildings.

In the intermediate zone (Article 48), all the above-mentioned activities are relatively prohibited and may only be carried out if authorized by the competent administrative body. It is also a condition for such activities that they do not cause interference with the resource or damage to the exploitation.

In the extended zone (article 49) there are no expressly prohibited or conditioned activities, but those listed in article 47 (immediate zone), when they represent a risk of interference with or contamination of the resource, may be prohibited by order of the Minister of Economy and Innovation.

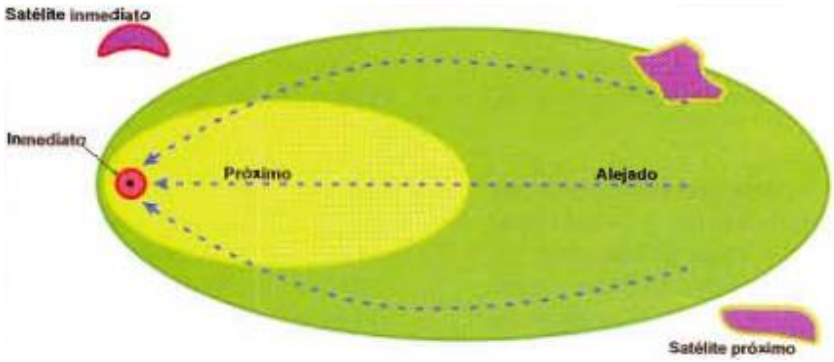


Figure 9. Diagram of protection perimeters in mineral water catchments.

4.2.5 European Directive

In addition to the legislation mentioned above, this activity is also regulated by EU and national legislation on the packaging, labeling and marketing of natural mineral water and spring water.

The European Directive framing and regulating the exploitation and marketing of natural mineral waters was signed on July 15, 1980 (Directive 80/777/EEC) and includes a definition of natural mineral water. In 1996, the European Directive was partially revised (Directive 96/70/EC) and now also includes a definition of "spring water".

For both categories of natural water, the same set of requirements is imposed, aimed at ensuring a single quality, in particular

- the obligation of bottling at source

- prohibition of transport in tanks

- the prohibition of any treatment capable of altering the essential characteristics of the water.

The Community legal framework was first transposed into national legislation by Decree-Law No. 283/91, of 9 August, regulated by Regulatory Decree No. 18/92, of 13 August. It was subsequently amended by Decree-Law 156/98, of July 6, 1998, which also covered spring waters. This Decree-Law defines and characterizes natural mineral waters and spring waters and establishes the rules relating to their bottling and marketing.

It is also important to take into account Decree-Law No. 72/2004 of March 25, 2004, which establishes the limits of certain elements that may be present in natural mineral waters and sets certain specific indications on the labels.

4.2.6 Labeling of natural and spring mineral water

The natural water label provides consumers with the necessary information to know the characteristics of the water they are going to drink. It can also be used to detect any adulteration of this natural product in the marketing channels, whether of fraudulent origin or as a result of non-compliance with storage standards.

On the label of a natural bottled water, in addition to the commercial name, it is mandatory to indicate natural mineral water or spring water, as the case may be. It is also obligatory to indicate the place of exploitation and the name of the spring or borehole from which it was extracted.

In the case of water containing high amounts of free carbon dioxide, the consumer will know whether this component exists naturally in the water or whether it was introduced during the bottling process. In fact, the terms "naturally carbonated", "gas-carbonated" or "natural gas-enriched" indicate that the carbon dioxide content of natural mineral water comes from the aquifer. On the other hand, the term "carbonated" on the label means that carbon dioxide has been added to the water after it has been extracted from the aquifer.

On the labels of all-natural mineral water, whether domestic or foreign, it is mandatory that the typical chemical composition of the water in the bottle be stated. In Portugal, it is also common for the chemical composition to appear on the labels of spring water.

Since it is clearly impossible to include on the label all the components of these waters, normally only the pH value, the total mineralization (total dissolved salts) and the quantities of the elements that are present in the greatest quantity are indicated, which makes it possible to distinguish a given water from other similar waters.

In the case of Portuguese bottled waters, the amounts of the main components are given in milligrams per liter (mg/l). For carbonated waters, the amount of free CO2 is expressed in grams per liter (g/l).

In 2013, APIAM prepared and published a Consumer Information Guide for natural mineral water and spring water which, despite focusing especially on labeling, provides a framework for a more comprehensive conception and approach to the information to be provided to consumers and the new legally established standards, especially in terms of how to mark the presentation of the indications (legibility standards) and the health claims authorized for water.

4.2.7 Quality control and sanitary monitoring

In Portugal, the bottled water sector is one of the sectors with the strictest controls, subject to constant routine visits by specialized technicians sent by the Food and Economic

Safety Authority, the General Direction of Health and the General Direction of Energy and Geology.

The close supervision of the natural mineral and spring water sector is also related to the fact that in Portugal there are important and good resources of natural mineral and spring water. In order for these resources to maintain their original quality, Portuguese legislation is strict and demanding in ensuring that these waters remain totally natural.

For this reason, official supervision focuses on the entire process, from extraction/collection, through bottling, marketing and distribution, to the final consumer.

The characteristics of these waters are certified by official authorities, including the General Directorate of Energy and Geology, which intervenes with an annual program of mandatory analyses, both physical-chemical and bacteriological.

Bottling units, storage, distribution and market operations in general are controlled by the Food and Economic Safety Authority (ASAE).

At all stages of the economic circuit, the Health Authority, coordinated by the General Directorate of Health, ensures sanitary vigilance by carrying out routine bacteriological analyses. The government ensures that public health is properly defended and promoted. Sanitary vigilance includes technological, analytical and epidemiological control and the establishment of a minimum frequency analytical program.

4.2.8 Food safety and traceability

Natural mineral water and spring water are some of the most regulated products, as are baby food and dietetic products. Regulations focus on both food quality and safety.

European Union directives, supplemented by specific national legislation, provide this sector with a set of regulations that give the final consumer the certainty of having a natural, healthy and safe food.

The bottled water sector in Portugal is fully covered by European and national food regulations, which means that it must use the most sophisticated and safest technical processes for the collection, bottling and distribution of natural mineral and spring waters.

The technical-sanitary regulations for bottled waters specify the permitted manipulations and the self-control actions necessary for the correct preparation of the product. The HACCP (Hazard Analysis and Critical Control Point) methodology is imposed by an international standard, which defines the requirements for proper food safety management and the system for identifying, evaluating and controlling possible risks in the process. It also establishes the necessary preventive and, corrective measures.

Traceability, mandatory for the entire food industry since January 1, 2005, guarantees the tracking of raw materials and the finished product from the origin to the final consumer. The packaging industry must therefore be able to identify all the previous steps of its suppliers and the destination of each of their deliveries to customers. The basic traceability tool is the batch, which represents a set of sales units, packaged under homogeneous conditions. The packaging of natural mineral water and spring water includes the inscription of the batch code on the label of glass bottles or directly on plastic bottles by laser.

4.3 Technology and technique in the bottled mineral water value chain in Portugal

The utilization of advanced technology and innovative techniques throughout the production, packaging, and distribution processes can greatly impact the environmental footprint of these companies. Sustainable practices often involve the adoption of energy-efficient machinery, water conservation technologies, and waste reduction strategies. Additionally, the implementation of techniques such as life cycle assessments, eco-design principles, and resource optimization methodologies can contribute to the overall sustainability and resilience of the value chain.

By examining the extent to which bottled mineral water companies embrace and integrate such technologies and techniques, it becomes possible to assess their commitment to sustainable practices. Companies that invest in and prioritize the use of environmentally friendly technologies and techniques demonstrate a proactive approach towards minimizing their environmental impact and improving their resilience. Thus, analyzing the role of technology and techniques within the bottled mineral water value chain provides valuable insights into their sustainability and resilience practices.

Figure 10 establishes a general flow diagram to produce bottled of natural mineral water..

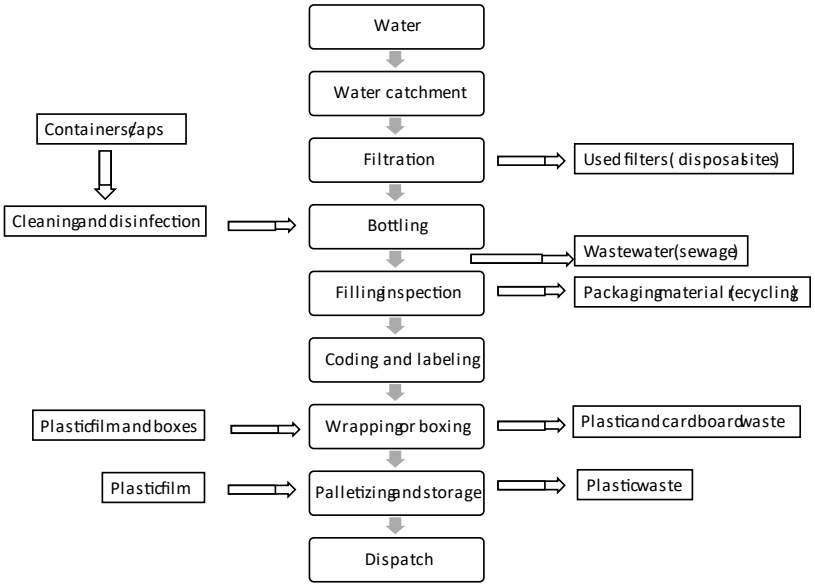


Figure 10. Basic and indicative flow chart for the bottling of natural mineral water.

The Table 7 summarizes the standard stages of the value chain of bottled mineral water companies according to (Garcia, 2008), where the Critical Control Points are identified.

Table 7.

Summary table where the Critical Control Points are identified.

Stage	*Requirements*	*Registers*	*Control parameters*	*CCP*
Natural mineral water extraction	Subterranean origin (natural or extracted) Spring protection Extraction with stainless steel pumps Stainless steel piping	Cleaning of the source	pH Temperature Microbiological control	YES
Storage	Continuous, enclosed, food grade conduit Temporary storage in stainless steel tank Cleaning and disinfection program	Cleaning of storage tanks	Microbiological control	YES
Pumping	Stainless steel pumps			NO
Filtration	Sanitary grade stainless steel filtration equipment Capable of retaining particles larger than 1um	Equipment maintenance program Cleaning and disinfection program	Integrity test	YES

Stage	*Requirements*	*Registers*	*Control parameters*	*CCP*
	Sterilizing grade filtration prohibited			
Reception of auxiliary materials	Vehicles with appropriate hygienic conditions An isolated and independent storage room is available	Entry register	Microbiological control	YES
Bottle blowing	Sterile blowing air, free of particles, oils and hydrocarbons Transport of empty PET containers is not allowed.	Registry of used material		NO
Bottling	Filling equipment shall be automatic, stainless steel and easy to clean. Containers should never be in contact with the ground.	Equipment maintenance program Cleaning and disinfection program		NO
Capping	Hermetically sealed and tamper-proof	Equipment maintenance program Cleaning and disinfection program		NO
Labeling	In accordance with applicable legislation	Equipment maintenance program		NO
Lotting	In accordance with applicable legislation			NO
Packaging	Perfect cleaning condition			NO
Final product storage	Clean and organized independent warehouse First-in first-out policy Do not place product directly on the floor No direct sunlight			NO
Distribution	Transport according to hygienic and cleanliness conditions	Order entry record		NO

PET and RPET containers

PET is polyethylene terephthalate, polyethylene terephthalate, polyethylene terephthalate or polyethylene terephthalate and is a type of plastic. PET can be processed by injection, blow molding (both on separate machines), injection blow molding (on the same machine) and extrusion.(AraPack, 2018)

PET containers can be continuously recycled through different collection and sorting processes. Different cleaning and extrusion methods, as well as decontamination at 280ºC,

allow a large part of PET containers to be recycled and reintroduced into the production chain, thereby reducing their environmental impact.(AraPack, 2018)

4.3.1 Mineral Water consumption in Portugal, activities and new lines of research and development in support of environmental resilience and sustainability.

The statistics for Águas Minerais e de Nascente de Portugal show, over the last ten years, a positive evolution in the sales of natural mineral waters and spring waters (national market and exports), in volume of liters, of around 19% Figure 11. The sales volume in this period, in number of packages, shows a negative evolution of about 14%.(APIAM, 2022).

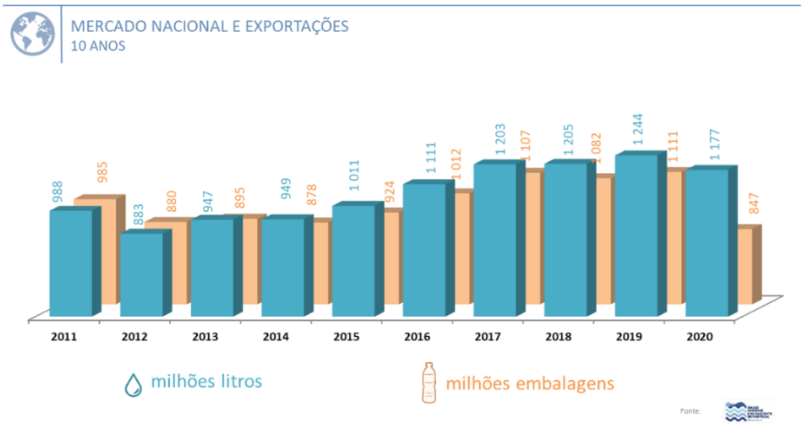


Figure 11.Amount of liters of mineral water vs. number of packages Source: (APIAM, 2022).

In the last year, the consumption of natural mineral waters and spring waters in Portugal (national market and export) had a negative evolution of 5.4% (liters) and 23.8% (packages). As for the consumption of natural mineral and spring waters in Portugal (domestic market) had a negative evolution of 4.9% (liters) and 23.8% (packages) Figure 12.

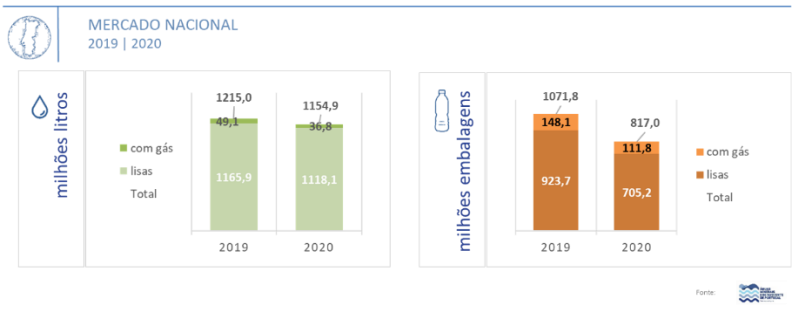


Figure 12. Bottled mineral water consumption data in Portugal 2019 vs 2020. Source: (APIAM, 2022)

In Portugal, there have been several initiatives to promote, for example, the consumption of tap water, such as the campaign run by the Direcção Geral da Saúde (DGS) as part of the Programa Nacional de Promoção da Alimentação Saudável (PNPAS), which promotes the consumption of water from drinking fountains in public places. This initiative, in addition to promoting water consumption, also aimed to show places in Portugal that could have drinking water available, with the help of citizens, through photos of drinking fountains in public spaces. (NIT, 2017).

(Empresa Portuguesa Das Aguas Livres [EPAL] S.A, 2015) with the aim of creating awareness among consumers as a more affordable option, of proximity and environmentally friendly through the campaign "Take tap water with you. Take the price. Take the environment with you", launched the "Fill Forever" bottle (Figure 13). This transportable, reusable, recyclable and nationally manufactured ergonomic bottle weighs only 27.5g and is made of 100% recyclable material, being a more ecological option to avoid the increase of packaging waste production (Associação Nacional dos Industriais de Refrigerantes e frutas [ANIRSF], 2007).

Figure 13. Fill forever bottle. Source (EPAL S.A, 2015)

The Pingo Doce supermarket chain with the aim of reducing the environmental impacts associated with the packaging of its own brand products in the Ecodesign project launched the campaign "Save on water of quality water, while helping the planet." In this campaign it promotes self-service through a water dispenser where customers will be able to fill their ECO bottle (Figure 14) with a capacity of 3 Liters. (Isabel & Gonçalves, 2018).

Figure 14. ECO bottle from Pingo Doce. Source (Isabel & Gonçalves, 2018)

Sociedade da Água de Monchique joined Mirpuri Foundation and the University of Minho to develop the first Portuguese packaging, 100% compostable and rapid degradation - "The Good Bottle".

"The Good Bottle" is a product composed of a polymeric base that can be composted in a domestic environment, and in its composition contains algae that during the degradation of the bottle serves as food for marine species. It has a biodegradability rate of 74% after 45 days under controlled composting conditions, and 90% up to 12 months, depending on the conditions it is exposed to. (Água Monchique, 2023).

Figure 15. The goog bottle deveopped by Agua de Monchique, Mirpuri foundation and Minho University. Source (Água Monchique, 2023)

Public insights

(Ferrara & Plourde, 2003) have discussed the substitution of plastic, for example, by glass. However, glass also has negative effects on the environment and it is not clear that its use is beneficial compared to plastic. Tap water is also an alternative.

(Orset et al., 2017) work shows that bottling companies are keen to innovate in a plastic of better environmental quality (i.e. biodegradable, recyclable and with organic properties). In fact, by analyzing the Willing To Pay (WTP), participants indicated their preferences, and thus their demands for different plastic bottles, they have found a significant premium associated with recycled plastic packaging (r-PET) and biodegradable bioplastic packaging (PLA). A plastic bottle with these three properties would be in demand by consumers and would increase the production of these types of plastic bottles by water companies.

4.3.2 Waste management process associated to bottled mineral water companies in Portugal

In 2019, 1072 million packages were produced for marketing bottled water, in the domestic market. About 85% of these packages are plastic (approximately 911 million) and taking into account that the average weight of a 0.33 L bottle is 11.35g and a 1.5 L bottle is 27.29g, we are facing a plastic production between 10 342 and 24 867 tons.(ZERO, 2019).

Portugal is the fourth country in Europe with the highest per capita consumption of bottled water, below countries like Italy, Germany and Hungary. Each Portuguese consumes on average 146.4L of bottled water, of which 85% (124.4L/inhab) is consumed in plastic containers. Assuming that the average weight of a package is 19.32g, each Portuguese is thus producing annually about 2.4 kg of plastic waste resulting from the consumption of bottled water.(ZERO, 2019).

The industry is aware of the importance of reorienting packaging. For this reason, in 1996 the sector created the "Sociedade Ponto Verde”, financed entirely by the sector's industry.

With the Sociedade Ponto Verde, the industry assumes full responsibility for the destination of the packaging waste it places on the market and undertakes to manage a system for the collection and recycling of packaging waste.(Sociedade Ponto Verde, 2022).

The Ponto Verde system in Portugal currently covers 100% of the Portuguese population and 100% of the national territory. By 2021, the collected volume data are shown in the Figure 16.

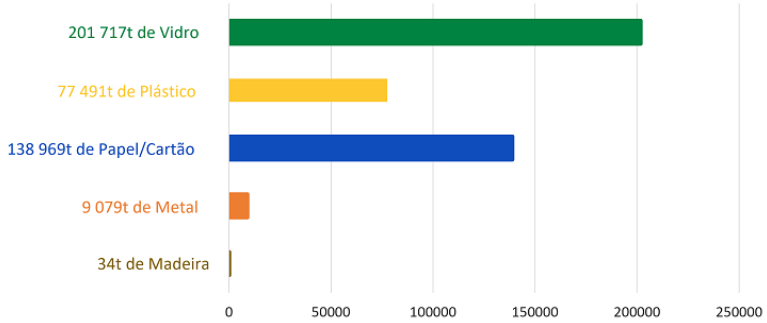


Figure 16Weight collected from packaging by sociedade ponto verde.

4.4 The SDGs as an indicator of sustainability and environmental resilience in the bottled mineral water industry

The Sustainable Development Goals (SDGs) serve as important indicators of sustainability and environmental resilience within the bottled mineral water industry. The SDGs, established by the United Nations, provide a comprehensive framework for addressing global challenges and promoting sustainable development. They encompass a range of goals and targets that specifically address environmental concerns, such as clean water and sanitation (SDG 6), responsible consumption and production (SDG 12), climate action (SDG 13), and life below water (SDG 14), among others.

By aligning their practices and initiatives with the SDGs, bottled mineral water companies can demonstrate their commitment to sustainability and environmental resilience. This alignment implies efforts to conserve water resources, reduce their ecological footprint, adopt sustainable packaging practices, mitigate climate change impacts, and promote responsible consumption patterns. Assessing the extent to which bottled mineral water companies integrate and contribute to the achievement of the SDGs provides valuable insights into their commitment to sustainability and environmental resilience. By embracing the SDGs, companies can effectively measure and communicate their progress and contributions towards a more sustainable and resilient future.

The 17 new Sustainable Development Goals (SDGs), represent an expanded and more ambitious plan of action to help end poverty by 2030. Goal 6 is a dedicated water target - "Ensure availability and sustainable management of water and sanitation for all". This agenda was adopted by member states at the Sustainable Development Summit in September 2015. The step to implementation is addressed by Target 17 by referring to the different means of implementation to be used for the achievement of the goals. This includes capacity building, financing, institutions, policies, partnerships and technology as catalysts for this change. (Santiso, 2004).

Some of the key challenges for the implementation of the various water-related sustainable development goals are as follows:

a) **Water, Sanitation and Hygiene - WASH**: There is a need to increase and properly localize sources of funding, institutional capacity, political support and management of inconsistencies in the implementation of legislation in this area. A need to scale up appropriate technologies and improve capacity to address inequalities and deal with the problems of open defecation, as well as sanitation and hygiene in schools and health centers.(Santiso, 2004).

b) **Water Resource Management - WRM**: Funding is insufficient and there is a need for improved financing for water resources management. Many countries are currently suffering from an infrastructure deficit. Without a significant increase in investment in their water infrastructure, many countries will struggle to meet their targets. Little progress has been made on payment for water services and ecosystem protection services. There are also challenges in implementing appropriate technologies. (Santiso, 2004).

Water efficiency in some countries is not integrated into water resources management. Few countries have made progress in implementing irrigation improvement techniques and rainwater harvesting. "Technological benefit" should be approached to ensure that technology becomes an effective means to achieve socially and ecologically sustainable development. Lack of capacity is also a problem. The most typical cases of it relate to the lack of human capacity, both in numbers and knowledge, to plan and manage.(Santiso, 2004).

c) **Water Quality**: There are numerous challenges in implementing water quality and ecosystem protection systems, which require, among others, improved financing of soft and

hard infrastructures, institutional capacity building for the development of standards and regulations and their monitoring and enforcement, the improvement of limited information and expertise in water quality accounting and ecosystem protection (scale, data, field verification and relevance, coverage and representativeness, added value for decision making, monetary valuation), and the disconnection between water regulations of land use.(Santiso, 2004).

d) **Risks:** Implementation challenges regarding risk management affect mostly the world's poorest communities. These include improved financing, lack of access to financial resources, insufficient new technologies, lack of capacity and limited use of traditional knowledge, improved water governance with greater emphasis on the resource itself, ensuring the participation of all relevant national sectors in climate actions, lack of discussion on institutional barriers and how to overcome them, making adaptation strategies difficult, lack of capacity, ability and time to access resources from local governments, unreliability, inaccessibility or lack of hydrological information.(Santiso, 2004).

SDG 6, water, covers the intertwined nature of water by including: increasing access to water, sanitation and hygiene, as well as addressing issues of water stress, water quality and integrated water and ecosystem management. It is also recognized that meeting the water SDG, and any other sustainable development goal, will require all stakeholders to act to commit resources, skills and expertise. Companies will have a role to play, given their dependence and impact on water resources. Many companies are already doing so through the development of sustainable water practices. These practices can be further enhanced by integrating the human rights to water and sanitation into corporate social responsibility.(Santiso, 2004).

Companies are in one way or another linked to water, either through their direct operations, in their supply chains, or in their role as water service providers.

• **Water is an irreplaceable resource:** Water itself, or the services it provides or offers, is an indispensable input for most businesses. Managing to ensure appropriate access in the necessary quantities, at the required quality, and at the right time and place are essential to the very existence of almost all businesses. This has become increasingly important as the demands on the finite masses of available water increase.

• **Water in the value chain:** Water plays a similar role throughout the value chain of industrial production and commercial activity, as well as in its multiple interactions with communities and stakeholders at all levels. Companies have an interest and responsibility to understand these complex relationships and to conduct their business accordingly.

• Guarantee legal licenses and social acceptance for the operation of a company in a location.

- Gain competitive advantage through the perception of the company by stakeholders as a company that uses natural resources responsibly and seeks to generate minimal impact on the communities and ecosystems it affects;

- Assure its investors and markets of the business's profitable operations, ensuring the availability of water for its operations and reducing water-related costs;

- Uphold corporate values based on sustainable and equitable development.

4.5 Sustainability in the value chain of bottled mineral water companies

4.5.1 The Sustainable Development Goals (SDGs)

Both mineral water and general businesses play a key role in ensuring sustainable development policies, which are implemented because of the critical and active role they play in transforming resources into products and services required by society. This case is reinforced further by the realization that the specific contribution of the business to sustainable development also plays a key role in the long-term viability of the business and its success. These actions are grouped into the following areas:

• **Ensuring good water governance**: Water-dependent businesses are aware that achieving development goals requires addressing aspects of water sustainability in its broadest dimension including: improving water governance systems and addressing security of access and water quality; all of which are important issues necessary to address water-related business risks. (Santiso, 2004).

• **More dynamic communities:** Beyond their employees, companies must also realize that healthy communities have a positive impact on their businesses. Companies are

increasingly engaging in activities that focus not only on their employees, but on their employees' families and the communities in general. Healthy families ensure a high level of productivity in the workplace, while active communities serve to reinforce not only a company's social acceptance to operate, but also a healthy customer base. (Santiso, 2004).

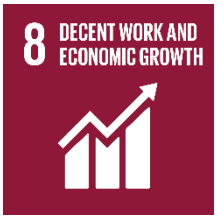
• **Triple Bottom Line:** Companies are aware that business action aligned with the achievement of sustainable development goals, offers in return opportunities to create new products and innovations in their markets.

These elements make it clear that ensuring adequate and sufficient water needs for their employees, communities and society are necessary for the long-term prosperity of companies. Inaction, on the other hand, is unsustainable, leading to increased potential for conflict over water resources, decreased social acceptance to operate, and increased reputational risks.(Santiso, 2004).

The Sustainable Development Goals (SDGs), set by the United Nations for 2030, are a universal call for everyone, institutions, companies and society in general, to participate in building a better world and to take concrete actions to protect the planet, end poverty and ensure that all people enjoy peace and prosperity. In reality, mineral water companies can implement activities and targets within the majority of the SDGs and their scope of action, for example, Table 8 lists some of them:

Table 8. Proposed targets for mineral water companies associated with the SDGs.

	To ensure long-term sustainable production, maintaining at all times the high quality standards achieved and guaranteeing the food safety of the mineral water.
	Continue to encourage cooperation with all its stakeholders concerned with the promotion of sustainability in order to continue to guarantee in the future, in a responsible and sustainable manner, a safe, healthy and quality source of hydration, 100% natural.

	Promote environmental education through education, dissemination of knowledge and best practices to involve and raise environmental awareness throughout society in the protection of biodiversity and prevention of littering.
	To achieve a 10% reduction in process water consumption by 2030 with respect to 2010 consumption, in addition to continuing to manage water resources sustainably to preserve and ensure the natural balance of springs in terms of quality and quantity.
	To reduce energy consumption by 30% by 2030 compared to 2010 and to ensure that 70% of the energy used in the packaging process comes from renewable sources.
	Continuing to generate quality employment in areas with hardly any industrial fabrication
	To achieve that by 2030 the average of PET containers in the Sector will contain 50% recycled material and to continue investing resources in R&D&I projects for the production of raw materials of non-fossil origin.
	Promote equality and conciliation measures to provide equal employment opportunities within the mineral water sector, regardless of any individual characteristics, and encourage these practices throughout the value chain.

	Implement a low carbon mobility plan, achieving that by 2025, 100% of the bottling companies have implemented an Integrated Transportation Plan to work centers and that by 2030, at least 50% of their fleet of vehicles dedicated to commercial activity does not use fossil fuels.
	To achieve zero landfill of industrial waste in the packaging plant, to increase the packaging recycling rate to 95% by 2030, to maintain the reusable packaging rate in the sector and to continue researching and applying eco-design criteria in the production of our packaging.
	To continue to be a proactive player in the transition to a low-carbon economy by reducing our carbon footprint by 30% by 2030 compared to 2015.
	Promote initiatives such as the preparation and dissemination of guides on bottled mineral waters and the sustainability of their aquifers and guides on self-monitoring of the quality of mineral water catchments and their protection perimeters, as well as being a proactive agent to reduce terrestrial littering.

4.5.2 Carbon, Energy and Water Footprints

Carbon Footprint

Raw Material: The most common material used in beverages such as bottled water is polyethylene terephthalate or PET. The production of this type of plastic, in addition to carbon emissions, includes several toxic substances such as benzene, ethylbenzene, ethylene oxide and nickel.(ZERO, 2019).

Bottle production: for every 200ml of water that is bottled, three times that amount, about 600ml, is wasted during the production process. Similarly, producing bottled water requires a lot of energy, in some cases up to 2,000 times more energy compared to tap water.

Waste production: The popularity of bottled water coupled with the consumption of other products also packaged in single-use plastic containers has created a growing environmental problem due to the amount of waste produced. (ZERO, 2019)

Recycling helps reduce your carbon footprint since by diverting this waste from landfills and incinerators, you are contributing to the reduction of greenhouse gas (GHG) emissions that are produced at these sites. One study showed a 79% reduction in CO2 emissions from recycled PET plastics when compared to the production of new materials. (ZERO, 2019).

Energy footprint

The consumption of bottled water, in Portugal, has been growing over the past few years. According to industry data, in 2019, the Portuguese consumed 1215 million liters of bottled water, corresponding to approximately 65% of the total non-alcoholic beverages consumed. This consumption of bottled water represents a per capita consumption of 146.4 liters, up from 113.6 liters in 2014. (ZERO, 2019).

The energy footprint required for the production of a 1L bottle of bottled water can vary between 5.6 and 10.2 MJ while the production of 1L of tap water requires about 0.005 MJ for treatment and distribution.

Bottled water production requires energy to produce, package, transport, cool, use and recycle the water and its packaging. The total amount of energy required depends on many factors, including the location and type of water source, the distance from the bottler to the consumer, the type of material used for packaging, the method of transportation, and more. According to some research, the energy used by the various stages of production of a 1 liter bottle of water is broken down as follows:

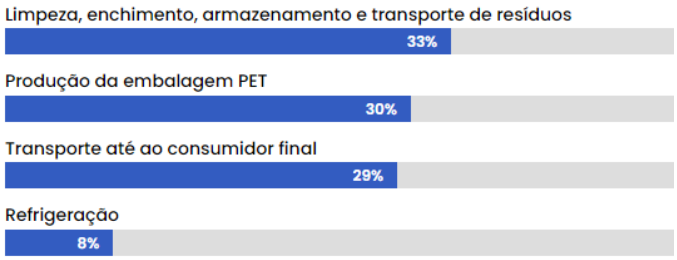


Figure 17. Proportion of energy use in the production of bottled mineral water. Source: (ZERO, 2019).

Water Footprint

The calculation of the Water Footprint is based on a previous Life Cycle inventory of the product, which in the case of drinking water includes the following stages: water extraction, production of PET preforms, transport of PET preforms to the bottling site, production of the packaging, production of ozone for bottle washing, bottle washing, filling, corking, labeling, packing, packaging and storage and distribution of bottled water to commercial surfaces and then to the final consumer.(Rolandr and Jambeck, 2017).

Determining the total water footprint of PET plastics includes calculating the "blue" and "gray" footprints, which means that it is necessary to take into account not only the water consumed in the creation of the raw material, but also the water needed to reduce thermal pollution caused by cooling processes included in the final stage of the production process. (Water Footprint Network, 2019).

Several studies comparing the water footprints of bottled water and tap water have concluded that, for a volume of 1.50 L, they have footprints of 3.43 and 3.63 L, respectively.(ZERO, 2019).

4.6 Resilience in the production chain of packaged mineral water companies

Climate change is manifesting itself through a number of water-related disruptions and companies must be prepared and ready to act in the face of these phenomena. Companies must actively plan for risks and build resilience, paying particular attention to risks to water sources, their (often sensitive) environment and waste management, using proven tools and approaches. The intensification and evolution of natural hazards requires companies to take into account elements that go beyond traditional risks and to take measures to prepare for unforeseen and progressive risks.(Haines-Young & Potschin, 2010).

The approach to reinforce resilience requires more than risk reduction measures. It requires consideration of adaptation, transformation and adjustment measures in the presence of observed risks throughout the production chain, as well as learning and, where possible, adopting a complementary "build back better" approach. For this reason, resilience must be addressed holistically and with the involvement of all actors and stakeholders. (LÉLÉ, 1998).

In the context of bottled mineral water companies, source disruptions, environmental disruptions (pollution, loss of diversity) and/or stresses (shortages, excess demand) can occur.

Technology is enabling companies to become more resilient by collecting huge sets of real-time data (mega-data) that can help monitor trends and patterns related to risks. Investing in essential infrastructure based on verifiable and reliable assessments of needs and risks remains essential.(Daza & Casas, 1999).

Response procedures must be established for companies to deal with natural and human hazards with minimal impact. Adaptation measures must be implemented before the effects of climate change are further intensified. For risks related to the mineral water production process, this means renewing and improving infrastructures, techniques, training and communication, operational and response plans, etc.(Calvente, 2007).

Temporary solutions involve greater long-term risks for those affected. The implementation of action plans and protocols can help prevent the emergence of new risks. While these actions help to assess the entire mineral water production chain, new tools and approaches must also be developed. Most importantly, more data is needed to make informed decisions within the company. It is more cost-effective to invest in prevention than in recovery; however, this approach requires a long-term vision. (Haines-Young & Potschin, 2010).

CHAPTER V – CONCLUSIONS AND FUTURE SUGGESTIONS.

A bibliographic search of bottled mineral water companies in continental Portugal and their environmental practices is crucial for the understanding of the current industrial state of the industry and identifying potential areas of improvement. This was achieved by a comprehensive review of relevant literature and sources, including academic journals, industry reports, government publications and official web pages, gathering information on the environmental impact of bottled mineral water companies operating in Portugal.

The data gathered allowed to identify the key environmental issues and challenges faced by the industry, as well as the current practices and initiatives being implemented by companies to address these issues. This information can be used to develop recommendations

for improving the sustainability and resilience of the industry, as well as to inform future research and policy development.

By defining sustainability and resilience a shared understanding of the goals and principles that should guide the industry's environmental practices was stablished. This understanding will enable companies to develop comprehensive sustainability strategies that address the ecological, social, and economic dimensions of sustainability. In addition, it was provides a framework for assessing the effectiveness of sustainability initiatives and identifying areas for improvement. By considering the principles of sustainability and resilience when designing their practices, bottled mineral water companies can enhance their environmental performance and reduce their ecological footprint.

Mineral water companies can contribute to the SDGs through a variety of activities and targets that align with the goals. These activities include promoting sustainable production, reducing water and energy consumption, promoting environmental education, generating quality employment, promoting equality and conciliation measures, implementing low-carbon mobility plans, and reducing their carbon footprint. In addition, mineral water companies should promote initiatives to prepare and disseminate guides on sustainability and self-monitoring of the quality of mineral water catchments to reduce littering.

On resilience subject, the involvement of all stakeholders is necessary, and investing in infrastructure and collecting real-time data is essential. The implementation of action plans and protocols can help prevent the emergence of new risks, and companies should prioritize prevention over recovery. Ultimately, a long-term vision and a holistic approach are required to reinforce resilience and effectively manage risks in the production of bottled mineral water.

Furthermore, analyzing how the concepts of environmental sustainability and resilience are integrated into these regulations and laws can provide insights into the priorities and objectives of regulatory bodies and policymakers. This information can be used to develop targeted solutions that align with regulatory requirements and promote more sustainable practices within the industry.

For instance, the process of granting licenses for the exploitation of these resources requires a hydrogeological study of the area, physicochemical and bacteriological characterization of the water, and evaluation of the environment from the point of view of

the vulnerability to contamination. The establishment of a protection perimeter is also necessary to guarantee the availability and characteristics of water and ensure the conditions for good exploitation. The restrictions and limitations in the immediate, intermediate, and extended zones are set out in articles 47, 48, and 49 of the law. The adequate protection of geological resources must be ensured with a view to their exploitation.

It was found by law that the labeling of natural and spring mineral water is mandatory and provides consumers with information on the water's characteristics, including the typical chemical composition, pH value, and total mineralization. Quality control and sanitary monitoring are strict in the bottled water sector, with the Portuguese government ensuring that public health is properly defended and promoted. The sector is also subject to regulations on food quality and safety, ensuring that natural mineral water and spring water are natural, healthy, and safe food.

The SDGs provide a framework for achieving sustainable development and addressing global challenges, and packaged mineral water companies can play a significant role in contributing to these goals. By identifying the SDGs that are most relevant to the industry, companies can develop strategies and initiatives that align with these goals and contribute to their achievement.

Some of the SDGs in which packaged mineral water companies may be involved include SDG 6: Clean Water and Sanitation, SDG 12: Responsible Consumption and Production, and SDG 13: Climate Action. Objectives and proposed activities to support these goals may include reducing water usage and improving water efficiency in production processes, promoting sustainable packaging and reducing waste generation, and investing in renewable energy sources to reduce greenhouse gas emissions.

Other proposed activities may include implementing sustainable sourcing practices, such as reducing the environmental impact of water sources and ensuring ethical labor practices within the industry. By prioritizing sustainability and responsible practices, packaged mineral water companies can contribute to a more sustainable future and support the achievement of the SDGs.

Industry professionals interviews allows to gain valuable insights into the current state of sustainability practices within the industry, identify gaps in knowledge or awareness, and develop targeted solutions to improve environmental performance.

Furthermore, assessing the awareness of industry professionals help to identify barriers to the adoption of sustainable practices, such as lack of resources or understanding, and develop strategies to address these challenges. While the interviews provided valuable insight into the inner workings of the factories, some difficulty in accessing certain information was encountered.

Given the complexity of the subject matter, it would be beneficial to conduct a larger number of interviews to gain a more comprehensive understanding of the issues at hand. Additionally, it was observed some lack of knowledge among the interviewees regarding specific issues of sustainability and resilience indicators. This highlights the importance of conducting further research in this area to better understand the factors that contribute to the success of these factories in these matters.

It is suggested that future interviews not only include technical workers but also management positions. This would provide a more well-rounded perspective on the operations of the factories and help to identify areas for improvement.

Technology and techniques currently used in the production of packaged mineral water in Portugal were analyzed in order to identify opportunities for improvement and develop targeted solutions that enhance the industry's environmental performance. The information of innovative technologies that are being developed worldwide and in Portugal, provide a broader perspective on emerging solutions that may be applicable to the industry.

The development of innovative technologies can help reduce the environmental impact of bottled water production by improving efficiency, reducing waste and energy consumption, and promoting sustainable practices throughout the supply chain. For example, the use of renewable energy sources such as solar or wind power in the bottling process can significantly reduce the industry's carbon footprint. Additionally, advances in packaging materials can lead to more sustainable options that are biodegradable, recyclable, or made from renewable materials.

The financial viability of switching from plastic bottling of mineral water to biomaterials depends on several factors such as the cost of production and availability of the biomaterials, consumer demand, and government regulations. In Portugal, there are also government initiatives and regulations promoting sustainable practices, including the use of biomaterials. Therefore, switching to biomaterials for mineral water bottling could be financially viable for companies in Portugal, especially if they are committed to promoting sustainable practices and meeting consumer demand for environmentally friendly products.

However, the exact cost implications would depend on the specific circumstances of each company and their supply chain. It may require significant investment in research and development to find cost-effective biomaterial alternatives to traditional plastic, and the availability and reliability of these materials may also impact their feasibility

By examining the current practices permits to analyze industry's strengths and weaknesses in terms of sustainability and environmental resilience. This examination also helps to identify opportunities for improvement and develop targeted solutions that enhance the industry's environmental performance. The production of packaged mineral water can have significant environmental impacts, including water usage, energy consumption, and waste generation. Therefore, it is crucial to assess the industry's current practices to ensure that they align with sustainable development goals and promote long-term environmental sustainability.

It is suggested that several complementary studies can be carried out to further explore the subject. In particular, a consumer survey would be valuable to supplement and contextualize the information gathered from technical workers in the industry. This would provide insight into the attitudes and behaviors of consumers towards sustainable and environmentally friendly practices in the industry.

Additionally, it would be interesting to conduct a comparative study between mineral water companies in Portugal and those in other countries to identify similarities and differences in approaches to sustainability and environmental resilience. This could provide valuable information for policy makers and industry leaders in Portugal to improve their practices and learn from the experiences of other countries.

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Annexes

Annex I – Interview presentation and questions

Very good morning, my name is Jonathan Vega and I am an international master's student at Politécnico de Leiria. I am a biotechnological engineer by profession and my master's degree is in Quality Management and Food Safety.

I thank you very much for the time in your agenda and remind you that the information will be presented quantitatively and not qualitatively in order to enrich my research work, impersonalizing the results without affecting any of the stakeholders.

The questions are open and semi-open questions in which you can answer your own assessment and even add your personal opinion when you consider it necessary. It is not mandatory to answer all the questions, but all the information provided will be very valuable for my research.

The idea is to address 7 main topics, each with a series of questions:

TOPIC 1: Company policy and values

1.1 Could you briefly describe the policies and values of the company and if any of them are related to environmental practices?

1.2 Within this scope of environmental practices (bearing in mind that everything is perfectible), do you think that the company pays sufficient attention to its policies in which areas?

1.3. Does the company comply with current environmental regulations to the best of its ability, in what percentage? Which is the main responsible control institution? Is the work of these control institutions positive?

1.4 Regarding the company's environmental practices? Have there been any complaints or claims from the population, clients, etc.?

1.5. Approximately how many people make up the company? Is the company's staff trained and aware of the values, policies and compliance (especially environmental)?

TOPIC 2: Technique and technology associated to the mineral water value chain

2.1 Could you briefly describe the value chain of packaged water production (include location)?

2.2. What (if any) extraction technique is used? Do you consider the technique efficient for the company's purposes? Why?

2.3. Is there a research department within the company? What are the main research lines? Are there any related to environmental care or improvement of the company's activities related to the environment?

2.4 Is the packaging management done by the company itself? The concern of good management of them, what activities does it involve?

TOPIC 3: Communication Strategies

3.1. Does the company have any kind of communication strategy aimed at its customers, the nearby population or the general population?

3.2. Within these communications, are any of them focused on environmental issues?

TOPIC 4: Environmental Resilience

4.1. Is the company familiar with the concept of environmental resilience?

4.2 What kind of environment surrounds the company's activities?

Is the environment in a protected area? does it have ecological diversity of plants and/or animals, can it be considered sensitive?

4.3 Are processes carried out with this concept of environmental resilience in mind? Describe them briefly.

TOPIC 5: Environmental Sustainability

5.1. Is the water, carbon, ecological and social footprints of the company measured as indicators of sustainability? Is this data available or publicly accessible?

5.2 If this parameter (footprint) is not used, how do you try to develop a sustainable activity?

5.3. Is the company aware of the SDGs (Sustainable Development Goals) and has it had to align its activities in some way to meet them?

TOPIC 6: Environmental Practices (in this case the questions are more close-ended and can be answered as far as possible, again remembering the anonymity of the data provided).

6.1 Is the recycling rate of your packaging measured (or is this handled by another entity)? Are materials reused in the production process itself? In what percentage?

6.2 What is the water consumption (excluding the one considered as final product) used by the company for its operation? Is there recirculation in any of the phases for a better use?

6.3 In relation to the total number of company plans, how many of them (in percentage) incorporate the environmental component?

6.4 Are environmental awareness activities performed? Approximately how many per year? Are they directed at employees, nearby communities or the general population?

TOPIC 7: Final Considerations

7.1 You concluded that the population's consumption habits changed due to a greater concern for environmental care. What changes were perceived?

7.2 In economic terms, due to changes in customer behavior, was there an impact on the company?

7.3 Has the company reacted to be in accordance with the new environmental trends in Portugal?

7.4 What strategies do you evaluate so that customers feel that they are not harming the environment by consuming your products?