MSc Program
Engineering Management

ACADEMY FOR CONTINUING EDUCATION

End-of-life product management in the pharmaceutical industry: A circular economy approach to addressing pharmaceutical waste collection in Austria and Slovakia

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
Em.O.Univ.Prof. Dipl.-Ing. Dr.techn. Dr.h.c.mult. Kopacek Peter

Armen Shakhnazarov

12130525

Vienna, 06.04.2023

Affidavit

I, **ARMEN SHAKHNAZAROV**, hereby declare

1. that I am the sole author of the present Master's Thesis, "END-OF-LIFE PRODUCT MANAGEMENT IN THE PHARMACEUTICAL INDUSTRY: A CIRCULAR ECONOMY APPROACH TO ADDRESSING PHARMACEUTICAL WASTE COLLECTION IN AUSTRIA AND SLOVAKIA", 80 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

Vienna, 06.04.2023

_____
Signature

ABSTRACT

The end-of-life product management is an important part of the circular economy that involves the collection, recycling, reuse, or disposal of products that have reached their end of life. In the case of pharmaceutical products, the collection of unneeded or expired medication (UEM) or pharmaceutical waste is a complicated and regulated process in the EU. This thesis focuses on public UEM collection, excluding hospitals, and investigates the knowledge, attitudes, motivation, and administrative aspects related to UEM collection.

Using survey, the study aims to test the following hypotheses: Hypothesis 1 suggests a difference between young participants and those under 60 years of age, as older populations are more likely to consume medication regularly and are therefore more knowledgeable on UEM collection. Hypothesis 2 assumes a difference between female and male participants due to differences in pharmacy visits and medication consumption. Hypothesis 3 suggests a difference between Austrian and Slovakian participants based on their cultural, traditional, and regulatory differences. Hypothesis 4 proposes a difference between parents with and without children under 18, as the former may be more informed about UEM collection due to their children's medication needs. Hypothesis 5 assumes a difference between participants with chronic illnesses and those without, as the former may be more acquainted with UEM collection due to their more frequent pharmacy visits.

The goal of this research is to identify key problems in pharmaceutical waste collection and offer solutions to increase collection and decrease the release of hazardous chemicals into the environment. The findings of this study may inform policies and programs aimed at improving UEM collection and reducing negative environmental impacts.

TABLE OF CONTENTS

1. INTRODUCTION

1.1. Overview

My thesis about UEM or Pharmaceutical waste collection as a crucial aspect of the life cycle economy and end-of-life product management strategy. The pharmaceutical industry plays a critical role in maintaining and improving public health. However, as with any industry, it also generates waste that can pose significant environmental and health risks if not managed correctly. Proper disposal of UEM is essential to prevent environmental contamination, reduce the risk of accidental ingestion or abuse, and minimize the potential for the development of antimicrobial resistance. At the same time, effective waste management can also help recover valuable materials, reduce greenhouse gas emissions, and create economic opportunities.

In this context, UEM collection serves as a key link in the life cycle of drugs and medical products, connecting the end of their useful life with new opportunities for recovery and reuse. It is achievable to develop a circular economy that prioritizes resource preservation, minimizes waste, and promotes products intended for maximum lifespan and efficacy by incorporating eco-friendly trash collecting systems. It's important to note that while the pharmaceutical industry is a significant contributor to UEM, hospitals and households also generate substantial amounts of waste through the use and disposal of expired or unused medications.

In hospitals, UEM is generated through the administration of medications to patients, the disposal of unused or expired drugs, and the handling of contaminated materials. These compounds can be extremely hazardous to human health and the environment, making proper disposal practices essential. Similarly, households generate a considerable amount of pharmaceutical waste through the disposal of expired or unused medications. Unfortunately, many people tend to dispose of these drugs by flushing them down the toilet or throwing them in the trash, which can result in the release of harmful chemicals into the water supply and the environment. As a result, UEM management is difficult task with lots of aspects that needs a partnership and coordination of a wide range of stakeholders, from manufacturers and regulators to hospitals, households, and waste management facilities.

As part of my research, I have been conducting a survey to assess households' awareness and participation in UEM collection programs in two countries. Based on the previses available information (OECD, 2022), (Mitkidis, et al., 2021). The research has shown that many households are not aware of the importance of proper UEM disposal and the impact that their actions can have on the environment and significantly from country to country (OECD, 2022). I will discuss the importance of education and awareness-raising campaigns to encourage households to participate in proper waste disposal practices, as well as the role of local authorities, pharmacies, and other stakeholders in providing accessible and convenient collection points and practices. It's also essential to understand the motivations that drive households to participate in UEM collection programs, as this can inform the design of effective awareness campaigns and waste management practices. Some households may be motivated by a desire to safeguard the environment and minimize their negative influence on the planet. Someone else could be anxious about the possible harms connected to improper waste disposal, such as accidental ingestion or the development of antimicrobial resistance. Additionally, some households may be influenced by the convenience and accessibility of waste collection programs, particularly those that provide convenient drop-off locations or home pickup services. By understanding the motivations that drive households' participation in UEM collection programs, education and awareness campaigns could be designed to address their specific concerns and priorities. This approach can help to promote more sustainable waste management procedures to safeguard the ecosystem and

public safety. By tailoring the strategies to household motivations, that can encourage greater participation in waste collection programs and move towards a more circular economy.

The life cycle of a product typically includes several distinct phases, each of which presents different challenges and opportunities for sustainability. The research and development phase, for example, is critical for ensuring that a product is designed with environmental and social considerations in mind. This involves conducting research to identify the most sustainable materials, manufacturing methods, and distribution channels, and ensuring that the product meets all necessary safety and regulatory requirements.

Once the product is finalized, it enters the production and distribution phase, where it is manufactured and transported to retailers or customers. This phase has a significant impact on the product's carbon footprint, energy consumption, and waste generation. Manufacturers can use sustainable production practices, such as decreasing waste and using renewable energy sources, as well as effective distribution strategies that reduce emissions from transportation, to lessen these effects. When the product comes to the end of the lifespan, it is disposed of, recycled, or sent to a landfill in the disposal and end-of-life phase. This phase presents a significant challenge for sustainability, as it is often difficult to ensure that products are disposed of in a way that minimizes their environmental impact. To address this challenge, some manufacturers are exploring ways to design products that can be easily disassembled and recycled, or that can be repurposed for other uses. Additionally, some companies are exploring new business models, such as product-as-a-service, which aim to reduce waste by enabling consumers to lease or rent products rather than purchasing them outright.

Some products, such as electronics and appliances, can also be reused, refurbished, or remanufactured to give them a second life. This helps to reduce waste and conserve natural resources, as well as create new business opportunities for manufacturers and service providers. To support these efforts, some companies are exploring new business models, such as take-back programs and repair services, that enable consumers to extend the life of their products and reduce waste. When analyzing the life cycles of products, it's crucial to note that different products may have varying life cycle stages, and different stages can be applicable to the product and industry. When comparing two products' life cycles, several factors should be considered. Firstly, the product category can affect its life cycle duration. Secondly, market conditions such as consumer demand, competition, and technological advancements can impact the product's life cycle. Thirdly, the availability and accessibility of a product through various distribution channels can also influence its life cycle. Fourthly, the product's features, including durability, innovation, and recycling capabilities, can also have an impact on its life cycle. Lastly, life cycle assessment is a tool that can be utilized to compare the environmental impact of two products throughout their entire life cycle. By considering these factors, a comprehensive understanding of a product's life cycle can be achieved, aiding in effective decision making and strategic planning.

For example, if I compare the life cycle of a smartphone and a refrigerator, I will likely see that the life cycle of the smartphone is shorter, as technology advancements and consumer demand for newer models lead to shorter product life cycles. Additionally, the smartphone is likely to have a higher environmental impact due to its shorter life cycle and the need to extract and process more resources to produce more frequent model changes. On the other hand, the refrigerator may have a longer life cycle, and its environmental impact may be less due to its longer lifespan and the potential for recycling.

The analysis of a drug's life cycle is an essential technique utilized to assess the commercial viability and profitability of a medication from development to market

launch. However, pharmaceutical life cycle analysis is not without its challenges. One of the most significant obstacles is patent expiration, which leads to a decline in sales and profitability due to the availability of generic versions. Additionally, market saturation caused by the increase in drugs to treat the same condition poses a hurdle for new drugs seeking to capture market share. The regulatory process of getting a drug approved can also be an expensive and lengthy process, with a risk of not being approved at all. Pricing pressure, driven by the desire to control healthcare costs, puts pharmaceutical companies under pressure to lower their prices. Reimbursement issues also affect the potential market of drugs that have reached the market but may not be reimbursed by all payers. Lastly, market trends for pharmaceuticals are ever-changing, and new technologies and treatments can swiftly disrupt established markets. These challenges must be considered in pharmaceutical life cycle analysis to achieve an accurate and comprehensive understanding of a drug's commercial potential.

Environmental contamination and troubles with public health may result from UEM. Environmental contamination is a major issue associated with UEM, as it might pollute water and soil, causing the deterioration of aquatic ecosystems, and contributing to the proliferation of antibiotic-resistant bacteria. In addition, UEM can also result in human exposure to harmful chemicals and drugs, which can have negative health impacts. Furthermore, disposing of UEM can be expensive for both the healthcare industry and local governments.

UEM can also pose a significant risk when they are not disposed of correctly, leading to unintended uses such as abuse or illegal sale, which can contribute to public health problems. A lack of proper disposal knowledge also results in many people flushing unused drugs down the toilet or throwing them in the trash, leading to environmental contamination and human exposure. The lack of federal regulations in most countries specifically addressing the disposal of UEM poses a challenge for healthcare providers and local governments to properly manage and dispose of this waste, further complicating the issue. Overall, effective management and proper disposal of UEM are crucial to prevent environmental contamination and public health risks. To address these issues, it is important to implement proper disposal methods for pharmaceutical waste, such as take-back programs and specialized collection sites, as well as regulations to promote safe and responsible disposal. Additionally, efforts should be made to reduce the amount of waste generated, for example, by promoting the use of generic drugs and encouraging patients to only take the medication they need.

In the European Union (EU), programs for the collection and disposal of UEM are implemented at the national level, with each member state having its own regulations and policies. These programs mainly focus on collecting and properly disposing of unused or expired medications, to reduce the environmental and health risks associated with UEM. The program includes over the counter and prescription drugs, as well as veterinary drugs and medical devices. And including the appropriate destruction or disposal of the collected drugs. It is important to note that EU countries are taking different approaches to the problem and that regulations and policies may change over time and vary between countries. Since 2004, the EU demanded its member countries to set up "an appropriate collection system" for not used and/or expired pharmaceuticals. This requirement is found in Article 127b of the European Union Directive on the Creation of a Community Code Relating to Medicinal Products for Human Use (2004/27/EC). It was transmitted in Slovakia by a document "Disposal of unused drugs by private individuals" (Ministry of Health of the Slovak Republic, 2020), (Ministerstvo životného prostredia SR), 2014 stated that: The document provides a methodological instruction on the correct handling and collection of hazardous waste, specifically medicines not consumed by individuals, in the premises of a public pharmacy. It provides a classification of pharmaceutical waste according

to the waste catalogue, with waste from medicines not consumed by individuals being divided into two categories: Cat. No. 200131 cytotoxic and cytostatic medications that belong to the category as dangerous waste, and Cat. No. 200132 for other pharmaceuticals, which are considered other waste. The document also includes guidelines from the Ministry of the Interior of the Slovak Republic, which specify that hazardous waste with Cat. No. 200131 includes all drugs listed in a list of medicines, including those containing precursors, and those with cytostatic and cytotoxic effects. It is also stated that this category of hazardous waste includes systems for administering medicinal products that are not intended for repeated use, such as medicated patches and filled syringes, but does not include dietary supplements, cosmetic preparations, or medical devices. The other waste category, with Cat. No. 200132 is created from homeopathic medicines and medicinal plant products. Additionally, it states that the public pharmacy is responsible for collecting these medications and transferring them to the ŠÚKL (State Institute for Drug Control) as the originator of this waste, who will then dispose of it at their own expense as per Act no. 79/2015 Coll. Austria has its own regulation document (Austrian Standards International, 2020) in cluse No. 4.5.1. indicates the classification and disposal of other medical waste, including UEM. It states that the hazard potential of these products can be determined by their composition or "signature". The text goes on to detail two specific categories of UEM. The first category is medicinal products with hazardous properties, such as cytotoxic drugs and unsorted drugs that contain hazardous components according to the Waste List Ordinance. This category also includes cytostatic preparations that are not required and mixtures of cytotoxic drug waste with other drugs. The second category is waste contaminated with liquid cytostatic, such as emptied containers and hose systems, which may be disposed of as waste without risk of injury or waste with risk of injury. The text notes that the handling of cytostatic is primarily an issue of employee protection. Finally, the text states that medicinal products without hazardous properties should be classified as non-hazardous, only if they do not contain cytotoxic or cytostatic components or if an appropriate professional separation has been made.

1.2. Research Objectives

Conducting research on the problem of household collection of pharmaceutical waste is motivated by a desire to address both environmental and public safety concerns. Improper disposal of pharmaceuticals can have negative effects on aquatic life and contaminate drinking water sources. Additionally, household collection of UEM can also address issues of public safety by preventing the accidental or intentional misuse of discarded drugs. Understanding how and why individuals dispose of their UEM, can improve the collection and disposal of UEM. Additionally, by studying the cultural and national differences between Austria and Slovakia, it can help to identify barriers and challenges that prevent individuals from properly disposing of their UEM, such as a lack of knowledge or accessibility to collection points. This research also aims to improve public health, and both promoting awareness about the concrete environmental problem, preserving the environment and motivate people to respect the regulations.

The research objectives for this study are to understand public awareness and motivation towards the collection of UEM as a part of end-of-life management in the pharmaceutical industry. Specifically, the study aims to explore the barriers and challenges that prevent individuals from properly disposing of their UEM, such as a lack of knowledge or accessibility to collection points. Additionally, the study also aims to examine the cultural and national differences in public behavior towards the collection of UEM. The focus of this study will be on the UEM collection public awareness and public motivation in Austria and Slovakia. My research will be done by using various kinds of methods, including combination of quantitative and

qualitative methods to gain a comprehensive understanding of the topic.

The research scope about UEM management will focus specifically on the issue of public awareness and motivation surrounding the collection of UEM. This will include an examination of the current level of public knowledge and understanding of the issue, besides an analysis of the factors that influence individuals' decisions to properly dispose of their UEM. Additionally, the research will explore potential barriers that may prevent individuals from properly disposing of their waste, such as a lack of access to collection points or a lack of information about proper disposal methods. The research will also investigate the effectiveness of existing awareness campaigns and programs, along with identifying best practices for increasing public awareness and motivation to properly dispose of UEM. The study will be conducted by several research techniques, including questionnaires, interviews, and statistical analysis. The study will be conducted in two countries Austria and Slovakia, to compare the cultural and national differences in public awareness and motivation.

As a research plan for studying the public awareness and motivation for UEM collection, I would be conducting a survey. The survey would aim to gather information about individuals' knowledge and attitudes towards proper disposal of pharmaceutical waste, likewise any barriers or challenges they may face. Queries may involve, but are not restricted to:

How familiar are you with the proper disposal methods for pharmaceutical waste?

- What best describes your attitude to the pharmaceutical waste collection??
- In how far do you agree with the following statements?

The detailed questionary with such headlines as: attitude, awareness, motivation is in the Addendum No. 1.

The survey would be distributed to a diverse sample of participants and the data collected would be analyzed quantitatively, to identify patterns and trends.

1.3. Section summery

A life cycle analysis is an approach to measure the environmental impact of a product throughout its entire life, from raw material extraction to disposal. This study aims to provide a literature review examination of the environmental impact of a specific product or class of products, evaluating key metrics such as energy consumption, carbon footprint, and waste generation. The life cycle of a product typically includes the following phases: research and development, design and testing, Production and distribution, marketing, and sales, use and maintenance, disposal and EOL, reuse, refurbish and remanufacture. When comparing the life cycles of two products, it is important to consider product category, market conditions, distribution channels, product features, and life cycle assessment. The analysis of the life cycle of drugs is a technique used to evaluate the commercial possibilities and profitability of a medication throughout its development and marketing.

The objective of this study is to provide a detailed examination of the management of EOL products in the pharmaceutical industry, with an emphasis on the management of waste, trends, legal regulations, and the main factors that influence the collection of UEM in two neighboring countries in the EU: Austria and Slovakia. UEM is a significant problem for both the environment and public health, and efforts should be made to reduce the amount of waste generated and implement proper disposal methods for UEM. In the EU, programs for the collection and disposal of UEM are implemented at the national level, with each member state having its own regulations and policies.

2. LITERATURE REVIEW

This section should review existing literature on the topic of EOL of product management. It should examine the various strategies and approaches used by organizations to manage the EOL of their products, together with the challenges and opportunities associated with this process. A literature search was carried out using the keywords: "live cycle economy", "end of live of product management", "pharmaceutical end of life of product management", "medicines disposal", "unused medicines", "medicines wastage", "collection of medicines from households", "incineration of medicines", "public awareness about medical waste collection", "public motivation for collecting medical waste", and "regulations for medicines waste collection".

2.1. Circular Economy

The concept of circular economy originated from the thought theory of industrial eco-development and is based on the balance between economy and environment. The circular economy aims to minimize resources used in the production process and insert cleaner technologies, providing organizations with profitability and a sustainable economic, social, and environmental development. The definition of circular economy currently applied in Asia has theoretical bases of Industrial Ecology, which predicts the type of association among the elements of different ways of business production using residual materials and by-products.

A literature review and bibliometric analysis on CE, showing its evolution over the past 13 years. CE research has risen exponentially, from 12 papers in 2008 to over 2,300 in 2020. 2020 saw no major changes in the field due to COVID-19. Geographically, CE research originally focused on China, but has since shifted to Europe, with China's significance decreasing. The US has also not had a notable role in CE research during this period. The leading role in CE research has likely shifted from China and USA to Europe due to China and USA being the world's most polluting countries. China, due to its growing economic development, is facing increasing pollution and greenhouse gas emissions. The USA, despite withdrawal from the Paris Agreement, has seen a rise in carbon dioxide emissions. Economic growth and emission reduction are inversely related, making it difficult for countries to agree on a universally acceptable CO2 emission policy. COP26 in Glasgow, 2021 saw a change in environmental policy for both countries with a joint statement committing to increasing climate cooperation and reducing emissions.

The field of Circular Economy (CE) research is underrepresented in certain regions and countries, including North America, Latin America, Africa, and India, according to a bibliometric analysis. The analysis found that only a small percentage of publications included these regions in their title, abstract, or keywords, with the highest being 2% in India. This contrasts with the significant representation of Europe and China in CE research, with around 13% of articles including these regions. Further research is needed in these underrepresented regions, given their economic significance, trade relations with China, status as world powers, population growth, and pollution levels. The CE research field has evolved over time, with a trend towards greater interdisciplinarity in the early years, and a split between economists and management researchers focusing on conceptualizing CE, and engineers and environmental scientists focusing on its applications. Additionally, the most common research topics were waste from electrical and electronic equipment and water problems. The previously mentioned scarcity of CE research located in North America, Latin America, Africa, and India represents a highly promising line of research due to the growing weight of these countries or regions in the world economy. (Alcalde-Calonge et al., 2022), (Martins-Rodrigues et al., 2020).

2.1.1. Circles of Circular economy

Circular economy butterfly diagram (adapted from EMF (2013)

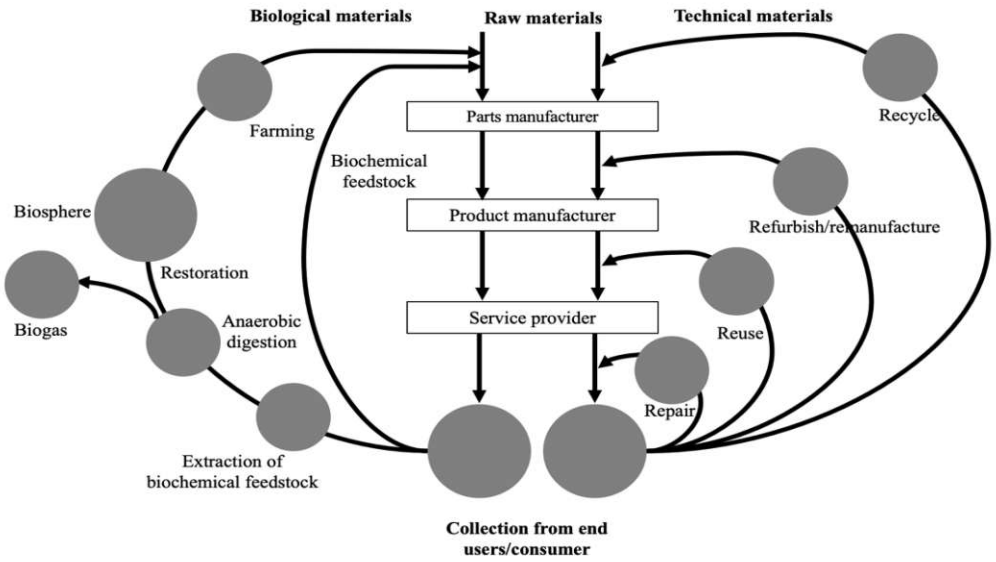


Figure 1. Source: (Ellen MacArthur Foundation, 2013)

The butterfly diagram, also referred to as the CE system diagram, depicts the uninterrupted movement of resources within a CE. The diagram distinguishes between two major cycles - the technical cycle and the biological cycle. Within the technical cycle, products and materials are maintained in a loop through practices such as reusing, repairing, remanufacturing, and recycling. The biological cycle, on the other hand, involves the restoration of natural resources by returning nutrients from biodegradable materials to the Earth (Ellen MacArthur Foundation, 2013).

The technical cycle is all about keeping products and materials in use for as long as possible. For example, a phone is more valuable when it is being used as a phone, instead of being broken down into parts. The technical cycle includes ways to keep products in use for longer, like sharing, reselling, and repairing them. When a product can no longer be used, it can be turned into new parts or materials to be used again. Even if recycling is the last step, it helps to keep materials in the economy and prevent waste.The biological cycle is a way to recycle materials that cannot be reused. These materials, like food waste, are broken down through processes like composting or digestion. This process releases valuable nutrients that can be used to help grow new plants. Some products, like cotton or wood, can go through both the technical and biological cycle. They can be reused and recycled but eventually, they will be broken down to be used as nutrients to grow new materials.

2.1.2. The principles of Circular Economy

The first principle of a circular economy are placed on eliminating waste and pollution by creating goods with the end-of-life cycle in mind. The current linear take-make-use-waste system is unsustainable in the long term as resources on our planet are finite. By treating waste as a design flaw and specifying that materials must re-enter the economy at the end of their use, a shift from a linear to a circular system occurs. This allows products to be maintained, shared, reused, repaired, refurbished, remanufactured, and recycled as needed. Additionally, biological materials can be safely returned to nature to regenerate the land and produce new food and materials. By focusing on design, the concept of waste can be eliminated.

The second principle of a CE is to ensure that products and materials are utilized to their fullest potential. This involves maintaining their value and keeping them in circulation, whether as a product, a component, or raw materials. This approach eliminates the concept of waste and maximizes the intrinsic value of the materials. To achieve this, it is essential to consider two main cycles - the technical cycle, where products are reused, repaired, remanufactured, and recycled, and the biological cycle, in which biodegradable materials are returned to the earth through composting and anaerobic digestion processes.

The third principle of the CE is to prioritize the regeneration and restoration of natural resources. Instead of continuously extracting resources and causing harm to the environment, a CE works to replenish and support the growth of natural resources through sustainable practices such as regenerative agriculture and returning biodegradable materials to the earth. This shift in focus helps to build natural capital and create a more sustainable and resilient future.

2.1.3. Resource efficiency in Circular economy

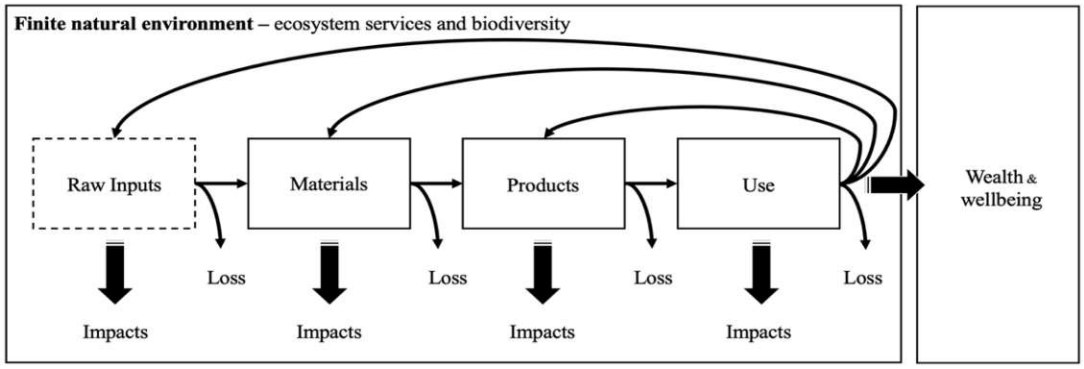


Figure 2. Source: (van Ewijk,2018).

The enhancement of economic performance while lowering demand on natural resources is characterized as resource efficiency. The CE, on the contrary, is a system that tries to maintain goods, components, and materials as useful and valuable as possible at all times while minimizing waste. Both concepts are regarded as critical to building a low-carbon, resource-efficient, and efficient economy. However, the appeal of these concepts may vary among different audiences and interpretations of them may be incommensurable. There may be tension between long-term and short-term benefits, along with environment-economic trade-offs.

Figure 2. visualizes by a diagram that shows the product life cycle, raw inputs, wealth or wellbeing, environmental impacts, finite natural environment, inefficiencies or losses and loops between inputs and outputs. Different interpretations may emphasize different elements, but the overall goal is to reduce raw inputs, increase material circulation and minimize losses while maximizing wealth and wellbeing without exceeding the limits of the natural environment.

The literature on barriers to resource efficiency and the CE often finds that there are market failures that make it hard to change things. A market failure is when the market does not give good results for society. For example, if the cost of pollution is not included in the price of a product, people will buy more of it than they should. The idea behind fixing market failures is that good markets will give the best results for society. There are many reports and papers that discuss market failures that prevent resource efficiency. Some common examples are externalities (goods or beds that are not priced), imperfect information (people do not have enough information to make good decisions), missing markets (goods that aren't supplied because of high costs), public goods (goods that cannot be supplied by one person

or group), and split incentives (when different people have different incentives). It's important to note that even good markets cannot always achieve society's long-term goals, and that big breakthroughs often happen because of government efforts, like research funding and infrastructure building, rather than just fixing market failures (van Ewijk, 2018).

In summary, the resource efficiency is about using fewer natural resources to create more wealth and wellbeing, while also protecting the environment. These concepts have the potential to increase productivity and economic growth, however, there are several obstacles that must be overcome. Public policy should focus on addressing these barriers and should consider trade-offs among economic and environmental benefits. Furthermore, public policy should take into account the global scope of the material life cycle and its impact on the environment outcomes.

2.1.4. Examples of practical implementations of Circular Economy

There are examples of efficiency of circle economy implemented in practice: The Circular House is a social housing project in Denmark that aims to be a blueprint for circular construction. Led by 3XN Architects, the project will use 90% of its construction materials may be disassembled and used again or sold again without losing their value. Alternative materials such as cork, old newspapers, eelgrass, granules, and used car tires will also be used in the construction to minimize the carbon footprint. The project is expected to be completed in 2023 and will be the world's first social housing project constructed according to circular principles. The goal is to provide valuable learnings on how circular buildings function in daily life, and to reduce carbon footprint in the construction sector. The potential economic benefit of implementing a CE in Denmark's building industry is estimated to be around €7.75 billion per year up to 2035.

The next example is a partnership between Plus Pack and Circqle, (Denmark) to develop a closed-loop, circular reuse model for food packaging. The partnership aims to create a unique system and digital solutions for packaging-as-a-service, focusing on four areas: designing and producing reusable food packaging, tracking the packaging throughout its use, transporting the packaging among different actors in the loop, and ensuring food safety, quality, and hygiene. The reuse packaging-as-service model aims to reduce packaging and waste and offers the potential to reduce CO2 emissions by up to 60% when compared to single-use packaging (State of Green, January 2023).

There is an example form the industry: CCL (North) Ltd. is one of the UK’s leading specialists in recycling. Company's approach is to achieve high recycling rates through avoiding sending by-products to landfill. The company builds new products for refurbished WEEE equipment and recycled components, in line with the principles of the CE. The company's ReBorn brand specializes in the reuse of IT, such as televisions, heaters, lawnmowers, Hifi systems, amplifiers, speakers, CD players, DVD players, coffee makers, Xbox, Wii, PlayStation, lamps, telephones, mobile phones, vacuum cleaners, floor steamers, hand tools, drills, fans, test equipment, while the company's Restructa division safely and responsibly recycles all forms of display screens, using the glass from these screens to manufacture reusable decorative aggregate, known as Glasglo, used by many councils. Additionally, the company utilizes the dust by-product produced from the glass recycling process to manufacture decorative tiles called SilicaStone (CCL North, January 2023). A CE approach in the practical area of fresh produce packaging has been demonstrated by the company "Apeel". The company has developed an innovative solution to eliminate single use shrink wrap plastic packaging on fresh fruit and vegetables, while also addressing food waste.

The solution involves the application of an edible, plant-based coating to fresh product which mimics and enhances the natural defenses of fruit and vegetables,

slowing down the two main causes of spoilage: water loss and oxidation. This technique designs out food waste by preventing product from prematurely rotting, plastic waste as no man-made packaging is needed, and energy and resource waste of water approximately is one avocado 23 liters and energy equivalent to charging a smartphone 9 times.

This is achieved by utilizing the building blocks that exist in the peels, seeds, and pulp of all fruits and vegetables, known as lipids and glycerolipids, which are natural substances that keep moisture inside the food and keep oxygen out. This maintains moisture and reduces oxidation, slowing the rate at which fruits and vegetables spoil and supporting the plant's natural abilities to protect itself. The "Apeel" provided to customers as a powder that is blended using water at packaging facilities. It may be applied using spraying, dipping, or brushing techniques. The fruit is coated until wet and then left to dry, extending the shelf life of fresh produce by 2-3 times, and improving the quality of fruits and vegetables while reducing food waste.

2.1.5. Future of Circular Economy

In the research of potential improvement of CE there are some opportunities which can be taken in account as close future reality: One such example is the textiles industry, which consumes vast amounts of fossil fuels and freshwater to produce clothes from synthetic fibers. This not only causes environmental harm but also results in the wasteful disposal of still-wearable clothes worth billions of dollars each year. A CE approach to textiles would involve a shift towards using recycled and recyclable materials, promoting sustainable consumption patterns, and ensuring the end-of-life collection, recycling, and repurposing of clothes. Research indicates that this approach could significantly reduce resource use and promote more sustainable practices in the textiles industry.

The CE concept aims to reduce emissions by making better use of resources. In addition to food production, product consumption and manufacturing account for around 45% of worldwide carbon dioxide emissions. Implementing CE strategies, such as shifting towards recycled materials and changing consumption patterns, can cut these emissions by 39% (22.8 billion tons) and play a crucial role in averting the dangerous impacts of climate change. For instance, reducing food loss and waste is particularly crucial in lowering emissions and creating a CE for food. A CE can help to protect human health and biodiversity by making better use of natural resources, mitigating the climate crisis, and managing products at the end of their life. On an annual basis, over nine million persons die as a result of pollution in the air, water, and soil. This contamination also poses a hazard to biodiversity. The CE approach helps to protect human health and biodiversity by reducing the amount of waste produced, through proper collection and processing of hazardous materials, and by designing products to be kept in use for longer, such as replacing plastic with other materials, designing plastics so that they can be more easily recycled, and scaling up collection and recycling. This can reduce the flow of plastic waste into the ocean by 80% in 20 years which would be highly beneficial for human health and biodiversity. A shift towards a CE can boost economies by reducing waste, stimulating innovation, and creating employment.

Research shows that the CE offers a $4.5 trillion economic opportunity. New companies based on the 3R principle (reuse, repair, remanufacturing) and sharing can lead to enormous prospects for innovation and growth. For example, a CE for plastics can benefit industries like fishing and tourism, reduce healthcare costs and mitigate climate change, all of which would have a positive impact on the economy. Policies that provide financial incentives for firms to establish new business models and facilitate the efficient movement of reused and recycled materials throughout world value chains may assist in driving this transition. Transitioning to a CE could bring about a net increase of 6 million jobs by 2030, as new jobs are created in fields

such as recycling, repair, and rental services, or in new enterprises that make innovative use of secondary materials. However, it is important to consider that jobs may be lost in more linear businesses and that this transition requires a clear focus on social and environmental justice. To invest in a fair transition through social discourse, social security, and training initiatives is key to ensure that this transition is inclusive and equitable. Furthermore, CE can provide formal work and improved working conditions for informal laborers, like the 15 million people worldwide who work as "waste pickers" salvaging reusable or recyclable materials from garbage, bringing them into formal work in collection or recycling and offering safer, more secure employment.

Creating a CE is a systemic change that requires a holistic approach to manage trade-offs and address interconnected issues. For example, using bio-based plastics and natural, recyclable textiles like cotton will use less fossil fuels but may increase demands for land and water, therefore it is important to ensure that materials are produced in a sustainable way and consumption habits change as well. It is important to recognize that many industries must shift to create systemic change, as many of the minerals and metals used in electronics are by-products from the mining of other materials. Additionally, it is crucial to keep social well-being and equity top-of-mind as moving to a CE can shift investment and employment away from production and manufacturing, which tends to happen in lower-income countries, and towards later stages of the value chain, such as repair, resale, sorting and recycling, which are often concentrated in wealthier countries, therefore ensuring economic benefits are equitably distributed is important to maximize the opportunity of a CE (World Resources Institute, 2017).

2.1.6. The importance of design in Circular economy

Design plays a crucial role in the success of the CE. It is essential for products to be designed with the goal of being able to be reused, repaired, or recycled for them to be circulated in either the technical or biological cycle. If products are not designed with this in mind, they will ultimately end up as waste. To ensure the success of the CE, designers must consider the product's life cycle and how it can be incorporated into the technical or biological cycles. This includes designing products to be easy to repair and maintain, easy to disassemble, and made of modular components that can be replaced. Products should also be made of materials that are easily recyclable. Additionally, products that are designed with the biological cycle in mind should be made of biodegradable materials, and any glues or paints used should also be biodegradable. Overall, the success of the CE is dependent on the design of products and the consideration of their life cycle (Ellen MacArthur Foundation, 2013).

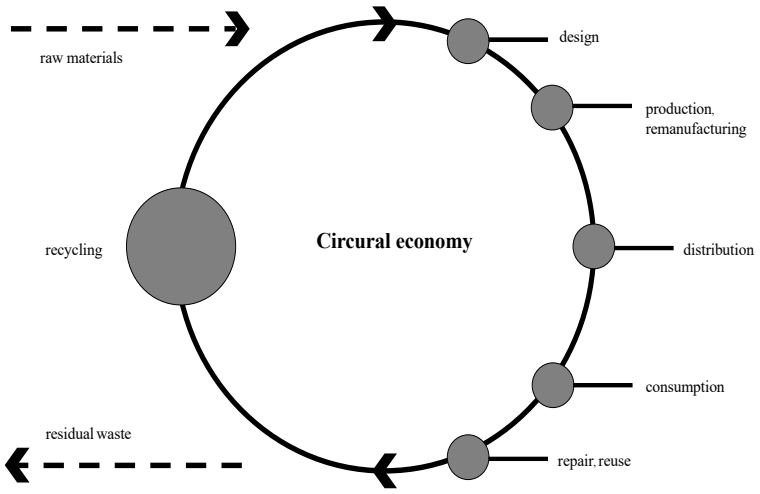


Figure 3. Source of the graph (Fintech Nexus, 2021)

Based on Nelson and Stolterman, design is a capability to transform towards a desired future by integrating scientific reasoning and judgment with artistic expression. (Nelson & Stolterman, 2012).

Figure 4 presents the framework utilized to guide the design process. This framework combines the Double Diamond model and IDEO's 5 Step Process. The illustration's backdrop uses the Double Diamond model to demonstrate the natural and dynamic design process along with how different types of thinking contribute to it. The steps of IDEO's model are in the forefront to emphasize the mindset that should dominate each mode of thinking (Most, 2018).

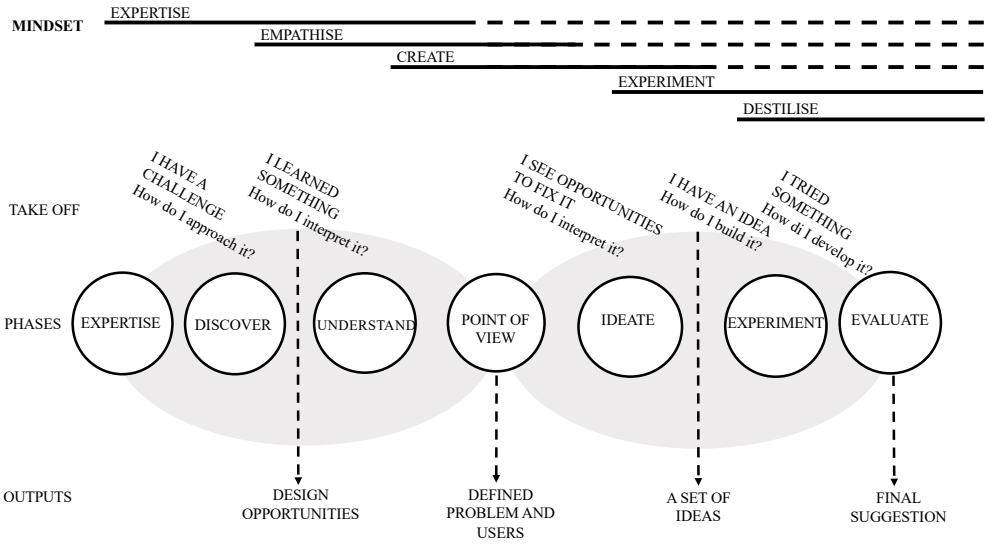


Figure 4. Designing process (Most, 2018)

There are different kinds of CE design approaches: Design for Disassembly (DFD), Design for Assembly (DFA), and design for Recycling (DFR).

DFD is a technique used by designers and engineers to consider the ease of disassembling a product during the initial design phase. This approach is driven by a range of factors including maintainability, serviceability, repairability, recyclability, component reuse, and waste reduction. DFD involves the separation of a product into its components, subassemblies, materials, and other groups in a systematic manner.

DFA is a methodology that involves considering the ease of assembly during the design phase of a product. It aims to minimize the number of components and simplify the assembly process, while also reducing the cost and time required for assembly. This can be achieved through various techniques such as modular design, standardization of components, and use of snap-fits or other simple fastening methods. DFA is often used in manufacturing and industrial design to improve efficiency and reduce costs. DFR is a methodology that incorporates the principles of recycling during the initial design phase of a product. This approach aims to make the product easy to recycle and increase the output of recycled materials. It includes guidelines on the use of hazardous materials, connections, construction, and accessibility of parts, and is a part of a broader concept of Design for Environment and Sustainability (DfES), which focuses on creating sustainable and environmentally responsible products (Elia, 2019).

2.1.7. Stakeholders of Circular Economy

There are several key stakeholders that play a crucial role in implementing the CE:

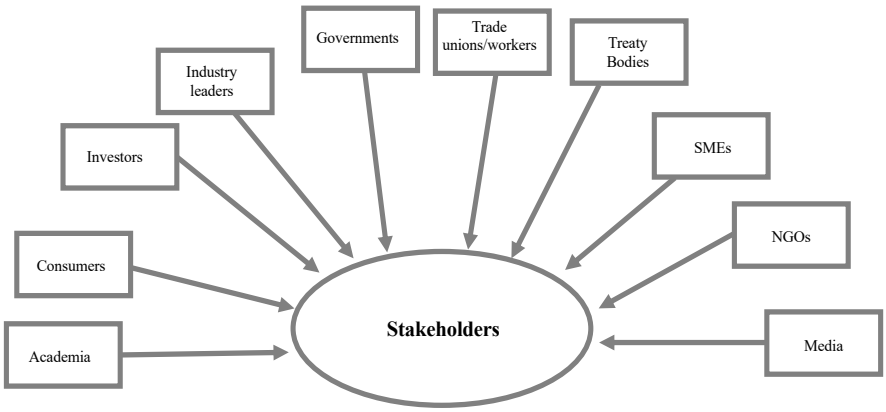


Figure 5.

Some of the mentioned above stakeholders play a crucial role in implementing the CE. Governments and policy makers are responsible for creating a legal and regulatory framework that supports the transition to a CE. Businesses have an important role to play in developing innovative products, services and business models that promote circularity. Consumers can also play a significant role in driving demand for circular products and services. Additionally, NGOs (non-governmental organization) and civil society groups can help raise awareness and educate the public about the benefits of the CE.

2.1.8. Barriers and challenges in Circular Economy

The implementation of a circular economy (CE) faces several challenges that need to be overcome. One major hurdle is the lack of awareness and understanding of the CE concept among stakeholders. Additionally, financing and investment for CE projects are often limited, and there is a lack of adequate infrastructure and technology to support the implementation of CE practices. Regulations and policies that promote the CE are also lacking, and resistance to change from traditional linear business models presents a significant barrier. The limited availability and supply of raw materials for CE and the difficulty in measuring and demonstrating the economic and societal benefits of the CE further complicate implementation. Collaboration and coordination among stakeholders are limited, and there is also a lack of education and training on CE practices and skills among the workforces.

To overcome the barriers, it is important to raise awareness and understanding of the benefits of the CE through education and communication efforts. Additionally, governments and policy makers can play a key role by providing the necessary regulations and incentives to support the transition to a circular economy. Investment in the development of CE infrastructure and technologies is also crucial. Finally, it is important to work closely with the private sector and other stakeholders to help them understand the benefits of transitioning to a CE and to support them in making the necessary changes to their business models.

In conclusion I would like to refer to the work made by (Bressanelli et al.), 2020 in CE in WEEE (waste electrical and electronic equipment) industry where the practical implementation is poor. The research found that the implementation of circular economy in WEEE industry has primarily focused on exploring and evaluating the potential impacts, with a heavy reliance on quantitative methods. There has been a lack of attention towards finding practical solutions to real-world problems. Most studies have focused on exploring the concepts of circular economy, while few have been focused on testing or validating these concepts. Additionally, only a small percentage of the research (23%) has used multiple research methods.

Circular economy and end of life product management are closely interconnected and dependent on each other. The circular economy focuses on keeping resources in use for as long as possible through strategies such as product design for disassembly, repair, refurbishment, and recycling. This approach aims to minimize waste and extend the life of products. On the other hand, end of life product management deals with the safe and responsible disposal of products that have reached the end of their useful life. *For the circular economy to be successful, it is essential that products are designed with end-of-life management in mind*. This means that products should be easily disassembled, repaired, and recycled, with a focus on using non-toxic and non-polluting materials. This, in turn, makes it easier and more cost-effective to recycle and dispose of products safely at the end of their life. Together, these two approaches can help to create a more sustainable and circular economy.

2.2. END OF LIFE OF PRODUCT MANAGEMENT

2.2.1. End of life of product definitions and problems

End-of-Life (EOL) management is a crucial aspect of the CE as it deals with the management of products, components, and materials at the end of their useful lives. The EOL phase begins once the product has reached the end of its intended use and is no longer useful to the consumer. The primary objective of EOL management is to minimize the environmental impacts of products, components, and materials by reducing the amount of waste generated and increasing the number of materials that are recovered and recycled.

In CE, EOL management plays a key role in creating closed loops of material flow, where resources are continuously cycled in the economy, rather than being discarded as waste. EOL management strategies in CE include product design for recyclability, extended producer responsibility, take-back systems, and product-service systems. These strategies aim to shift the focus from a "take-make-use-dispose" linear model of production and consumption to a circular model where resources are kept in use for as long as possible. The problem of EOL management refers to the challenge of dealing with the disposal or reuse of products and materials at the end of their useful life. This can include issues such as waste management, product recycling, and the safe disposal of hazardous materials. EOL management is becoming increasingly important as the world faces growing environmental and sustainability challenges, and as the volume of waste and discarded products continues to increase. EOL is a problem for many industries as it leads to the generation of waste and can have negative environmental and economic impacts.

Automotive industry: In the automotive industry, EOL is a significant problem as cars have a relatively short lifespan and are often discarded in large numbers. This leads to a significant amount of waste and pollution and has economic consequences as valuable resources are lost.

Electronics industry: The fast pace of technological change in the electronics industry means that products often have a short lifespan and are quickly replaced by newer models. This leads to a large amount of electronic waste, which can be harmful

to the environment and human health if not properly disposed of.

Pharmaceutical industry: In the pharmaceutical industry, EOL is a problem as drugs expire and can no longer be used. This leads to the disposal of large quantities of UEM, which can have negative environmental impacts if not properly managed. Additionally, expired drugs can also pose a risk to public health if not properly disposed of.

2.2.2. Key principles of End of life of product

The adoption of sustainable practices has become increasingly crucial in the current global climate. Among these practices, the concept of the circular economy has gained significant attention in recent years. The circular economy aims to minimize waste and resource consumption by keeping products and materials in use for as long as possible. This is achieved through a set of principles that guide the design, production, consumption, and disposal of products. These guiding principles for sustainable product management include designing products with end-of-life considerations, using resources efficiently and selecting materials that are recyclable or biodegradable. The principles also encourage reuse and refurbishment of products before recycling or disposal, as well as maximizing recovery and recycling of materials to conserve resources. Responsible disposal is emphasized for products that cannot be reused, recycled, or recovered, and manufacturers are held responsible for the end-of-life management of their products, including proper waste collection, transport, and treatment.

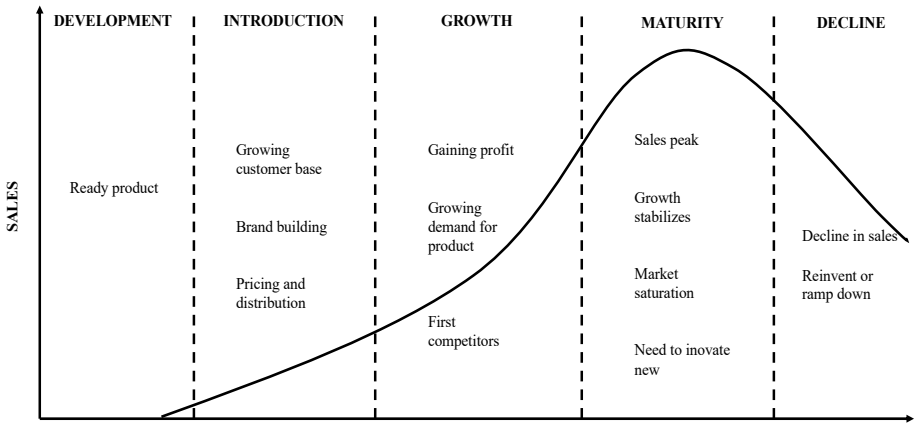


Figure 6. Product live circle (Kaisanlahti, 2018)

New product development: The process of turning an idea into a mass production-ready product that can be taken to the market, while also developing a business plan, as new product development. The stages of new product development include idea generation, concept development, market research, product design, testing, and commercialization.

Introduction: Once the product is ready for the market, the introduction stage

begins, where the focus is on building the brand, promoting the product, and building a customer base through early adopters. During this stage, the price of the product is decided, and strategies for selling and distributing the product are established in preparation for the growth stage.

Growth: If the introduction stage is successful, the product will start to gain users and enter the growth stage, where the demand for the product increases and profits starts to be made. During this stage, it is important to keep up with the demand and expectations to gain loyal customers.

Maturity: The maturity stage is a time of stabilization, where sales of the product reach their peak, and most customers are buying the product. The challenge at this stage is to hold the market position and come up with new ways to keep customers happy, as competitors enter the growth stage, and the market has more options.

Decline: The decline stage is marked by a steady drop in sales, and a loss of interest from customers, who may switch to newer, better products from competitors. To fight the decline stage, innovating new improvements or making a second-generation product is key, or discontinuing the product if it no longer serves its purpose (Kaisanlahti, 2018).

2.2.3. End of life of product business strategies

Product-level EOL business strategies: When a product reaches the end of its lifecycle, companies need to decide how to handle it. Different industries have different product-level EOL business strategies. Here are five examples:

Discontinuation: This strategy involves ceasing production and sales of a product. It's commonly used in industries such as consumer electronics, agriculture, and fashion, where products have a short lifespan and are quickly replaced by newer models. I was not unable to find examples of discontinuation strategy in EOL I consider that it happens since EOL is a specific stage in the product lifecycle, whereas discontinuation strategy is a broader concept that can be applied at any stage of the product lifecycle. Discontinuation strategy involves deciding to stop selling or producing a product due to various reasons such as low demand, high production costs, or outdated technology. On the other hand, EOL is the phase in which a product has reached its end-of-life and is no longer manufactured or sold by the company. However, the decision to discontinue a product may be part of a company's EOL strategy, which involves managing the phase-out process of a product and minimizing the impact on the company and its customers. A good example is represented by Canadian company "CropLife" (CropLife Canada, 2011) where they offered the following check list for the strategy:

CHECKLIST - PRODUCT DISCONTINUATION PROCESS:
Timeline: Product Launch ⟹ Commercial Life ⟹ Decision to Discontinue Product

- Ensure licensee agreements:

Take product discontinuation/phase-out timelines into account.
Address transfer of stewardship accountability (e.g., IRM, reporting or monitoring)

- Consider timing of patent(s)
- Consider timing of next generation product(s)
- Consider timing of registration (eg: prior to growing season, vs mid or at harvest)
- Consider product lines affected by the discontinuation, and portfolio consequences.
- Evaluate impact of discontinuation on third parties and downstream value chain.

Harvesting: This strategy involves reducing costs to maximize profit during the end of a product's lifecycle. It's important to plan and implement a harvesting strategy before the product reaches the end of its life cycle. It's commonly used in industries such as automobiles and appliances, where products have a longer lifespan but are eventually replaced. A company may choose to implement a harvesting strategy for a variety of reasons, such as when a product or business line reaches its cash-cow or decline stage, where focusing on marketing is no longer necessary and resources can be redirected to more profitable ventures. Another reason is the development of new products or interests, which may require more resources and investment. Additionally, discontinuing a product or business line can also lead to the implementation of a harvesting strategy as there is no longer a need for marketing or reinvestment (Corporate Finance Institute, January 2023).

The landline telecommunications business is a commonly used illustration of a harvesting strategy. With the widespread availability of wireless signals across the US, the necessity of having a landline phone diminished. Although telecommunication companies still provide support for the technology, they have chosen not to rebuild their wired network in the event of damage from storms, instead opting to enhance and broaden their wireless coverage.

Repositioning: This strategy involves changing the marketing and positioning of a product to target a new market or customer segment. It's commonly used in industries such as consumer goods and healthcare, where products have a longer lifespan but need to adapt to changing customer preferences. As an example of the strategy implementation is a company Gucci which tried to appeal to a younger, more progressive audience. The brand repositioning strategy included an increased focus on Instagram-style communication, a refreshed logo that was prominently displayed on all products, and a supportive stance towards gender fluidity. These changes helped Gucci attract a younger audience and remain relevant in the changing cultural landscape (Viau, 2020).

Repackaging: This strategy involves updating the packaging or branding of a product to give it a fresh look. It's commonly used in industries such as food and beverages, where products have a longer lifespan but need to adapt to changing customer preferences. The management of a product life cycle must use various strategies to determine a product's success or failure before its introduction. A company can adopt re-packaging as a marketing strategy to refresh a product, especially in its decline or maturity stage. Re-packaging a product helps to differentiate it from competitors and improve the company's product image. This strategy is important when a product is underperforming and the decision on which marketing strategy to adopt becomes critical. Many organizations, including manufacturers, distributors, retailers, and trade associations, recognize the importance of re-packaging as a marketing strategy for improving market performance and adding value to the company's products.

Revitalization: This strategy involves updating the product with new features or technology to make it more competitive. It's commonly used in industries such as technology and software, where products have a longer lifespan but need to adapt to changing market conditions. The goal of a brand revitalization program is to recover lost brand equity and find new ways to build it. This process involves looking at changes in the marketing environment, competition strategies, user behavior, cultural shifts, and many other factors to identify why the brand has declined and how to improve it. The ways to revitalize can include expanding the market, changing the product, or repositioning the brand.

2.2.4. The impact of End of life of product on supply chain management

EOL is a critical stage in the product life cycle, as it marks the transition from a product being in use to it being discarded. The impact of EOL on supply chain

management is significant, as it can cause a range of problems and challenges for organizations. One of the key factors that exacerbates the impact of EOL is the uncertainty surrounding the timing of the end-of-life event. This unpredictability can result in organizations having excess inventory or stock, which can be difficult to manage and dispose of effectively. Additionally, the increasing focus on sustainability and environmental responsibility has placed additional pressure on organizations to manage their EOL products in a responsible and environmentally friendly manner. This has resulted in organizations having to navigate complex regulations and compliance requirements, which can further complicate their EOL management strategies. Furthermore, the increasing globalization of supply chains has resulted in a more complex web of suppliers and stakeholders, making it difficult for organizations to effectively communicate and collaborate on EOL management initiatives.

The importance of supply chains in improving efficiency has grown as the pace of business operations has accelerated. The integration of technology, such as automation, artificial intelligence, and data analysis, has also allowed for a more streamlined supply chain process. Nevertheless, to reap the benefits, companies must embrace digital transformation. To research the impact of EOL on supply chain management, it is important to focus on the following key topics: Understanding the impact of EOL on the supply chain. This includes examining the challenges and obstacles faced by companies when managing EOL products and exploring the impact of EOL on overall supply chain performance.

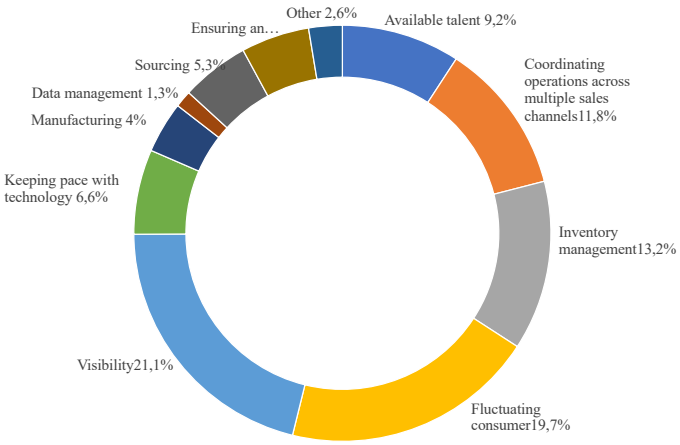


Figure 7. (FC Business Intelligence Ltd., 2018)

I conclude from the offered above Figure 6 represented in research made by (W. Spencer Askew, Teknowlogi, CEO & Founder) on the challenges of the EOL supply chain problem, it is evident that there are several factors that are contributing to the difficulties faced by organizations. The main problems include fluctuating customer demand (19.7%), visibility (21.1%), and coordinating operations across multiple sales channels (11.8%). These factors are indicative of the complex and

dynamic nature of modern supply chain operations, where there are multiple variables at play that can impact the overall efficiency and effectiveness of the system. Other challenges, such as inventory management (13.2%) and ensuring an ethical supply chain (5.3%), also contribute to the difficulties faced by organizations. In conclusion, managing the end-of-life supply chain is a complex and multifaceted problem that requires a thorough understanding of the various challenges and the development of effective strategies to mitigate them. Best practices for managing EOL products. This includes identifying and implementing effective strategies for managing EOL products, such as inventory management, product disposal, and recycling.

2.2.5. Inventory management in the context of End of life of product

Inventory management in the context of EOL products refers to the systematic control and organization of goods or materials that are no longer in high demand or have reached the end of their product lifecycle. The goal of EOL inventory management is to minimize the costs associated with storing, handling, and disposing of these items while ensuring that they are treated in an environmentally responsible manner. This process involves a variety of activities, including forecasting, demand planning, order management, stock control, and product disposition. Effective EOL inventory management requires a detailed understanding of the unique challenges and opportunities associated with managing these products, including issues related to product obsolescence, demand fluctuations, and the impact of product returns and returns. The goal of EOL inventory management is to minimize waste, increase efficiency, and create value for the organization and its stakeholders.

The work by (Hipólito, Nabais, Botto, & Negenborn, 2020) concentrate on research of a continuous-flow Supply Chains which are most designed to meet regular customer demand with some fluctuations while operating at the lowest possible cost. This is achieved by maximizing the utilization of storage and handling resources and storing only the exact amount of inventory needed to meet expected demand. Nonetheless, this requires strong cooperation between all players in the supply chain and can lead to difficulties when dealing with irregular demand patterns. The "just-in-time" management policy, where goods are delivered on-demand to meet immediate customer needs, is commonly used in industries such as paper and low-cost fashion.

The complexity of supply chains makes it difficult to find universal solutions for inventory management. They have tried to solve these problems by breaking down the supply chain into stages and focusing on specific network configurations. The Operations Research (OR) field has developed simple and efficient methods, but these approaches lack a comprehensive view of the entire supply chain operation. On the other hand, the Control Theory (CT) field uses optimal control techniques to describe the main dynamics and drivers of supply chains, but also faces difficulties in modeling and dimensionality. Combining OR and CT concepts may be a promising solution to overcome these limitations. This paper presents two key contributions: the integration of Control Theory and Operations Research to improve the efficiency of a central Model Predictive framework and the implementation of a demand-driven strategy where customer demand is the primary focus of Supply Chain Management. Centralized Model Predictive Control (MPC) is an optimization-based control algorithm that uses mathematical models to predict the behavior of a system and makes control decisions based on that prediction. In the centralized MPC approach, a central controller is responsible for making control decisions for the entire system. This approach is commonly used in supply chain management to optimize the flow of goods and resources. The MPC algorithm considers the constraints of the system and aims to find the best control strategy that minimizes a certain objective, such as the cost of inventory or the delivery time. The focus of this paper is to provide three variations of a centralized Model Predictive Control approach that utilizes inventory data from a retailer.

Inventory management is a crucial aspect of any business as it helps in managing the flow of goods, reducing costs, and increasing profits. The key features of inventory management include order management, tracking, purchasing management, sales management, a product catalog, and inventory optimization. Order management monitors order placements and ensures that restocking happens at the right time. Tracking helps in monitoring in-stock products and is usually done through barcoding. Purchasing management processes reorders, manages their costs, and keeps a record of purchase history. Sales management manages quotations, invoicing, and receipts.

The product catalog acts as a central hub for product specifications. Inventory optimization helps businesses in tracking stock levels and maximizing inventory items. Manufacturing inventory, specifically for manufacturers, handles requirements such as job costing, work orders, and kitting assembly. Inventory management software helps businesses keep track of their inventory levels, orders, sales, and deliveries. This software helps businesses avoid overstocking and leads to benefits like improved efficiency, reduced costs, enhanced security, and better organization of the warehouse. Such solutions are offered by companies: Zoho Inventory, Cin7, Katana, QuickBooks Commerce, Brightpearl, SellerCloud, and FinancialForce ERP are all inventory management solutions (Epstein, 2023).

2.2.6. The role of product design in End of life of product management

The role of product design in EOL management. This includes exploring the impact of product design on EOL management and how product design can be used to minimize the impact of EOL on the supply chain.

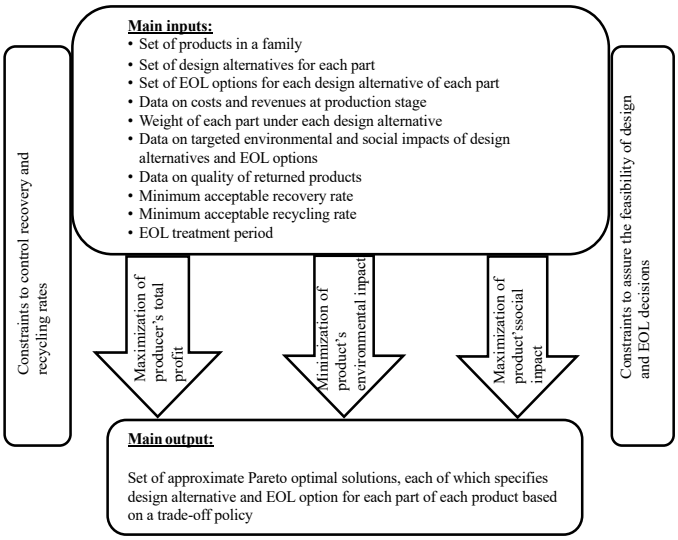


Figure 8. The model for integrating design and EOL consideration.
Source: (Ameli, Mansour, & Ahmadi-Javid, 2019)

A classical approach in the literature to incorporate EOL considerations into the design stage is to adapt Design For X (DFX) methods, such as design for disassembly (Soh et al., 2014), design for reuse (Sabbaghi et al., 2015), and design for remanufacturing (Li and Liang, 2012). Most of these studies have focused on

design for disassembly (Esmaeilian et al., 2016), where the aim is to minimize disassembly time (Santochi et al., 2002), to find the most efficient disassembly sequence (Huang et al., 2015), or to plan disassembly sequences (Behdad and Thurston, 2012).

The use of mathematical models in design-for-end-of-life problems has gained popularity due to the increasing complexity of decision making in this field. On the other hand, some simplifications are necessary to make the mathematical models manageable. The solutions from these models need to be adjusted by experts to account for real-world factors. These models can assist designers in evaluating product designs and making necessary modifications to meet EOL treatment goals. This paper (Ameli, Mansour, & Ahmadi-Javid, 2019) presents a multi-criteria optimization model based on the IPR (Intellectual Property Right) that considers sustainability performance of a product family by addressing design-alternative selection and EOL-option determination. The model considers uncertainties like quality, return times, and EOL treatment costs/revenues, and aims to maximize total profit, minimize environmental impact, and maximize social impact while meeting recycling and recovery rate constraints. A simulation-based optimization algorithm, based on multi-objective simulated annealing, is used to find approximate Pareto optimal solutions for the complex expected values in the objective functions and environmental constraints.

2.2.7. End of life of product disposal and recycling

The importance of sustainability and environmental responsibility in EOL product disposal and recycling practices. This includes examining the impact of sustainability and environmental responsibility on supply chain management and how companies can adopt sustainable practices in their EOL management processes.

Disposing of EOL products is becoming an increasingly important issue, as the amount of waste generated by discarded products continues to grow. One challenge with EOL product disposal is that many of these products contain hazardous materials that can be harmful to the environment if not properly handled. This can also be a challenge for recycling, as some materials may not be easily recycled and may end up in landfills, where they can harm the environment. Additionally, products are often designed with built-in obsolescence, making them difficult to repair or recycle. This means that, even if a product can be recycled, it may not be easily or economically feasible to do so. The solution to these challenges is to design products with "end-of-life" in mind, so that they can be easily and safely recycled or disposed of when they reach the end of their lifecycle.

In the literature review, most of the cases discussed are from specific industries that are attempting to implement effective practices in the disposal and recycling phase of EOL products. The components of EOL construction products mainly consist of inert materials such as concrete and ceramic, with small amounts of non-inert items like wood, packaging waste, and gypsum waste (GW). Despite being a small part of the overall construction and demolition (C&D) waste, GW accounts for between 0.2% and 0.4% by weight. The disposal of gypsum waste through landfilling often results in increased hydrogen sulphide emissions and greenhouse gas emissions. In contrast, recycling gypsum can help achieve the 70% recovery goal. Studies on C&D waste management have analyzed successful strategies, with a focus on prefabrication implementation. Still, little attention has been paid to the specific waste streams at the EOL stage, where *collection for reuse* or recycling should be prioritized over waste reduction strategies (Jiménez-Rivero et al., 2017).

Recycling is a popular approach to decrease the largest amount of waste, but it can be difficult or suboptimal. The circular economy is strategy for reducing the environmental impact of construction. By decreasing the number of materials used in construction, the production of waste is reduced. Reusing building components is less

carbon and energy intensive, fostering both environmental and economic advantages. Systems analysis tools have been developed to quantify the environmental impact of buildings, but a method for quantifying the reusability of building materials does not yet exist (O'Grady, et al., 2021).

The development of a circularity index would address the lack and provide practitioners the information they need to choose actions that will lessen the impact of buildings on the environment. This research is focused on designing a circularity index that at any stage of a building's life cycle can use the model, to increase material circulation and reduce waste generation.

WEEE (Waste Electrical and Electronic Equipment) refers to any electrical and electronic equipment that has been discarded by its owner and is now considered waste. WEEE includes a wide range of products, such as large household appliances, small household appliances, IT and telecommunications equipment, consumer equipment, lighting equipment, electrical and electronic tools, toys, leisure and sports equipment, medical devices, monitoring and control equipment, and automatic dispensers. These electronic items are made of different materials, like metal, glass, plastic, ceramics, and special metals. For example, a TV usually has 6% metal and 50% glass, while a cooker has 89% metal and just 6% glass.

Only in UK estimated 2 million tons of WEEE items are discarded by householders and companies every year. WEEE has become a growing concern in recent years due to its impact on the environment. WEEE contains many harmful substances that can have a negative impact on the environment and human health if not properly managed. To mitigate these impacts, many countries have introduced regulations to encourage the proper disposal of WEEE and to promote its reuse and recycling. Here are some worldwide statistics for WEEE: According to a report by the United Nations, the world generated 52.2 million tones in 2021. China is the largest producer of e-waste, followed by the United States and India. Only 20% of e-waste is properly recycled, while the rest is often illegally dumped or treated in a manner that can harm the environment and human health. The increasing amount of e-waste has raised concerns about the potential harm to the environment and human health, as e-waste contains toxic materials such as lead, mercury, and cadmium.

The treatment of WEEE varies greatly, and proper management is crucial to control exposure to hazardous substances during processing. *Some treatment facilities use shredding technologies, while others utilize a disassembly process that can be manual or automated*. The Waste Resources Action Programme (WRAP) in UK (WRAP, 2021) provides guidance on the collection and processing of WEEE, including best practices for treatment and health and safety policies. Treatment facilities must comply with minimum requirements outlined in DEFRA's Guidance on Best Available Treatment, Recovery, and Recycling Techniques (Department for Environment, Food and Rural Affairs, 2006) and remove specific substances and components to avoid risks to health and safety. To efficiently handle the growing amount of electronic waste, the disassembly process needs to be automated to extract components for re-use or to gather materials for recovery of precious and critical metals like rare earths. Automation will play a crucial role in reducing costs and improving working conditions. Some companies have developed and successfully applied industrial solutions for disassembling components from printed circuit boards, selectively extracting components, and disassembling small ICT products, computer monitors, and TV-sets.

Mobile extraction and recovery of precious and critical metals make the disassembly economically attractive, the technologies work with extraction of rare and precious metals with high purity, from various sources including Liquid Crystal Displays (LCDs), Fluorescent lamps, Cathode Ray Tubes (CRTs) from computer monitors and TV-sets, Batteries, Printed circuit boards, Mobile phones and other smart ICT devices, and more. The main advantages mobile solution includes its

mobility, which makes it convenient for the customers. Some of the solutions based on a revenue-share-model, which means that the customers do not have to make any investment in technology. The mobile solution is also flexible to various input streams, which means that it can extract metals from different sources in the same plant. Additionally, the solutions are designed to be energy efficient and aims at achieving "zero waste", while also using low impact chemical reagents, making it easy to run (ResouTech, February 2023).

Almost all countries in the world meet with a WEEE problem, like an example I would like to indicate a Brazilian experience and problems studied in the work (Dias et al., 2018), estimating e-waste generation is challenging due to the lack of structure for collecting and recycling and the dispersed agents involved in the life cycle of WEEE. In 2006, e-waste generation was estimated to be 351 thousand tons per year, increasing to 710 thousand tons in 2008 and 1.42 million tons in 2014, a 100% increase in 6 years. Subjective obsolescence was found to be a major motivator for replacing electronic goods in Brazil.

Waste management in Brazil is regulated by the federal government's 2010 Brazilian Policy of Solid Waste, which emphasizes waste reduction, reuse, and reutilization. Companies are responsible for finding alternatives for EOL products, the government is responsible for regulation and collection, and users are responsible for proper disposal. Despite the national policy, over 3300 companies still dispose of waste in irregular sites. Studies have shown that the Brazilian population has a positive attitude towards e-waste recycling, but only a minority practices adequate recycling. The main issue with e-waste recycling in Brazil is the inadequate collection system that fails to gather EOL WEEE and separate it for recycling. Local and state governments are responsible for solid waste collection, and there is a need for a more structured system for WEEE collection and recycling.

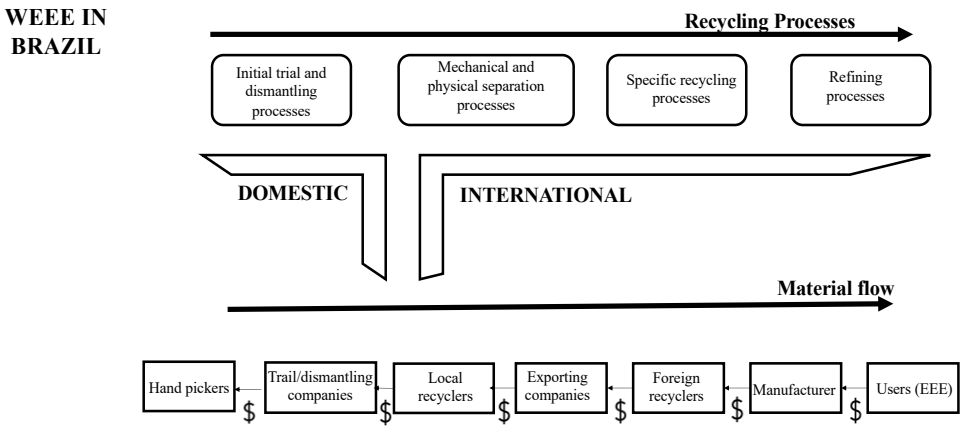


Figure 9. Source: (Dias et al., 2018)

2.2.8. Methods of responsible disposal and safe recycling of End of life of product products

Waste disposal methods can be broadly categorized into recycling, incineration, chemical-physical and biological treatment, and landfilling. Recycling involves the direct reuse of used products or the recovery of raw materials from waste. Incineration refers to the thermal treatment of combustible waste, where the heat generated is used to produce electricity and heat buildings. Chemical-physical and biological treatment aims to remove pollutants from waste, making it safe for landfilling. Landfills are used to deposit waste residues that are not suitable for other methods of treatment. Collection and logistic is an important aspect of waste management, involving the collection of waste from source, intermediate storage, and handover to specialized waste disposal operations.

2.3. END OF LIFE OF PHARMACEUCTICAL PRODUCT

There are three minor phases in the manufacture of pharmaceuticals: 1. Research and development (R&D) of Active Pharmaceutical Ingredients (API); 2. Synthesis of the APIs, from organic and natural substances: several processes may be combined at this level using high-value technologies, such as fermentation, extraction, chemical synthesis, etc.; and 3. Formulation of the final medicinal product: mixing of APIs with excipients to produce various dosage forms (such as tablets, pastilles, spray, syrup, or patch) and tastes. The more detailed pharmaceutical live cycle represented in the Figure 9.

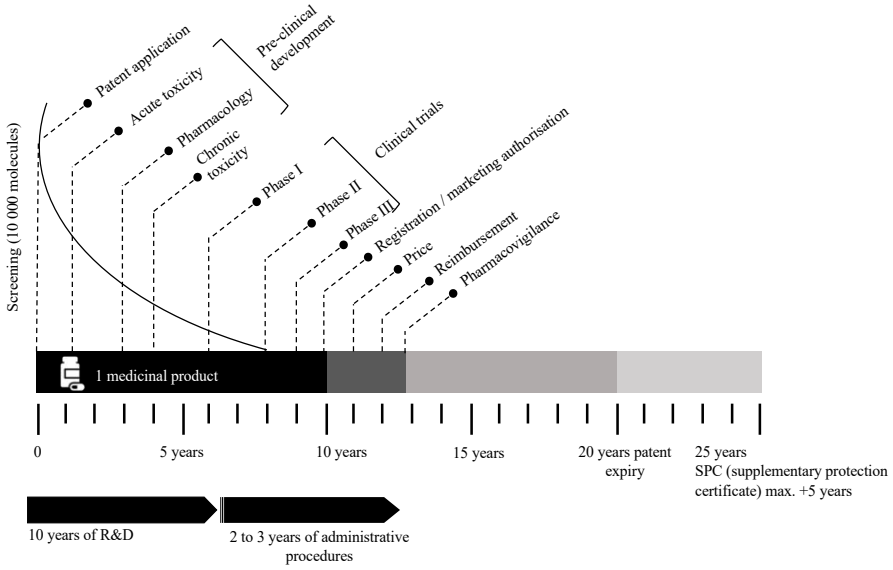


Figure 10. Life cycle of pharmaceutical product. Source: (EFPIA, 2020)

The life cycle of a pharmaceutical product typically starts with the discovery and development of a new drug formula. This stage involves the identification of a target medical condition, the discovery of a new active ingredient, and the development of a drug candidate. The discovery process typically involves laboratory research and testing to identify potential drug candidates and assess their safety and efficacy. Once a drug candidate has been identified, it moves on to the preclinical development stage, where it is tested in animal models to determine its safety and effectiveness.

The next stage is the clinical development stage, where the drug candidate is tested in human trials to gather data on its safety, efficacy, and optimal dosing. This stage typically involves three phases of clinical trials: phase I trials, phase II trials, and phase III trials. If the drug candidate proves to be safe and effective in clinical trials, it can then be submitted to regulatory agencies for approval. Once approved, the drug can be manufactured and distributed for commercial use. The post-approval stage involves ongoing monitoring of the drug's safety and efficacy, besides any updates to its labelling or dosing information. The life cycle of a pharmaceutical product ends when the drug is no longer marketed or sold.

When medicines enter the environment, they harm living species and ecosystems. Improper disposal of household pharmaceutical waste or UEM - Unused or expired medicines. UEM are drugs that can no longer be used because of being expired, unused, spilled, withdrawn, recalled, damaged, contaminated, or for any other reason. It also contains discarded objects that were significantly contaminated when handling medications, such as gloves, masks, connecting tubing, bottles, vials, that had pharmaceutical compounds. (Mohammed, Kahissay, & Hailu, 2021), (World Health Organization, 2018). UEM increases the amount of medicines in the environment, which has negative effects:

- Environmental contamination: UEM can contaminate soil and water. This can have negative impacts on the environment and on human health.
- Resistance to antibiotics: UEM can contain antibiotics, which can contribute to the development of antibiotic-resistant bacteria. This can make it more difficult to treat infections and diseases in humans and animals.
- Harm to wildlife: UEM can be harmful to wildlife. For example, if a bird consumes a discarded pill, it may become sick or die.

It is especial to define the hazardous and non-hazardous UEM. The biggest part of UEM is non-hazardous, from 85 to 75% according to different studies.

Hazardous UEM is a term used for pharmaceutical materials that can cause harm to human health or the environment due to their chemical, physical, or biological properties. These materials are strictly regulated by the European Environment Agency (EEA) and require specific handling and disposal procedures to prevent any harm. There are five examples of hazardous UEM, including chemotherapy drugs which are toxic and can be dangerous if not handled properly. Corrosive substances such as acids and bases can cause chemical burns and damage infrastructure if not handled with care. Reactive substances like peroxides and oxidizers can be a potential cause of explosions or fires when they react with other substances. Some pharmaceuticals, such as certain antibiotics and antivirals, can have long-term health effects if not disposed of properly, and some can be toxic if ingested or absorbed through the skin. The P-listed waste is a category of hazardous waste that includes certain pharmaceuticals, which are considered acutely hazardous due to their toxicity, corrosivity, or ignitability. Examples of these include warfarin and nicotine (HERO, February 2023).

It is important to properly identify and manage hazardous UEM to protect public health and the environment. This may involve training staff on proper handling procedures, using appropriate containers and labels, and working with certified waste management vendors to ensure safe disposal.

Households (Figure 10,11) are a significant provider of UEM due to several factors. One reason is the accumulation of unused or expired medications, as people often have leftover medications that they no longer need and do not dispose of properly. Additionally, the widespread use of over-the-counter drugs and personal care products that contain APIs contributes to household UEM. Furthermore, people may not be aware of the proper disposal methods for these products, leading to improper disposal and the potential for environmental pollution. The lack of access to

safe disposal options in some communities can also contribute to the problem. All these factors combined make households a significant provider of UEM.

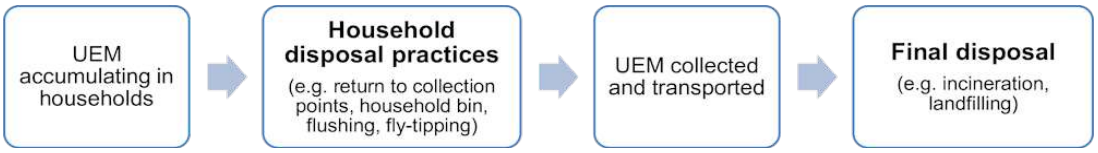


Figure 11. Source: (OECD, 2022)

Managing the EOL of pharmaceutical products is crucial to prevent environmental and health risks associated with the improper disposal of unused or expired medications. There are several challenges that households face when it comes to the take-back of UEM, including limited access to collection sites, lack of awareness, inconvenience, limited participation, security concerns, limited capacity of collection sites, limited funding, and limited regulations. Addressing these challenges requires a multi-faceted approach that involves increasing public awareness, making collection sites more accessible, and providing incentives for households to participate in take-back programs. To mitigate the problem of UEM, households can take several measures, such as proper disposal of unused or expired medications in designated collection sites or through mail-back programs, returning unused medications to the pharmacy, raising public awareness about the dangers of UEM and the importance of proper disposal, taking only the medication needed, proper storage, following the instructions for disposal, and complying with government regulations (Dar, Maqbool, & Rasool, 2019).

The lack of awareness about take-back programs for UEM can be addressed through several solutions. One solution is launching public awareness campaigns through various channels to educate households about the dangers of improper disposal of medications and the availability of take-back programs. Partnering with community organizations, such as local pharmacies, schools, and health clinics, can also raise awareness and educate households. Additionally, collaborating with waste management companies and offering incentives for participation can encourage households to properly dispose of their medications. Implementing an ecological education program in schools that includes knowledge about the UEM problem can also be an effective solution. Educating students at a young age, incorporating hands-on learning activities, curriculum integration, community outreach, and partnering with local organizations can help raise awareness and encourage environmentally friendly practices among future generations (Product Stewardship Institute, 2017), (Shah, Rajbongshi, & Sajib, 2016).

Hospitals (Figure 10) are a significant provider of UEM due to the large volume of medications and medical supplies they use daily. Additionally, hospitals are required to dispose of any expired or unused medications, which can contribute to their UEM. The use of intravenous medications, chemotherapy drugs, and other hazardous drugs in hospitals also contribute to their UEM. Furthermore, hospitals may generate waste from the packaging materials used for medications, likewise medical supplies. With the high volume of drugs and medical supplies used in hospitals, combined with strict disposal regulations, it's no surprise that hospitals are a significant provider of UEM.

In developed countries, hospitals generate an average of up to 0.5 kg of hazardous waste per bed per day, while in low-income countries, this number is lower at 0.2 kg. Nonetheless, it is important to note that health-care waste is often not properly separated into hazardous and non-hazardous categories in low-income countries, which means the actual amount of hazardous waste generated may be much higher

than reported (WHO, 2018).

There are various solutions that hospitals can adopt to tackle the problem of UEM. One of the solutions is the proper disposal of unused or expired medications, which can be achieved through designated collection sites or mail-back programs. Another approach is the repurposing or recycling of medications, where expired antibiotics can be used in animal feed and unused cancer drugs can be utilized to treat other diseases. Hospitals can also minimize medication waste by prescribing the appropriate amount of medication and encouraging patients to only take what is needed. Staff education and training on the handling, storage, and disposal of medications can also help to reduce waste. Additionally, inventory management systems can be implemented to track medications, identify those about to expire, and remove them from inventory before they become waste. Collaboration with other healthcare providers, pharmaceutical companies, and waste management companies can lead to finding sustainable solutions that reduce waste while protecting public health and the environment. Finally, hospitals must comply with government regulations to ensure proper disposal and repurposing of medications, avoiding any negative impact on the environment and public health (Shah, Rajbongshi, & Sajib, 2016).

Major pathways of release of human and veterinary pharmaceuticals into the environment

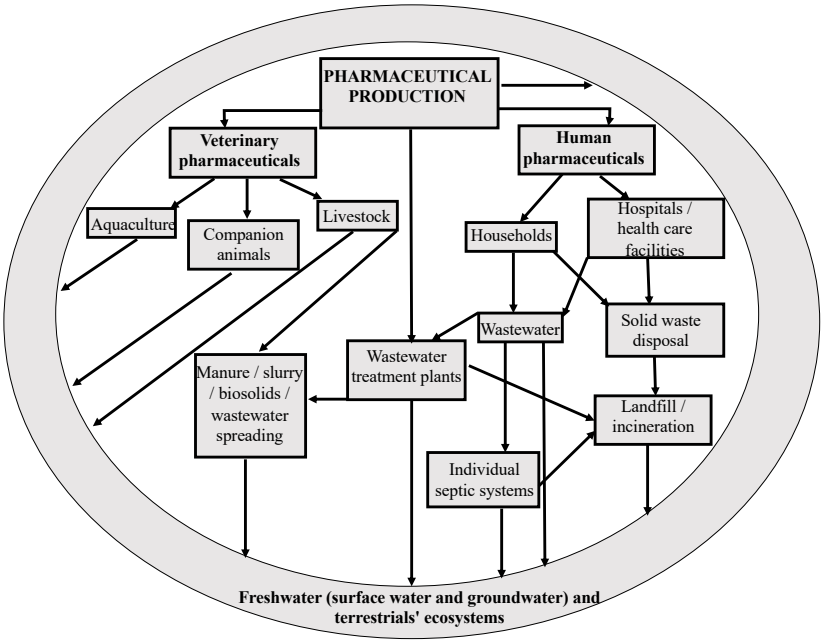


Figure 12. Source: (OECD, 2022)

2.3.1. Environmental and health impact

According to the (FEAM EBPF, FVE, & EFPIA, 2022) globally, more than 100,000 tones of pharmaceutical products are consumed annually, with Europe accounting for 24% of the total consumption**.** There are currently more than 4 000 active ingredients are available worldwide. It is estimated to reach 4.5 trillion doses in 2020, which is 24% higher than in 2015 (IQVIA, 2020).

Pharmaceuticals are necessary for both human and animal health, and used to prevent, treat, and improve the quality of life of the human population in health facilities. From the other side their residues that get into freshwater systems cause environmental problems. When leftovers are expelled after ingestion or when UEM is disposed of improperly, aquatic pollution can happen. In surface water, groundwater, and seas all around the world, pharmaceutical residues are now pervasive.

According to (Dusi, Rybicki, and Jungmann, 2019), the update and new analysis of the "Pharmaceuticals in the Environment" database revealed that pharmaceuticals have been found in 75 different countries and 771 substances have been detected in the environment, sometimes above pollution thresholds. The effects of freshwater contamination on human health and the environment differ significantly according on the pharmaceutical type. Some medications have an endocrine effect, which means they influence the hormonal system. Even at low quantities, endocrine-disrupting medications have been demonstrated to have negative impacts on wildlife. For instance, steroidal hormones in birth control pills have been shown to reduce fish population reproduction, while mental medications have been discovered to change fish behaviour (Brodin et al., 2013), (Nash et al., 2004). Furthermore, the discharge of antibiotics in water bodies can be linked to the spread of pathogenic organisms that are resistant to antimicrobials, causing an alarming public health threat worldwide (OECD, 2018).

UEM represents a wasted healthcare resource. Several studies estimate the costs of unused or expired drugs to be in the order of billions of USD (Law et al., 2015), (BMJ, 2016). After intake, the main source of household emissions is flushed medications. Typically, between 30% and 90% of pharmacological oral dosages are eliminated, either as the original substance or as a metabolite. Wastewater may also contain creams and ointments that have been removed from skin (BIO Intelligence Service, 2013). UEM is a significant waste stream and when disposed of improperly can also contribute to household emissions. An estimated 3-50% of pharmaceuticals become waste (OECD, 2022). From the other side 1 in every 100 dispensed items is eventually returned to a pharmacy or dispensing practice unused, or only partially used reported in England (Trueman et al. 2010). UEM is significant risk to the general public's health also the health of patients and professionals, both directly and indirectly through environmental deterioration. Enterococci, non-hemolytic streptococci, anaerobic cocci, clostridium tetani, klebsiella, HIV are the hosts of the bacteria that cause infection. In addition to the environmental issues, this results in the loss of financial resources, the inability to get essential medications, a rise in out-of-pocket costs, and a decline in the quality of healthcare services. It is clear indicated in the article (EC, 2022) that "the European Commission said that currently the pharmaceuticals and the cosmetics sectors are jointly responsible for 92% of the toxic load in wastewaters. “For both sectors, there is sufficient evidence on the existence of micropollutants from these products in wastewater, and there are treatments to remove their harmful residues,” said the European Commission in an October 26, 2022, statement".

An estimated from 700 000 (IMI, 2017) to 5 million deaths in 2019 were associated with bacterial antibiotic resistance (AMR), with 1.27 million deaths directly attributed to AMR. The estimated all-age death rate attributable to resistance was highest in western sub-Saharan Africa at 27.3 deaths per 100,000 and lowest in Australasia at 6.5 deaths per 100,000. The six leading pathogens for deaths associated with resistance were Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae, Streptococcus pneumoniae, Acinetobacter baumannii, and Pseudomonas aeruginosa. These pathogens were responsible for around 3.5 million deaths (Christopher J L Murray, et al 2022), (BIO Intelligence Service, 2013).

There are various reasons why drugs can end up being classified as waste. Firstly, if medication prescribed for treatment is found to be ineffective or causes

adverse reactions, it is no longer used, and the treatment is modified. Secondly, patients may have a history of not taking their medications as prescribed, resulting in leftover medication that is no longer needed. Thirdly, patients may recover from their illness or pass away sooner than expected, leaving behind unused medication. Fourthly, patients may store medication for future use, leading to expiration before being fully consumed. This issue is not limited to households but can also occur in public places such as hotels, hospitals, and military bases where drugs are stored for emergencies but used infrequently. Lastly, prescription or purchasing errors can result in patients being prescribed or purchasing the wrong medication, and overprescribing can also contribute to medication waste (OECD, 2018).

Biomedical waste categories, their treatment and disposal methods see a Table No. 1 was offered by K. V. Radha (Corresponding author) Department of Chemical Engineering, Anna University, Chennai 600025, India in the work " A Case Study of Biomedical Waste Management in Hospitals" (Arunprasath & R, 2009).

Table 1. UEM categories

Waste No.	Waste Category (Type)	Treatment and disposal
1	Human Anatomical Waste: human tissues, organs, body parts)	Incineration/deep burial
2	Microbiology and Biotechnology waste (waste pharma laboratory cultures, stocks of specimens of micro-organisms, live or attenuated vaccines, human and animal cell culture used in research and infectious agents from research laboratories, waste from production of biologicals, toxins, dishes, and devices used for transfer of cultures)	Local autoclaving/incineration and micro waving
3	Waste sharps: (needles, scalpels, blades, glass (broken and unbroken) etc. that may cause punctures and cuts	Disinfection by chemical syringes, treatment/autoclaving, microwaving
4	Discarded Medicines and cytotoxic drugs: (wastes comprising of outdated, contaminated drugs and discarded medicines)	Incineration/destruction disposal in secured landfills
5	Soiled waste: (items contaminated with blood, body fluids including cotton, dressing, soiled plaster casts, lines, bedding, other material contaminated with blood)	Incineration/autoclaving/and microwaving
6	Solid waste: (waste generated from disposable items other than treatment, waste sharps as catheters, intravenous sets, etc.)	Disinfection by chemical, autoclaving/microwaving, and mutilation/shredding

7	Ligiid waste: (waste generated from laboratory and washing, cleaning, housekeeping, and disinfecting activities)	Disinfection by chemical, treatment, and discharge into drain
8	Incineration ash: (ash from incineration of any bio-medical waste)	Disposal in municipal landfills.

2.3.2. Pharmaceutical waste management

Article 168 of the Treaty on the Functioning of the European Union (TFEU) deals with the protection of public health. It states that the EU shall take measures to protect public health, but it does not specifically mention the issue of UEM. However, the EU's action in the field of public health is based on the principle of subsidiarity, which means that the EU can act only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the Member States and can therefore, by reason of the scale or effects of the proposed action, be better achieved by the EU.

Article 168 TFEU states that the EU shall contribute to the protection of public health by encouraging cooperation among Member States and, if necessary, by adopting measures. The EU can do this by providing information and by promoting and coordinating action by Member States. The EU also has the power to take measures to prevent the spread of serious cross-border health threats, and to adopt public health measures to protect citizens from serious public health risks. UEM can be considered as a serious public health risk coupled with a threat to the environment. Therefore, it can be argued that the EU can take action to mitigate this problem through the provisions of Article 168 TFEU, by encouraging cooperation among member states, promoting, and coordinating (TFEU, March 2023).

There are several EU documents that deal with the issue of UEM: Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives: This directive sets out the EU's legal framework for the management of waste, including UEM. It establishes the waste hierarchy, which prioritizes the reduction, reuse, recycling, and recovery of waste over disposal [53] Council of the European Union, 2008.

Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labeling and packaging of substances and mixtures: This regulation, also known as the CLP Regulation, establishes a system for classifying, labeling, and packaging chemicals, including those used in pharmaceuticals. It is intended to ensure the safe handling, transport, and disposal of these substances (EP&C, 2008).

The EU Pharmaceutical Strategy for the Circular Economy: The EU adopted this strategy in 2019, to encourage the implementation of circular economy principles in the pharmaceutical sector, including the reduction of waste, the reuse and recycling of materials, and the development of new, more sustainable business models (EC, 2020).

Overall, these EU documents aim to address the issue of UEM through different approaches, by providing a framework for the management and reduction of waste, the safe handling and disposal of pharmaceuticals, and the promotion of circular economy principles in the pharmaceutical sector. It is important to note that the amount of UEM generated worldwide per year is not an easy number to estimate, and there are many factors that can affect the number such as, lack of regulations, lack of proper disposal and lack of awareness. The Extended Producer Responsibility (EPR) (35 countries worldwide) principle is a policy approach that places a significant portion of the responsibility for a product and its associated environmental impacts on the producer of that product. The principle is based on the idea that producers, who

make the decision to bring a product to market, should be responsible for the life cycle of that product, including its environmental impacts. In the context of UEM, the EPR principle is implemented through take-back programs, which require producers to finance the collection, transport, and disposal of the UEM. This includes the cost of setting up and running collection points, as well as the cost of properly disposing of the waste. The goal of these programs is to reduce the environmental and health risks associated with the disposal of unused or expired drugs.

The EPR principle aims to reduce the environmental and health risks associated with the disposal of unused or expired drugs, by ensuring that the costs of collection and disposal are borne by the producer and not by the public or the government. The principle also encourages producers to design more sustainable products and packaging, and to invest in recycling and recovery technologies. EPR can be used to increase the efficiency of the collection and disposal of UEM, and to reduce the environmental and health risks associated with this waste (Alev et al., 2021).

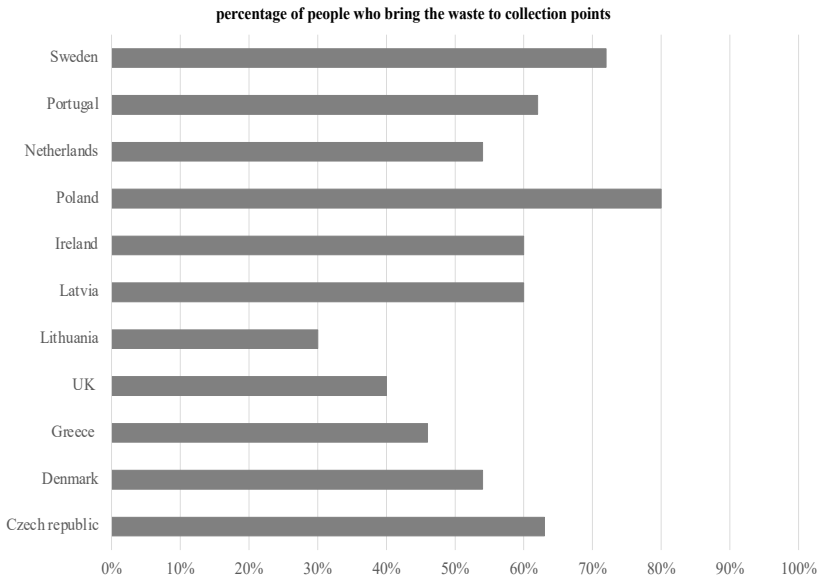
Waste management involves the handling of waste, which encompasses collecting, transporting, recovering (like sorting), and disposing of waste. These activities are supervised and followed up with after-care measures at disposal sites. Dealers or brokers also undertake waste collection, packaging, storage, segregation, transport, treatment, and disposal using scientific methods. Due to the significant environmental and social impact, hospital waste management requires careful planning. Pharmaceutical waste should be separated from other types of waste and the amount of waste generated should be estimated for waste management budget planning and optimization of waste management procedures.

Pharmaceuticals are wasted because of poor inventory control, protracted procurement processes, poor storage, inadequate monitoring of drug expiration dates, distribution issues, and irrational drug usage. There are several key aspects of UEM management, including the proper handling and storage of waste materials, the selection of appropriate disposal methods, and the implementation of regulatory policies and guidelines to ensure compliance with environmental and public health standards. UEM management practices in public health facilities: container or bag used for segregation, writing label on segregated waste, recording of segregated waste, storage of segregated waste awaiting removal, waste disposal guideline, waste disposal plan, waste disposal team, place of disposal, frequency of disposal, method of disposal, impact of waste disposal on the environment. Therefore, UEM management is a complex and important issue, and requires the coordination of efforts across the pharmaceutical industry and other stakeholders, such as regulatory agencies and environmental organizations, to ensure that waste materials are handled and disposed of in a safe and responsible manner.

Pharmacies, hospitals, and other medical facilities are the main collection points for the return of pharmaceuticals, where consumers can return their unused or expired drugs. The collected drugs are then sent to specialized waste disposal companies for destruction, or in some cases, for treatment and disposal.

2.3.3. Expired and unused medicines collection

Large disparities (Graph No.1) in the systems and their application in different EU members persist. The reasons for pharmaceuticals wastage were expiry (92.05%).



Graph 1. Source: (OECD, 2022), (Mitkidis et al., 2021)

The pharmacy receives and handles leftover medicines correctly. In Sweden, it is estimated that approximately 75 percent of the remaining medicines go back to the pharmacies (FASS, 2011).

2.3.4. Expired and unused medicines disposal methods

Incineration: This method involves burning the waste at high temperatures in a specialized incinerator. Incineration destroys most of the organic compounds and can reduce the volume of waste by up to 90%.

Medium temperature incineration is a method that can be used to dispose of different types of UEM, including solids, semi-solids, powders, and controlled substances. This method is used when high-temperature incinerators are not available or when other methods are not safe. The incinerator has two chambers, which reach a temperature of 850 degrees Celsius. The second chamber has a combustion retention time of 2 seconds. To dispose of UEM, it should be mixed with municipal waste in a ratio of 1:1000. The use of medium temperature incinerators for the disposal of halogenated compounds is not recommended. since some halogen amounts will be found in combustion gases.

On the other hand, the novel high-temperature incineration method can be used to dispose of different types of UEM, including solids, semi-solids, liquids, powders, controlled substances, and antineoplastics. Such incinerators, like cement kilns, operate at temperatures above 1200 degrees Celsius, have a short gas residence time, proper emission controls, long combustion retention time, are expensive, and use sophisticated technology. All organic waste components are destroyed by this incinerator, which also removes any harmful combustion byproducts. They can be used to dispose of significant volumes of UEM in a short time. Pharmaceuticals should be put in small amounts (5%) in the furnace than fuel

feed (95%). Before incineration, remove packaging materials and grind the pharmaceuticals to avoid blockage of fuel feed (OECD, 2022), (Nyaga, et al., 2020), (Hazardous Waste Experts, 2013), (Chamberlain 2019).

Incineration uses different technologies, including mass burn, rotary kiln, fluidized bed, and incineration with energy recovery. Mass burn involves burning large amounts of waste in a chamber with other materials to ensure complete combustion, while rotary kiln technology uses a rotating cylinder to mix waste with air and fuel. Fluidized bed technology uses a heated bed of sand or material to combust waste, and incineration with energy recovery captures the heat energy to generate electricity or heat. Still, incineration can be expensive and may produce hazardous emissions. One of the main issues with UEM incineration is the release of toxic pollutants into the air. Burning pharmaceuticals can release a range of pollutants, including dioxins furans, and heavy metals, which can have harmful health effects on both humans and the environment (WHO, 1999).

Dioxins (PCDDs) (one of the chemical formulas is C12H4Cl4O2), are a class of compounds that are chemically like dibenzofurans and are often referred to collectively as dioxins. They are characterized by the presence of two benzene rings linked by two oxygen atoms in a specific configuration. PCDDs can exist in different forms, depending on the number and position of chlorine atoms in the molecule. PCDDs are persistent in the environment and can accumulate in the food chain, particularly in fatty tissues. They are known (Stockholm Convention, 2004) to have a range of harmful effects on human health, including reproductive and developmental disorders, immune system suppression, and cancer. In addition, they can have serious environmental effects, such as causing damage to ecosystems, particularly in aquatic environments. Due to their toxicity, PCDDs are subject to strict regulations, and their production and use are closely monitored and controlled by national and international organizations, such as the United Nations Environment Program (UNEPand the Stockholm Convention on Persistent Organic Pollutants) (UNEP Chemicals, 1999), (Stockholm Convention, 2004).

Pyrolysis can be used as an alternative to direct UEM incineration (Czajczyńska et al., 2017). The thermochemical decomposition of organic material at high temperatures in the absence of oxygen is the essence of the process. Compared to incineration, pyrolysis has lower process temperatures, less particulate carryover, and reduced emissions of air pollutants, resulting in a decreased environmental impact (Gerasimov 2019). One of the main issues with UEM pyrolysis is the release of harmful pollutants into the air. The process can generate a variety of emissions, including particulate matter, dioxins, furans, and other toxic compounds. These emissions can pose a health risk to workers at the facility and people living in the surrounding area.

Another concern is that the process of medical waste pyrolysis can be energy-intensive and can contribute to greenhouse gas emissions. Additionally, the quality of the end products of UEM pyrolysis can vary widely, and there may be residual hazardous materials that require proper disposal. The oils and other products generated by pyrolysis may contain toxic substances that need to be carefully managed to prevent further environmental and health risks.

Chemical treatment/disinfection is best suited for treating bio medical waste (BMW) such as blood, urine, stools, or sewage from a health care facility. Pathogens in BMW are killed or inactivated by the addition of strong oxidants such as chlorine compounds, ammonium salts, aldehydes, or phenol compounds. Chemical disinfection can, nevertheless, be used to treat microbiological cultures, mutilated sharps, or shredded solids. Chemical treatment can be effective for certain types of waste but may require specialized equipment and careful handling to prevent accidents (Hazardous Waste Experts, 2013), (Chamberlain 2019), Jaseem, et al., 2017).

Autoclaving. (Chamberlain 2019), (Jaseem, et al., 2017). This method involves using steam and pressure to sterilize UEM. For sterilization, autoclaving uses saturated steam in direct contact with the BMW in a pressure vessel at time lengths and temperatures sufficient to kill the pathogens. The Biomedical Waste Rules specify the minimum temperature, pressure, and residence time for autoclaves for safe disinfection. Before autoclaving, BMWs must be shrunk to an acceptable size, which is a laborious process that would result in frequent breakdowns. Autoclaving generates waste that can be landfilled alongside municipal waste. A wastewater stream is produced, which must be disposed of using proper controls. Autoclave operation necessitates qualified technicians additionally a moderate investment and operating cost. Despite its many advantages, autoclaving is not appropriate for human anatomical, animal, chemical, or pharmaceutical waste.

Microwaving. An electromagnetic field applied to the BMW causes the liquid in the waste to oscillate and heat up, destroying the infectious components via conduction. Ultraviolet radiation reaches the waste material only when there is water in the waste. Because the radiation directly works on the water, not the solid components of the waste microwave treatment, as a result, humidifiers are frequently included with treatment units. BMWs require shredding to an acceptable size because microwaves can penetrate to where infectious microbes are, smaller pieces enhance the heating action. Microwaving generates waste that can be landfilled alongside municipal waste. The benefits of this treatment technology include low electrical energy requirements and no need for steam.

Landfill disposal. This method involves disposing of the UEM in a landfill, where it is typically mixed with other solid waste. Yet, this method is generally not recommended for pharmaceutical waste because it can result in leaching of chemicals into the soil and groundwater. Secure landfills are designed and operated to receive hazardous wastes such as biomedical waste, including discarded medicines, cytotoxic drugs, solid chemical wastes, and incineration ash. In contrast, it is important to note that older, poorly designed, or poorly managed landfills can create various environmental problems, such as wind-blown litter, attraction of vermin, and generation of liquid leachate. Moreover, the organic waste that is buried in landfills can produce gas, which creates odor problems, kills vegetation, and contributes to greenhouse gas emissions. To mitigate these issues, modern landfills are designed with features like clay or plastic lining materials to contain leachate, compacted waste to increase its stability and density, and covers to prevent attracting vermin. Many landfills also have gas extraction systems to extract the methane and carbon dioxide produced by the organic waste and burn it to generate electricity (Kumar, 2016), (Malsparo, March 2023).

Proper disposal of unused or expired medications is crucial, and there are several ways to do it. One way is by disposing of medications at specific collection sites or through mail-back programs. Repurposing or recycling medications is also an option, where certain drugs can be used for other purposes. For example, expired antibiotics can be used in animal feed, and unused cancer drugs can be used to treat other illnesses. To reduce the amount of UEM, healthcare providers must prescribe the appropriate amount of medication and encourage patients to only take what they need. Raising public awareness about the dangers of UEM and proper disposal is also essential in decreasing waste. Government regulations can play a significant role in regulating the disposal and repurposing of medications, to prevent any adverse impact on the environment and public health. Collaboration between healthcare providers, pharmaceutical companies, and waste management companies can also work together to find solutions to reduce waste and protect the environment and public health.

The study of the legislation regulating pharmaceutical take-back systems in four EU member countries confirms that while these countries have implemented

Article 127b of the Community code, they have done so differently. The empirical study found varied levels of usage of these systems, furthermore differences in individuals' beliefs and behavior. It also provided insight into which framing of the EUM problem leads to the highest levels of intention to use the systems in the future.

Designing an EU unified take-back system for UEM would require a comprehensive approach that addresses several key considerations.

Accessibility: The system should be easily accessible to all EU citizens, regardless of location or socioeconomic status. This can be achieved by providing enough collection sites, mail-back programs, and other options for disposing of medications.

Efficient logistics: The system should have efficient logistics in place to transport and process the collected waste. This includes ensuring the safe transportation of medications, not to mention proper storage and processing at collection sites.

Transparency and traceability: The system should have a transparent and traceable system for tracking medications from collection to disposal. This is essential for ensuring the safety and security of the medications, also for monitoring the effectiveness of the system.

Compliance and enforcement: The system should have a strong compliance and enforcement mechanism to ensure that EU citizens comply with the regulations, along with to penalize those who do not.

Cost-effective: The system should be cost-effective and sustainable, considering the cost of collection, transportation, processing, and disposal.

Public awareness: The system should have a strong public awareness campaign to educate EU citizens about the importance of proper disposal of medications and the dangers of improper disposal. Monitoring and evaluation: The system should have a monitoring and evaluation mechanism to track the performance of the system and make necessary adjustments.

Overall, designing an EU unified take-back system requires a balance of different elements to ensure it is both effective and sustainable.

3. STUDY DESIGN

In accordance with the regulations to 2004, Article 127b of the Community code, the two countries under study Slovakia and Austria have implemented a pharmacy-based take-back system for pharmaceutical waste for households (waste categories No. 3 and 4 Table 1). My research aims to determine the scale of pharmaceutical waste management awareness. I used as data collection tool in the study. The survey is composed of 4 factors and 5 groups, including "Attitude" (9 items), "Knowledge" (16 items), "*Administrative*" (5 items), "*Motivation*" (5 items), group 1 (G1: young participants and participates under 60 years old, group 2 (G2: female and male participants), group 3 (G3: Austrian and Slovakian participants), group 4 (G4: with children up to 18 years old and without one's participants), group 5 (G5: with chronic illnesses and without one's participants).

The poll focuses on four key demographic groups: young singles, parents with children under the age of 18, people with chronic illnesses, and seniors, presuming that the groups with the highest levels of awareness are those that frequently visit pharmacies. Questionary: Appendix 1. to the Thesis.

A total of 205 responders and 35 self-administered questionnaires were distributed to public via personal contact, universities TUWien, and social changes. The overall response rate was 75%. A consumer study was initially conducted to learn how the general population disposes of EUM in homes and to identify the public awareness and motivation.

Data collection instruments: A structured checklist adopted from world health organization (WHO) waste management checklist was used to collect data on pharmaceutical wastage awareness and motivation. *Data management and analysis:* The mechanisms for collecting structured data were accurately designed to ensure the accuracy of the information. During data collection, processing, and interpretation, every piece of information was checked for consistency and completeness.

4. SURVEY RESULTS AND INTERPRETATION

I consider the survey is good starting point for a research topic on pharmaceutical waste management. It could be also a valuable source of information to understand the attitudes and behaviors of individuals towards pharmaceutical waste disposal.

This thesis aims to investigate the level of user awareness and behaviors towards the disposal of pharmaceutical waste, in addition to the factors that influence such behaviors. It could also explore the impact of educational campaigns and other interventions on customer attitudes and behaviors towards pharmaceutical waste disposal. The study could provide valuable insights into the current state of pharmaceutical waste disposal practices among consumers and inform the development of effective strategies to promote responsible waste disposal behaviors.

In statistics, several parameters are used to describe and summarize the data collected from a survey. Here are the definitions of the parameters you mentioned and their influence on survey results:

Note: The scales for all questions ranged from 1 to 5, with 1 being "fully disagree" and 5 being "fully agree". The abbreviations used in the table are as follows: Mean (average), SD (standard deviation), Median (middle value), Trimmed Mean (average after removing outliers), MAD (median absolute deviation), Min (minimum value), Max (maximum value), Range (difference between maximum and minimum values), Skewness (measure of the asymmetry of the distribution), Kurtosis (measure of the "peakedness" of the distribution), SE (standard error of the mean).

Mean: The mean is the average value of the responses given by the survey participants. It is calculated by adding up all the responses and dividing by the total number of participants. The mean can be influenced by extreme values or outliers in the data.

Standard Deviation (SD): The SD is a measure of how spread out the responses are from the mean. It is calculated by taking the square root of the variance, which is the average of the squared differences from the mean. The SD can be influenced by extreme values or outliers in the data.

Trimmed Mean: The trimmed mean is the mean calculated after removing a certain percentage of extreme values from the data. This can be useful in cases where extreme values are skewing the mean in one direction or another.

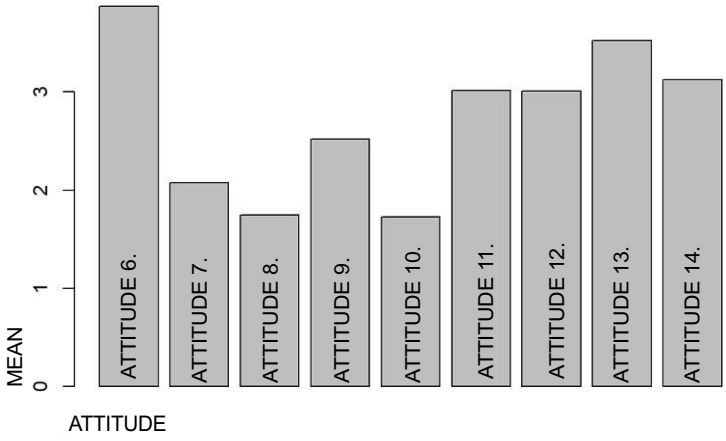
Median Absolute Deviation is a robust measure of variability that is not affected by extreme values or outliers. It is calculated by taking the median of the absolute differences among each response and the median of the data.

Mean absolute deviation is a measure of the average distance among each data point and the mean of the data. It can be useful in understanding the spread of the data and identifying any outliers that may be present.

Range: The range is the difference between the maximum and minimum values and provides a quick measure of the spread of the data.

Depending on the specific research question and study design, some of these measures may be more relevant or informative than others. For example, in my study the tree most relevant parameters I take for evaluation the result is: Mean, Standard Deviations, Median.

4.1. Section "Attitude" survey results



Graph 2

ATTITUDE [6]. What best describes your attitude to the pharmaceutical waste collection? [I check the expiration date only before taking the medicine.]
ATTITUDE [7]. What best describes your attitude to the pharmaceutical waste collection? [I usually dispose the pharmaceutical waste in (sewage, bins, toilets)]
ATTITUDE [8]. What best describes your attitude to the pharmaceutical waste collection? [The pharmaceutical waste produced by me as a person is so insignificantly small that I can neglect its impact on the environment]
ATTITUDE [9]. What best describes your attitude to the pharmaceutical waste collection? [I believe that if I take my medications orally, they shouldn't be harmful to the environment]
ATTITUDE [10]. What best describes your attitude to the pharmaceutical waste collection? [I consider it is a waste of time and additional costs (parking a car, gasoline, etc.) to hand over pharmaceutical waste to special collection points]
ATTITUDE [11]. What best describes your attitude to the pharmaceutical waste collection? [I usually visit pharmacies when I or a family member gets sick, and I do not remember bringing pharmaceutical waste at that situation]
ATTITUDE [12]. What best describes your attitude to the pharmaceutical waste collection? [I do inventory of my pharmaceutical waste regularly during a year]
ATTITUDE [13]. What best describes your attitude to the pharmaceutical waste collection? [I always return unused or expired medications to my neighbourhood pharmacy or another location for collection]
ATTITUDE [14]. What best describes your attitude to the pharmaceutical waste collection? [I unpack medicine at home and deliver it to a collection location]

Section "Attitude" interpretation

Attitude question [6] "I check the expiration of medicine date only before taking the medicine" - the range is from 1 (I fully do not agree) to 5 (I fully agree)" Result is: mean=3.87, SD =1.40, mad = 1.48, My evaluation is following:

Based on the results of the survey question, the mean score of 3.87 indicates that on average, the respondents somewhat agree with the statement that they only check the expiration date of medicine before taking it. The standard deviation of 1.40 suggests that there is some variability in the responses, with some people strongly agreeing or disagreeing while others are more neutral. The median absolute deviation (MAD) of 1.48 indicates that the data is somewhat dispersed, with many respondents providing scores that are either slightly above or below the mean.

Overall, the results suggest that while a significant proportion of respondents do check the expiration date of medicine before taking it, there are also some who do not. It is important to note, however, that this survey only captures self-reported behavior and attitudes and may not necessarily reflect actual behavior in practice.

Attitude question [7] "I usually dispose the pharmaceutical waste in (sewage, bins, toilets)" - the range is from 1 (I fully do not agree) to 5 (I fully agree). Survey result is mean=2.08, SD = 1.44, median = 1. My evaluation is following:

Based on the results of the survey question, the mean score of 2.08 indicates that on average, respondents disagree with the statement that they usually dispose of pharmaceutical waste in sewage, bins, or toilets. The standard deviation of 1.44 suggests that there is a wide variability in responses, with some people strongly disagreeing and others being more neutral.

The median score of 1 indicates that most respondents chose a response that is lower than the mean, indicating that a large proportion of respondents do not dispose of pharmaceutical waste inappropriately.

Overall, the results suggest that most respondents are aware of the importance of proper disposal of pharmaceutical waste and are likely taking steps to dispose of it safely.

Attitude question [8] "The pharmaceutical waste produced by me as a person is so insignificantly small that I can neglect its impact on the environment". The scale ranges from 5 - fully agree - (small impact) to 1 fully disagree (big impact). Survey result is mean=1.75, SD=1.22, median = 1, My evaluation is following:

Based on the results of the survey question, the mean score of 1.75 indicates that on average, respondents disagree with the statement that the pharmaceutical waste they produce as individuals has an insignificant impact on the environment. The standard deviation of 1.22 suggests that there is some variability in responses, with some people strongly disagreeing and others being more neutral.

The median score of 1 indicates that many respondents chose a response that is lower than the mean, indicating that a large proportion of respondents believe that their pharmaceutical waste has a significant impact on the environment.

Overall, the results suggest that most respondents recognize that their individual actions can contribute to the environmental impact of pharmaceutical waste, and that proper disposal and management of this waste is important.

Attitude question [9] "I believe that if I take my medications orally, they shouldn't be harmful to the environment". The scale ranges from 5 - fully agree - (not harmful for the environment) to 1 fully disagree (harmful for the environment). Survey result is: mean=2.52, SD=1.36, median = 2, My evaluation is following:

Based on the results of the survey question, the mean score of 2.52 indicates that on average, respondents are somewhat neutral or slightly disagree with the statement that taking medications orally shouldn't be harmful to the environment. The

standard deviation of 1.36 suggests that there is some variability in responses, with some people strongly disagreeing or agreeing and others being more neutral.

The median score of 2 indicates that most respondents chose a response that is around the midpoint of the scale, indicating a neutral or slightly disagreeing attitude towards the statement.

Overall, the results suggest that respondents are not entirely convinced that taking medications orally does not have any environmental impact, but there is no clear consensus on the issue.

Attitude question [10] "I consider it is a waste of time and additional costs (parking a car, gasoline, etc.) to hand over pharmaceutical waste to special collection points". The scale ranges from 5 - fully agree - (it's waste of time) to 1 fully disagree (it's not waste of time). Survey result is mean=1.73, SD=1.24, median = 1, My evaluation is following:

Based on the results of the survey question, the mean score of 1.73 indicates that on average, respondents disagree with the statement that it is a waste of time and additional costs to hand over pharmaceutical waste to special collection points. The standard deviation of 1.24 suggests that there is some variability in responses, with some people strongly disagreeing or agreeing and others being more neutral.

The median score of 1 indicates that most respondents chose a response that is lower than the mean, indicating that most respondents do not believe that handing over pharmaceutical waste to special collection points is a waste of time.

Overall, the results suggest that most respondents are aware of the importance of proper disposal of pharmaceutical waste and are willing to try to dispose of it correctly, even if it involves additional time and costs.

Attitude question [11] "I usually visit pharmacies when I or a family member gets sick, and I do not remember bringing pharmaceutical waste at that situation". The scale ranges from 5 - fully agree - (I do not remember) to 1 fully disagree (I remember). Survey result is: mean=3.1, SD=1.68, median = 3, My evaluation is following:

Based on the results of the survey question, the mean score of 3.1 indicates that on average, respondents are somewhat neutral or slightly agree with the statement that they do not remember bringing pharmaceutical waste when visiting pharmacies when they or a family member gets sick. The standard deviation of 1.68 suggests that there is some variability in responses, with some people strongly agreeing or disagreeing and others being more neutral.

The median score of 3 indicates that most respondents chose a response that is around the midpoint of the scale, indicating a neutral or slightly agreeing attitude towards the statement.

Overall, the results suggest that respondents are somewhat unsure about their behavior when visiting pharmacies and whether they bring pharmaceutical waste for proper disposal.

Attitude question [12] "I do inventory of my pharmaceutical waste regularly during a year". The scale ranges from 5 - fully agree - (I do) to 1 fully disagree (I do not do). Survey result is mean=3.01, SD =1.60, median = 3, My evaluation is following:

Based on the results of the survey question, the mean score of 3.01 indicates that on average, respondents are somewhat neutral or slightly agree with the statement that they do inventory of their pharmaceutical waste regularly during a year. The standard deviation of 1.60 suggests that there is some variability in responses, with some people strongly agreeing or disagreeing and others being more neutral.

The median score of 3 indicates that many respondents chose a response that is around the midpoint of the scale, indicating a neutral or slightly agreeing attitude towards the statement.

Overall, the conclusion is that most respondents neither agree nor disagree with doing an inventory of their pharmaceutical waste regularly during the year.

Attitude question [13] "I always return unused or expired medications to my neighborhood pharmacy or another location for collection". The scale ranges from 5 - fully agree - (I do) to 1 fully disagree (I do not do). Survey result is mean=3.52, SD=1.62, median = 4, My evaluation is following:

Based on the results of the survey question, the mean score of 3.52 indicates that on average, respondents somewhat agree with the statement that they always return unused or expired medications to their neighborhood pharmacy or another location for collection. The standard deviation of 1.62 suggests that there is some variability in responses, with some people strongly agreeing or disagreeing and others being more neutral.

The median score of 4 indicates that most respondents chose a response that is above the midpoint of the scale, indicating a generally positive attitude towards returning unused or expired medications for proper disposal.

Overall, the results suggest that respondents generally understand the importance of returning unused or expired medications for proper disposal, but there is still room for improvement in terms of increasing awareness and encouraging more people to adopt this behavior.

Attitude question [14] "I unpack medicine at home and deliver it to a collection location". The scale ranges from 5 - fully agree - (I do) to 1 fully disagree (I do not do). Survey result is mean=3.13, SD=1.64, median = 3, My evaluation is following:

Based on the results of the survey question, the mean score of 3.13 indicates that on average, respondents are somewhat neutral or slightly agree with the statement that they unpack medicine at home and deliver it to a collection location. The standard deviation of 1.64 suggests that there is some variability in responses, with some people strongly agreeing or disagreeing and others being more neutral.

The median score of 3 indicates that most respondents chose a response that is around the midpoint of the scale, indicating a neutral or slightly agreeing attitude towards unpacking medicine at home and delivering it to a collection location.

Overall, the results suggest that respondents are somewhat unsure or neutral about their behavior regarding unpacking medicine at home and delivering it to a collection location.

Section "Attitude" conclusion.

Overall, the survey results suggest that there is a lack of awareness and understanding about the proper disposal of pharmaceutical waste. While some respondents indicated that they check the expiration date of medications and return unused or expired medications to a collection point, most respondents do not dispose of pharmaceutical waste properly, do not do regular inventory of their pharmaceutical waste, and are unsure or neutral about their behavior regarding unpacking medicine at home and delivering it to a collection location.

To address this issue, it may be necessary to increase public awareness and education about the proper disposal of pharmaceutical waste. This could include providing information about the environmental impact of pharmaceutical waste and the importance of returning unused or expired medications to a collection point. Additionally, it may be necessary to make it easier and more convenient for people to dispose of their pharmaceutical waste properly by providing more collection points or implementing a pick-up service for pharmaceutical waste.

There are several positive notes that I can take from this section: Firstly, responders generally recognize the importance of checking the expiration dates of their medication before taking them. The survey results indicate that responders have

a relatively high level of awareness about the potential harm of improper disposal of pharmaceutical waste. This is a positive note as it suggests that people understand the need to dispose of their medication responsibly.

Moreover, responders generally acknowledge the impact of their pharmaceutical waste on the environment, which is another positive note. This awareness of the potential harm caused by medication waste shows that people are willing to take responsibility for it. Together, these findings suggest that responders are conscious of the need to properly dispose of their pharmaceutical waste and are aware of the potential impact of their actions.

The survey also showed some areas for improvement. For example, responders had a relatively low score in terms of their willingness to visit designated collection locations to dispose of their medication waste, with a mean score of 1.73 out of 5. This suggests that people may not be willing to go out of their way to dispose of their medication waste properly.

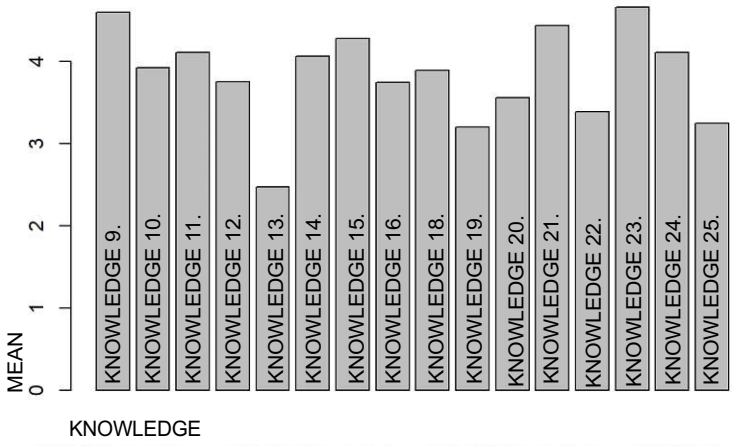
Furthermore, responders had a relatively low score in terms of their memory of disposing of their medication waste during periods of illness, with a mean score of 3.1 out of 5. This suggests that people may not be thinking about disposing of their medication waste during time of illness.

Lastly, responders had a relatively low score in terms of their regular inventory of pharmaceutical waste, with a mean score of 3.01 out of 5. This suggests that people may not be taking regular steps to assess and dispose of their medication waste properly.

Hypotheses of the most probable behavior of the three most representatives of the survey could be:

- Someone who scored high on checking medication expiration dates is likely to be conscious of their health and wellbeing and wants to avoid any potential harm from expired medication.
- Someone who scored high on acknowledging the impact of their pharmaceutical waste on the environment is likely to be environmentally conscious and wants to take responsibility for their actions.
- Someone who scored low on their willingness to visit designated collection locations may be someone who values their time and convenience over the importance of proper disposal of medication waste.

4.2. Section "Knowledge" survey results



Graph 3

KNOWLEDGE [9]. In how far do you agree with the following statements: *I think that*...pharmaceutical waste increases environmental pollution
KNOWLEDGE [10]. In how far do you agree with the following statements: *I think that*...pharmaceutical waste increases health problems
KNOWLEDGE [11]. In how far do you agree with the following statements: *I think that*...pharmaceutical waste transfers of compounds within the food chain
KNOWLEDGE [12]. In how far do you agree with the following statements: *I think that...*pharmaceutical waste increases antibiotic resistance level
KNOWLEDGE [13]. In how far do you agree with the following statements: *I think that...*pharmaceutical waste collection methods are the same for all types of waste
KNOWLEDGE [14]. In how far do you agree with the following statements*: I think that*...pharmaceutical waste requires special kind of packaging for waste collection and storage
KNOWLEDGE [15]. In how far do you agree with the following statements: *I think that*...the most important stage of pharmaceutical waste management is collection from public and hospitals
KNOWLEDGE [16]. In how far do you agree with the following statements: *I think that*...collection of pharmaceutical waste is done by licensed firms
KNOWLEDGE [17]. In how far do you agree with the following statements: *I think that...*incineration of pharmaceutical waste reduces pharmaceutical active ingredients (API) content in aquatic environment and negatively influence on fish, daphnia, algae etc.

KNOWLEDGE [18]. In how far do you agree with the following statements*: I think that*...incineration of pharmaceutical waste increases energy consumption
KNOWLEDGE [19]. In how far do you agree with the following statements: *I think that*...incineration and collection of pharmaceutical waste creates jobs for people
KNOWLEDGE [20]. In how far do you agree with the following statements*: I think that*...incineration of pharmaceutical waste factories should have special filtration system
KNOWLEDGE [21]. In how far do you agree with the following statements: *I think that...*incineration of pharmaceutical waste is done by licensed plants at the approximately 1000 degree of Celsius
KNOWLEDGE [22]. In how far do you agree with the following statements: *I think that...*pharmacies are obliged to take-back pharmaceutical waste from public
KNOWLEDGE [23]. In how far do you agree with the following statements: *I think that...*pharmaceutical waste bins are not reachable by public because of security measures
KNOWLEDGE [24]. In how far do you agree with the following statements: *I think that*...I evaluate my knowledge about pharmaceutical waste problem

Knowledge question [9] "In how far do you agree with the following statements: *I think that*...pharmaceutical waste increases environmental pollution" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.59, SD=0.71, median = 5.

My interpretation is following, the mean score of 4.59 indicates that, on average, respondents tend to agree that pharmaceutical waste increases environmental pollution. The median score of 5 further supports this conclusion, as it falls on the highest end of the scale. The standard deviation of 0.71 indicates that the responses were somewhat consistent, with a relatively small amount of variability around the mean. This suggests that most respondents hold similar views on the topic. Overall, the most respondents agree that pharmaceutical waste increases environmental pollution.

Knowledge question [10] "In how far do you agree with the following statements: *I think that...*pharmaceutical waste increases health problems" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=3.92, SD=1.07, median = 4.

My interpretation is following, the mean score of 3.92 indicates that, on average, respondents tend to agree to a moderate extent that pharmaceutical waste increases health problems. The median score of 4 further supports this conclusion, as it falls closer to the agree end of the scale.

The standard deviation of 1.07 indicates that the responses were somewhat varied, with some respondents strongly agreeing while others strongly disagreeing with the statement. This suggests that there may be some disagreement or uncertainty among respondents regarding the relationship between pharmaceutical waste and health problems. While a majority of respondents tend to agree that pharmaceutical waste increases health problems, there is some variability in opinion.

Knowledge question [11] "In how far do you agree with the following statements: *I think that*...pharmaceutical waste transfers of compounds within the food chain" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.10, SD=1.01, median = 4.

My evaluation is following, the mean score of 4.10 indicates that, on average, respondents tend to agree to a moderate extent that pharmaceutical waste transfers

compounds within the food chain. The median score of 4 further supports this conclusion, as it falls on the agree end of the scale.

The standard deviation of 1.01 indicates that the responses were somewhat varied, with some respondents strongly agreeing while others strongly disagreeing with the statement. This suggests that there may be some disagreement or uncertainty among respondents regarding the relationship between pharmaceutical waste and the transfer of compounds within the food chain. Overall, while most respondents tend to agree that pharmaceutical waste can transfer compounds within the food chain, there is some variability in opinion.

Knowledge question [12] "In how far do you agree with the following statements: *I think that...*pharmaceutical waste increases antibiotic resistance level" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=3.75, SD=1.2, median = 4. evaluate the result and make conclusion?

My interpretation is following, the mean score of 3.75 indicates that, on average, respondents tend to agree to a moderate extent that pharmaceutical waste increases antibiotic resistance levels. The median score of 4 further supports this conclusion, as it falls on the agree end of the scale.

The standard deviation of 1.2 indicates that the responses were somewhat varied, with some respondents strongly agreeing while others strongly disagreeing with the statement. This suggests that there may be some disagreement or uncertainty among respondents regarding the relationship between pharmaceutical waste and antibiotic resistance levels. Overall, while most respondents tend to agree that pharmaceutical waste can increase antibiotic resistance levels, there is some variability in opinion.

Knowledge question [13] "In how far do you agree with the following statements: *I think that*...pharmaceutical waste collection methods are the same for all types of waste" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=2.47, SD=1.24, median = 3.

My interpretation is following, the mean score of 2.47 indicates that, on average, respondents tend to disagree to a moderate extent that pharmaceutical waste collection methods are the same for all types of waste. The median score of 3 further supports this conclusion, as it falls on the disagree end of the scale.

The standard deviation of 1.24 indicates that the responses were somewhat varied, with some respondents strongly disagreeing while others agreeing with the statement. This suggests that there may be some disagreement or uncertainty among respondents regarding the homogeneity of pharmaceutical waste collection methods.

Overall, the survey results suggest that most respondents tend to disagree that pharmaceutical waste collection methods are the same for all types of waste.

Knowledge question [14] "In how far do you agree with the following statements: *I think that*...pharmaceutical waste requires special kind of packaging for waste collection and storage" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.06, SD=1.09, median = 4.

My interpretation is following, the mean score of 4.06 indicates that, on average, respondents tend to agree to a moderate extent that pharmaceutical waste requires special kinds of packaging for waste collection and storage. The median score of 4 further supports this conclusion, as it falls on the agree end of the scale.

The standard deviation of 1.09 indicates that the responses were somewhat varied, with some respondents strongly agreeing while others strongly disagreeing with the statement. This suggests that there may be some disagreement or uncertainty among respondents regarding the need for special packaging for pharmaceutical waste.

Overall, the most respondents tend to agree that pharmaceutical waste requires special kinds of packaging for waste collection and storage.

Knowledge question [15] "In how far do you agree with the following statements: *I think that*...the most important stage of pharmaceutical waste management is collection from public and hospitals" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.28; SD=0.95; median = 5.

My interpretation is following, the mean score of 4.28 indicates that, on average, respondents tend to agree to a moderate extent that the most important stage of pharmaceutical waste management is collection from the public and hospitals. The median score of 5 further supports this conclusion, as it falls on the fully agree end of the scale.

The standard deviation of 0.95 indicates that the responses were somewhat consistent, with most respondents falling within a relatively narrow range of agreement. This suggests that there may be broad consensus among respondents regarding the importance of collection as a key stage in pharmaceutical waste management.

Overall, the most respondents tend to agree that collection from the public and hospitals is the most important stage of pharmaceutical waste management.

Knowledge question [16] "In how far do you agree with the following statements: *I think that...*collection of pharmaceutical waste is done by licensed firms" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=3.74; SD=1.09; median = 4.

My interpretation is following, the mean score of 3.74 indicates that, on average, respondents tend to somewhat agree that collection of pharmaceutical waste is done by licensed firms. The median score of 4 further supports this conclusion, as it falls on the agree end of the scale.

The standard deviation of 1.09 indicates that the responses were somewhat varied, with some respondents strongly agreeing while others strongly disagreeing with the statement. This suggests that there may be some disagreement or uncertainty among respondents regarding whether licensed firms are responsible for collecting pharmaceutical waste or not.

Overall, the most respondents tend to agree that collection of pharmaceutical waste is done by licensed firms.

Knowledge question [17] "In how far do you agree with the following statements: *I think that*... incineration of pharmaceutical waste reduces pharmaceutical active ingredients (API) content in aquatic environment and negatively influence on fish, daphnia, algae etc." survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=3.89; SD=1.04; median = 4.

My interpretation is following, the mean score of 3.89 indicates that, on average, respondents tend to somewhat agree that incineration of pharmaceutical waste reduces active pharmaceutical ingredients (API) content in aquatic environment and negatively influences fish, daphnia, algae, etc. The median score of 4 further supports this conclusion, as it falls on the agree end of the scale.

The standard deviation of 1.04 indicates that the responses were somewhat varied, with some respondents strongly agreeing while others strongly disagreeing with the statement. This suggests that there may be some disagreement or uncertainty among respondents regarding the impact of incineration of pharmaceutical waste on the aquatic environment.

Overall, the most respondents tend to agree that incineration of pharmaceutical waste reduces API content in the aquatic environment and negatively affects aquatic organisms.

Knowledge question [18] "In how far do you agree with the following statements: *I think that...*incineration of pharmaceutical waste increases energy consumption" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=3.2; SD=1.2; median = 3.

My interpretation is following, the mean score of 3.2 indicates that, on average, respondents tend to somewhat agree that incineration of pharmaceutical waste increases energy consumption. The median score of 3 further supports this conclusion, as it falls on the somewhat agree end of the scale.

The standard deviation of 1.2 indicates that the responses were somewhat varied, with some respondents strongly agreeing while others strongly disagreeing with the statement. This suggests that there may be some disagreement or uncertainty among respondents regarding the impact of incineration of pharmaceutical waste on energy consumption.

Overall, the most respondents tend to agree that incineration of pharmaceutical waste increases energy consumption.

Knowledge question [19] "In how far do you agree with the following statements: *I think that...*incineration and collection of pharmaceutical waste creates jobs for people" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=3.56; SD=0.95; median = 3.

My interpretation is following, the mean score is 3.56, which indicates a moderate agreement among the respondents. The standard deviation is 0.95, which is relatively low, suggesting that the responses are clustered around the mean. The median score of 3 also confirms that most respondents agreed to some extent with the statement.

Based on this data, we can conclude that a significant proportion of the respondents believe that incineration and collection of pharmaceutical waste creates jobs for people.

Knowledge question [20] "In how far do you agree with the following statements: *I think that...*incineration of pharmaceutical waste factories should have special filtration system" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.43; SD=0.84; median = 5.

My interpretation is following, the participants generally agreed that incineration of pharmaceutical waste factories should have a special filtration system, as evidenced by the high mean (4.43), median (5), and relatively low standard deviation (0.84). This suggests a high level of agreement among the participants on this statement. Therefore, it can be concluded that most participants recognize the importance of having a special filtration system in incineration of pharmaceutical waste factories.

Knowledge question [21] "In how far do you agree with the following statements: *I think that...*incineration of pharmaceutical waste is done by licensed plants at the approximately 1000 degree of Celsius" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=3.39; SD=0,83; median = 3.

My interpretation is following, the mean score of 3.39 indicates that the respondents are slightly leaning towards agreement that incineration of pharmaceutical waste is done by licensed plants at approximately 1000 degrees Celsius. However, the median score of 3 suggests that there is a significant number of respondents who either disagree or are neutral on this statement. The standard deviation of 0.83 indicates that there is moderate variability in the responses.

Overall, it can be concluded that while there is some level of agreement that licensed plants incinerate pharmaceutical waste at around 1000 degrees Celsius,

there are also a considerable number of respondents who are either uncertain or disagree with this statement.

Knowledge question [22] "In how far do you agree with the following statements: *I think that...*pharmacies are obliged to take-back pharmaceutical waste from public" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.66; SD=0.77; median = 5.

My interpretation is following, the mean score of 4.66 and median score of 5 indicate that most of the survey respondents agree that pharmacies are obliged to take-back pharmaceutical waste from the public. The standard deviation of 0.77 shows that the responses were relatively consistent and not widely dispersed.

This result aligns with the concept of extended producer responsibility (EPR), which involves the responsibility of manufacturers, importers, and retailers to manage the waste generated from their products. In many countries, pharmacies are considered as retailers of pharmaceuticals and are therefore responsible for the take-back of pharmaceutical waste from the public. Overall, the respondents recognize the importance of pharmacies in the proper management of pharmaceutical waste.

Knowledge question [23] "In how far do you agree with the following statements: *I think that...*pharmaceutical waste bins are not reachable by public because of security measures" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.11; SD=1.15; median = 5.

My interpretation is following, the mean score of 4.11 indicates that, on average, respondents tend to agree that pharmaceutical waste bins are not reachable by the public due to security measures. The median score of 5, which is the highest possible score, suggests that most respondents agreed with the statement. The standard deviation of 1.15 is relatively high, indicating a wide range of responses. Overall, the result suggests that respondents believe that pharmaceutical waste bins are not easily accessible to the public due to security concerns.

Knowledge question [24] "In how far do you agree with the following statements: *I think that*...I evaluate my knowledge about pharmaceutical waste problem" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=3.25; SD=1.2; median = 3.

My evaluation is following, the mean score of 3.25 suggests that the respondents neither fully agree nor fully disagree with the statement, but rather have a moderate level of agreement. The standard deviation of 1.2 indicates that there was a fair amount of variability in the responses, suggesting that some respondents may feel more confident in their knowledge than others. The median score of 3 falls in line with the mean and suggests that most respondents have a moderate level of knowledge about pharmaceutical waste problem, but there is some variability in their responses.

Based on the survey results, I could define the following three major groups of respondents:

- Well-informed respondents: These are respondents who scored consistently high on most of the questions, indicating a good level of knowledge on pharmaceutical waste management. They are likely to have a good understanding of the issue and may have experience working in the healthcare industry, environmental field, or waste management sector.
- Moderately informed respondents: These are respondents who scored moderate to high on some questions, but also scored low on others. They may have a general understanding of the issue but lack specific knowledge on certain aspects of pharmaceutical waste management.

- Poorly informed respondents: These are respondents who consistently scored low on most of the questions, indicating a lack of knowledge on pharmaceutical waste management. They may have limited exposure to the issue or may not have an interest in environmental or healthcare topics.

If I consider, the total number of the survey participants I could identify the approximate groups number:
Low knowledge: 20% (approximately 28 participants)
Moderate knowledge: 60% (approximately 86 participants)
High knowledge: 20% (approximately 28 participants)

It is interesting to note that, the highest score is Question [5]: "I know what to do with expired medicines" (mean=4.8) but at the same time the lowest score Question [16]: "I evaluate my knowledge about pharmaceutical waste problem" (mean=3.25). How can my perspective contribute to the discussion of the conflicting results? On one hand, respondents demonstrate good knowledge about the subject, but on the other hand, they rate their knowledge at a low level.

This difference between Question [16] and Question [5] could be attributed to a phenomenon known as the Dunning-Kruger effect. The Dunning-Kruger effect is a cognitive bias where people with low ability in a particular subject overestimate their competence and knowledge, while those with a high level of ability in the same subject tend to underestimate their competence and knowledge.

In the case of the survey, it's possible that respondents have a general awareness of what they should do with pharmaceutical waste, but when asked to evaluate their knowledge specifically, they may feel uncertain or lack confidence in their understanding of the subject matter. On the other hand, respondents who scored high on Question [5] may be more aware of the complexity and nuances of the issue, and therefore more likely to rate their knowledge lower because of recognizing their own limitations and potential blind spots.

Another explanation could be that respondents are aware of the general issue of pharmaceutical waste management but may not be aware of all the specifics and details, which is reflected in their lower rating of their knowledge level on Question [16]. This could be due to a lack of information or education on the topic.

Section "Knowledge" conclusion

The survey results suggest that there is a need for increased education and awareness campaigns to inform the public about the importance of proper pharmaceutical waste disposal. The study found that while most participants were aware of the harmful effects of pharmaceutical waste on the environment, a significant portion were not aware of the legal requirements for disposal and the potential consequences of improper disposal. This highlights the importance of targeted education and awareness-raising campaigns to improve knowledge about the issue.

In terms of motivating people to dispose of their waste properly, the survey results suggest that environmental and personal responsibility motivations were more effective than convenience and rewards/incentives. However, further research is needed to determine the most effective strategies for encouraging proper disposal, including the use of rewards or incentives.

Based on the survey results, there are several areas that could be focused on to improve pharmaceutical waste collection. These include improving education and awareness, increasing accessibility and convenience, and offering incentives and rewards to motivate individuals to properly dispose of their waste. A multi-faceted approach that addresses these areas may be most effective in improving pharmaceutical waste collection and reducing the potential negative impact on the environment and public health.

In addition to the areas for improvement mentioned above, there may also be opportunities for collaboration between healthcare providers, pharmacies, and government agencies to improve pharmaceutical waste collection. For example, pharmacies and healthcare facilities could provide more information and resources to patients on how to properly dispose of their medication, while government agencies could provide funding for the expansion of collection sites and educational campaigns.

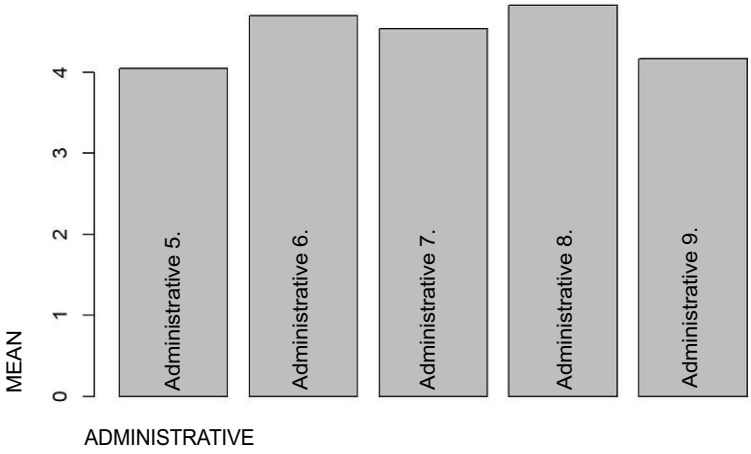
It is important to note that the issue of pharmaceutical waste disposal is not limited to just one country or region. This is a global issue that requires cooperation and collaboration on an international scale. By sharing best practices and working together, it may be possible to develop more effective strategies for improving pharmaceutical waste collection and reducing its negative impact on the environment and public health.

Overall, the survey results provide valuable insights into the knowledge and motivations of individuals when it comes to proper disposal of pharmaceutical waste. Addressing the areas for improvement and implementing a multi-faceted approach can lead to progress in the collection and management of pharmaceutical waste. This will not only benefit the environment and public health, but also promote a culture of responsibility and sustainability.

This section study highlights the importance of addressing knowledge gaps and identifying effective motivators to improve pharmaceutical waste collection. The findings can inform the development of targeted interventions to improve disposal practices and promote environmental sustainability.

The section survey results can also have a significant impact on the end-of-life management of pharmaceutical products. The proper disposal of pharmaceutical waste is just one aspect of a broader issue of managing products at the end of their life cycle. The survey findings can inform the development of effective strategies for managing pharmaceutical products at the end of their useful life, such as implementing take-back programs or encouraging responsible disposal through education and awareness campaigns. By identifying areas where such campaigns could be improved, regulators can better inform the public about the importance of proper disposal and encourage compliance with legal requirements. This can lead to more effective end-of-life management of pharmaceutical products and reduce their potential negative impact on the environment and public health.

4.3. Section "Administrative" survey result



Graph 4

ADMINISTRATIVE [5]. In how far do you agree with the following statements: *I think that...*governments should financially support the incineration and collection of pharmaceutical waste]
ADMINISTRATIVE [6]. In how far do you agree with the following statements: *I think that...*awareness should be raised in society about environmental problems caused by pharmaceutical waste inappropriate disposal]
ADMINISTRATIVE [7]. In how far do you agree with the following statements: *I think that...*education provided in schools is important in developing pharmaceutical waste awareness]
ADMINISTRATIVE [8]. In how far do you agree with the following statements: *I think that…*pharmacies should provide an information about pharmaceutical waste take-back rules]
ADMINISTRATIVE [9]. In how far do you agree with the following statements*: I think that...*societies do not have the required level of information about pharmaceutical waste]

Administrative question [5] "In how far do you agree with the following statements*: I think that...*governments should financially support the incineration and collection of pharmaceutical waste " survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.04; SD=1.19; median = 5.

My evaluation is following, the mean score of 4.04 indicates that the respondents, on average, agreed that governments should financially support the incineration and collection of pharmaceutical waste. The median score of 5 also indicates that more than half of the respondents strongly agreed with this statement.

The standard deviation of 1.19 suggests that there was some variability in the responses, with some respondents strongly agreeing while others were more neutral or disagreed. Overall, the result suggests that there is support for the idea of government involvement in the incineration and collection of pharmaceutical waste.

Administrative question [6] "In how far do you agree with the following statements: *I think that...*education provided in schools is important in developing pharmaceutical waste awareness" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.7; SD=0.68; median = 5.

My evaluation is following, the mean score of 4.7 indicates that the respondents, on average, strongly agreed that education provided in schools is important in developing pharmaceutical waste awareness. The median score of 5 also indicates that more than half of the respondents strongly agreed with this statement. The relatively low standard deviation of 0.68 suggests that there was relatively little variability in the responses, with most respondents agreeing strongly with the statement.

Overall, the result strongly supports the idea that education provided in schools can play an important role in developing pharmaceutical waste awareness.

Administrative question [7] "In how far do you agree with the following statements: *I think that...*awareness should be raised in society about environmental problems caused by pharmaceutical waste inappropriate disposal" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.54; SD=0.76; median = 5.

My evaluation is following, the mean score of 4.54 indicates that the respondents, on average, strongly agreed that awareness should be raised in society about environmental problems caused by pharmaceutical waste inappropriate disposal. The median score of 5 also indicates that more than half of the respondents strongly agreed with this statement. The standard deviation of 0.76 suggests that there was some variability in the responses, with some respondents strongly agreeing while others were more neutral or less certain.

Overall, the result strongly supports the idea that there is a need to raise awareness in society about the environmental problems caused by pharmaceutical waste inappropriate disposal.

Administrative question [8] "In how far do you agree with the following statements**:** *I think that...* pharmacies should provide an information about pharmaceutical waste take-back rules" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.83; SD=0.43; median = 5.

My evaluation is following, the mean score of 4.83 indicates that the respondents, on average, strongly agreed that pharmacies should provide information about pharmaceutical waste take-back rules. The median score of 5 also indicates that more than half of the respondents strongly agreed with this statement. The relatively low standard deviation of 0.43 suggests that there was relatively little variability in the responses, with most respondents strongly agreeing with the statement.

Overall, the result strongly supports the idea that pharmacies should provide information about pharmaceutical waste take-back rules. This information can help to ensure that patients and consumers are aware of proper disposal methods and can reduce the amount of pharmaceutical waste that ends up in the environment.

Administrative question [9] "In how far do you agree with the following statements: *I think that...*societies do not have the required level of information about pharmaceutical waste" survey result: The scale ranges from 5 - fully agree - to 1 fully disagree, is mean=4.17; SD=1.02; median = 5.

My evaluation is following, the mean score of 4.17 indicates that the respondents, on average, agreed that societies do not have the required level of information about pharmaceutical waste. The median score of 5 also indicates that more than half of the respondents agreed with this statement. The standard deviation of 1.02 suggests that there was some variability in the responses, with some respondents strongly agreeing while others were more neutral or disagreed.

Overall, the result suggests that there is some agreement among respondents that societies do not have sufficient information about pharmaceutical waste. This lack of information can contribute to inappropriate disposal and other environmental problems.

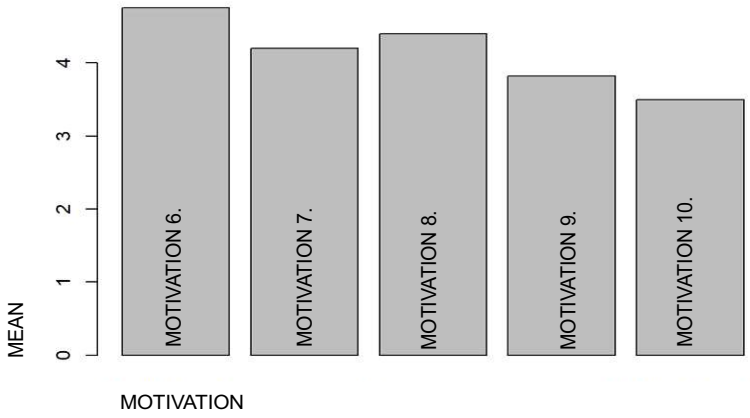
Section "Administrative" summary.

The survey results highlight the importance of addressing the issue of pharmaceutical waste and the need for increased education and awareness. It is encouraging to see that respondents recognize the need for government involvement in addressing this issue and believe that schools and pharmacies have a role to play in providing information and take-back rules. One interesting finding is the need for more education and information on proper disposal methods. This suggests that current efforts may not be sufficient in reducing the amount of pharmaceutical waste that ends up in the environment. As a student, I believe that more education on this issue could be integrated into healthcare curriculums to ensure that future healthcare professionals are equipped with the knowledge and skills to address this issue.

The support for government involvement in the incineration and collection of pharmaceutical waste is also noteworthy. Governments could play a significant role in implementing policies and initiatives aimed at reducing the negative impact of pharmaceutical waste on the environment.

Overall, the survey results provide valuable insights that can inform policies and initiatives aimed at addressing the issue of pharmaceutical waste. For future healthcare professionals, it their responsibility to act on this issue and work towards reducing the negative impact of pharmaceutical waste on the environment.

4.4. Section "Motivation" survey results



Graph 5

MOTIVATION [6]. What would motivate you most to bring pharmaceutical waste to a collection point? [Environmental concerns: Proper disposal of pharmaceutical waste helps to protect the environment and prevent contamination of soil and water sources]
MOTIVATION [7]. What would motivate you most to bring pharmaceutical waste to a collection point? [Legal requirements: In many jurisdictions, it is illegal to dispose of pharmaceutical waste in regular trash or down the drain. Collection points provide a legal and safe way to dispose of these materials]
MOTIVATION [8]. What would motivate you most to bring pharmaceutical waste to a collection point? [Personal responsibility: Some people may feel a sense of personal responsibility to dispose of their waste properly and do their part to protect the environment]
MOTIVATION [9]. What would motivate you most to bring pharmaceutical waste to a collection point? [Convenience: Collection points are often located in convenient locations, making it easy for people to drop off their pharmaceutical waste]
MOTIVATION [10]. What would motivate you most to bring pharmaceutical waste to a collection point? [Rewards or incentives: Some collection programs may offer rewards or incentives to encourage people to bring in their waste]

Motivation question [6] Environmental concerns: Proper disposal of pharmaceutical waste helps to protect the environment and prevent contamination of soil and water sources. The scale ranges from 5 - fully agree to 1 fully disagree. Survey result is mean=4.76, SD=0.63, median = 5.

My evaluation is following, it looks like most of the people who took the survey agree that getting rid of medicine waste the right way is important to keep the environment safe and make sure our soil and water do not get messed up. The average score of 4.76 shows that a lot of people agree with this idea. The middle score of 5 means that most people agree too. The standard deviation of 0.63 means that some people had different opinions, but mostly everyone was on the same page. Overall, the survey shows that most people really believe it's important to dispose of medicine waste properly to keep our environment safe.

Motivation question [7] Legal requirements: In many jurisdictions, it is illegal to dispose of pharmaceutical waste in regular trash or down the drain. Collection points provide a legal and safe way to dispose of these materials. The scale ranges from 5 - fully agree to 1 fully disagree. Survey result is mean=4.20, SD=1.12, median = 5.

My interpretation is following, most people who took the survey think it's important to get rid of medicine waste in a safe and legal way, like using collection points. The average score of 4.20 shows that lots of people agree, but there were some who didn't agree as much or were unsure, which is shown by the higher standard deviation of 1.12. But even with some differing opinions, the middle score of 5 tells us that most people still think it's important. So, it seems like most people know that it's necessary to follow the rules and use collection points to dispose of medicine waste properly.

Motivation question [8] Personal responsibility: Some people may feel a sense of personal responsibility to dispose of their waste properly and do their part to protect the environment. The scale ranges from 5 - fully agree to 1 fully disagree. Survey result is: mean=4.40, SD=0.88, median = 5.

My interpretation is following, most people who took the survey think it's their own responsibility to dispose of waste in a way that helps the environment. The average score of 4.40 shows that lots of people agreed with the statement. The middle score of 5 also backs up this idea. Even though some people had different opinions,

as shown by the standard deviation of 0.88, most people agreed with the statement. So, overall, the survey shows that many people feel like it's their job to dispose of waste properly and protect the environment. This means that if we promote responsible waste disposal, it could inspire people to take action to keep the environment safe.

Motivation question [9] Convenience: Collection points are often located in convenient locations, making it easy for people to drop off their pharmaceutical waste. The scale ranges from 5 - fully agree to 1 fully disagree. Survey result is mean=3.82, SD=1.26, median = 4,

My interpretation is following, it seems that the participants of the survey were somewhat neutral on the idea that collection points for pharmaceutical waste are in convenient locations.

The mean score of 3.82 indicates that the participants, on average, were neither in strong agreement nor disagreement with the statement. The standard deviation of 1.26 suggests that there was a wider range of responses, with some participants agreeing or strongly agreeing, while others may have disagreed or strongly disagreed with the statement.

The median score of 4 suggests that many participants were at least somewhat in agreement with the statement.

Overall, it seems like people had different opinions on whether collection points for getting rid of medicine waste are conveniently located. Some people agreed, some people disagreed, and some people were in the middle. So, I can say that people were generally neutral on the idea.

This tells me that if I want to make sure medicine waste is disposed of properly, I might need to make it easier for people by having more collection points or making them easier to get to.

Motivation question [10] Rewards or incentives: Some collection programs may offer rewards or incentives to encourage people to bring in their waste. The scale ranges from 5 - fully agree to 1 fully disagree. Survey result is mean=3.50, SD=1.29, median = 4.

My interpretation is following, it looks like people who took the survey had mixed feelings about offering rewards or incentives to encourage proper disposal of medicine waste. The average score of 3.50 shows that, on average, people were neither really for it nor really against it. The standard deviation of 1.29 tells us that some people were okay with the idea, while others were not so sure about it.

But the middle score of 4 shows us that most people were at least somewhat open to the idea.

Overall, I can say that the survey suggests people had mixed opinions on offering rewards or incentives to encourage proper disposal of medicine waste. However, because most people were at least somewhat open to the idea, it might be a good idea to try offering rewards or incentives to encourage more people to dispose of their medicine waste properly.

Section "Motivation" summary

I could conclude what the survey has found is encouraging proper disposal practices and increasing awareness of the environmental impact of improper disposal can motivate people to change their behavior. Most participants agreed that proper disposal of pharmaceutical waste is important for protecting the environment, and that following legal requirements for proper disposal is also important. This suggests that enforcing legal requirements and raising awareness of the consequences of improper disposal can be effective in encouraging behavior change.

Additionally, I could conclude that promoting personal responsibility and emphasizing the impact of individual actions on the environment can motivate people to dispose of waste properly. In addition to, participants were less sure about the convenience of collection points for disposing of pharmaceutical waste. This implies that adding more collection points or making them easier to access could help promote proper disposal of pharmaceutical waste. Furthermore, many participants were open to using rewards or incentives to encourage proper disposal of pharmaceutical waste. Overall, the survey emphasizes that it is important to address both personal responsibility and external factors in promoting proper disposal practices for pharmaceutical waste.

At the end is I could prioritize the motivation in the survey group from low to high:

Convenience (mean=3.82)
Rewards or incentives (mean=3.50)
Legal requirements (mean=4.20)
Personal responsibility (mean=4.40)
Environmental concerns (mean=4.76)

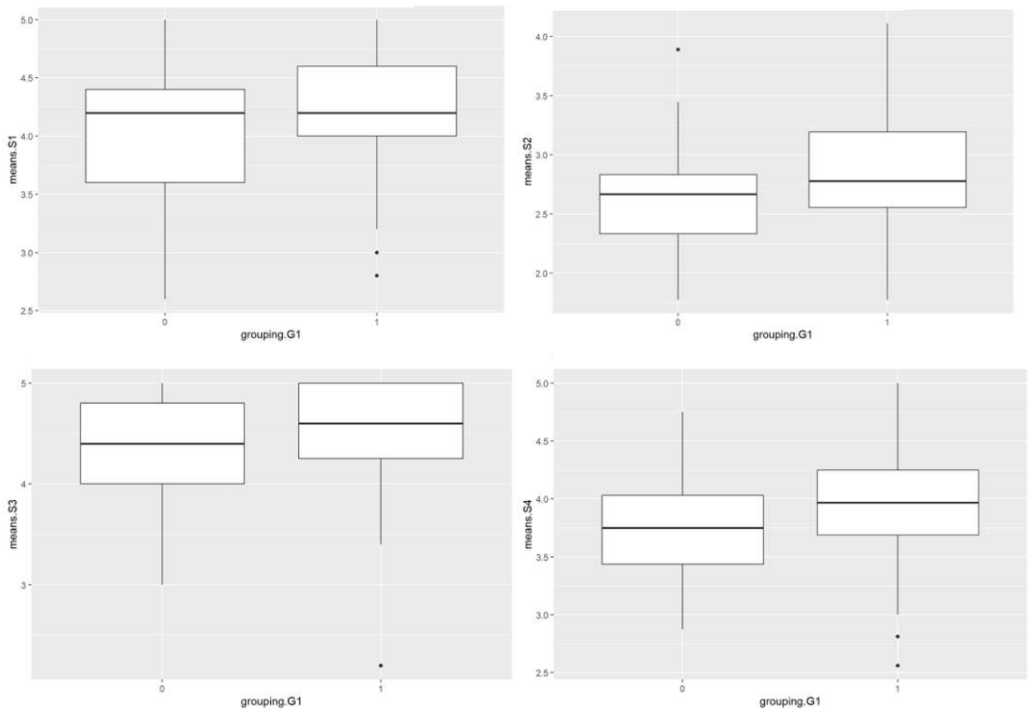
This suggests that the participants in the survey were most motivated by environmental concerns and personal responsibility when it comes to proper disposal of pharmaceutical waste and were less motivated by convenience and the possibility of rewards or incentives. The importance of following legal requirements fell somewhere in the middle.

4.5. Section Groups comprise survey results

In this section, I will now compare the aggregated values of item batteries for motivation, attitude, administration, and knowledge around UEM collection across groups. Specifically, I will compare five different pairs, based on chronological age (0 = young, old = 1; separated at the median age of the sample), gender (0 = female, 1 = male), country (0 = Austria, 1 = Slovakia), parental status (0 = respondent has no children up to 18 years old, 1 = respondent has children up to 18 years old), and existence of chronic illnesses (0 = no chronic illnesses prevalent in the respondent, 1 = chronic illnesses prevalent in the respondent).

Before I present the statistical tests, I want to explain some of the underlying assumptions. Firstly, I want to mention the scales used in this study. The scales are tools that were used to gather information. These scales used a method called formative measurement to collect the data. Secondly, I have checked if the data from all the groups follow a normal distribution by using a statistical test called the Shapiro-Wilk test. A normal distribution means that the data follows a certain pattern that is common in many datasets. Although most of the data follows this pattern ($p > 0.05$), I will use a different statistical test called the Mann-Whitney U-Test instead of the t-Test for all comparisons. This is to maintain consistency across all the comparisons.

Hypothesis 1
Graph H1
Here I compare two groups G1: young participants and participates under 60 years old.
S1 - Motivation; S2 - Attitude; S3 - Administrative; S4 - Knowledge



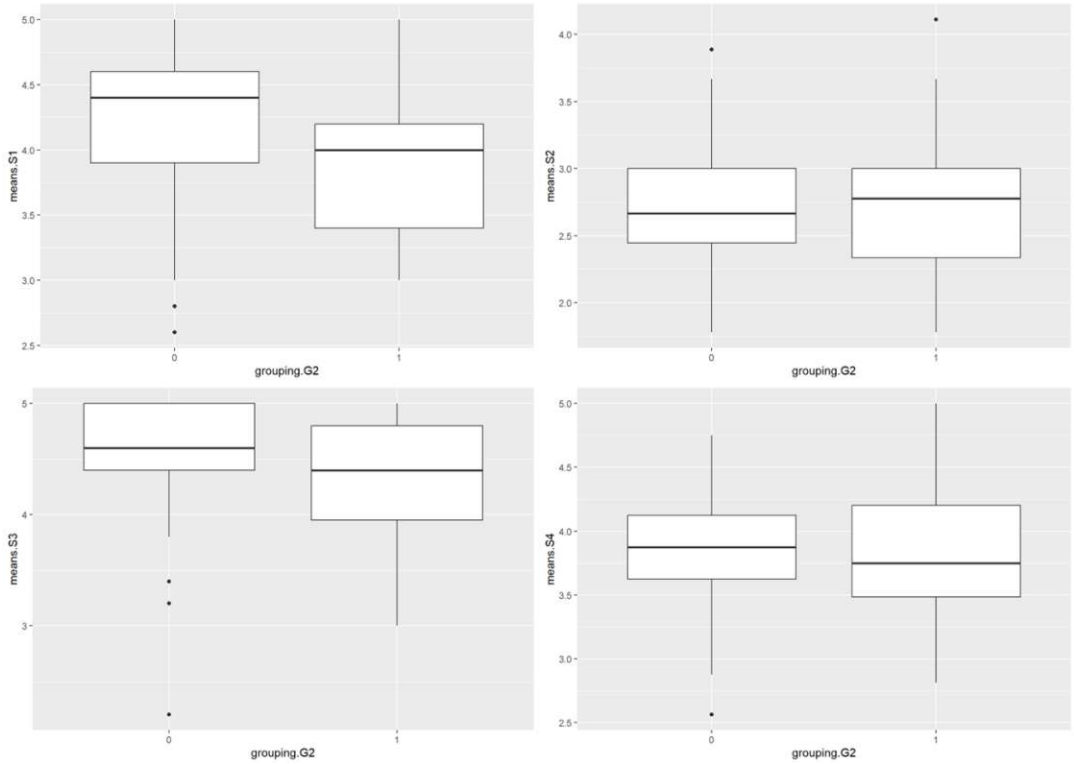
I assumed that, due to the information about the UEM collection usually spread via pharmacies, that suggested that older populations are more likely to consume medication regularly, and as a result, would score higher on all dimensions related to UEM collection (Hypothesis 1 and Graph H1).

Based on the results of the Wilcoxon rank sum tests suggest that there are statistically significant differences in the scores between the two groups (older vs. younger participants) on some dimensions related to UEM collection.

The W values obtained from the tests reflect the sum of the ranks of the observations in the older group. The exact interpretation of the W value may not be as important as the p-value, which indicates the level of significance of the test. The p-values obtained for all four dimensions (Motivation, Attitude, Administrative, and Knowledge) are less than 0.05, indicating that the observed differences in scores between the older and younger participants are unlikely to have occurred by chance.

Therefore, I can conclude that older participants have higher scores in these dimensions related to UEM collection than younger participants, which supports the hypothesis that older populations are more likely to consume medication regularly and are more knowledgeable and experienced in UEM collection than younger populations.

Hypothesis 2
Graph H2
Here I compare two groups G2: female and male participants.
S1 - motivation; S2 - attitude; S3 - administrative; S4 - knowledge



I assumed that there should be differences between female and male participants because women more often visit pharmacies then men, and more regularly consuming medicine products then men and, therefore, will score higher on all dimensions (Hypothesis 2 and Graph H2).

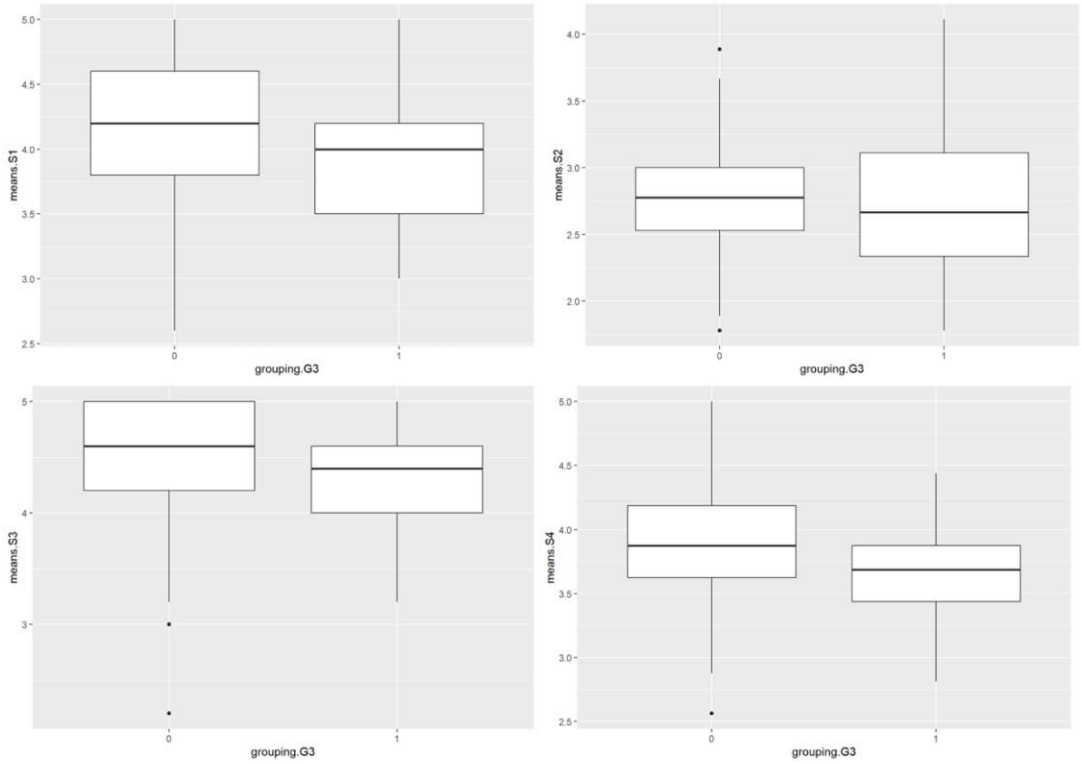
Based on the results, it appears that there are significant differences between female and male participants on two out of the four dimensions. Specifically, the Wilcoxon rank sum tests for motivation and administrative dimensions yielded a statistically significant p-value ($p<0.05$), indicating that there is likely a true connection between female and male participants on these dimensions.

For the motivation dimension, the test statistic $W=3112.5$, which suggests a large difference in medians among the two groups. Similarly, for the administrative dimension, the test statistic was $W=3063$, indicating a relatively large difference in medians.

On the other hand, the tests for the attitude and knowledge dimensions did not yield statistically significant results ($p>0.05$), suggesting that there is likely no connection between female and male participants on these dimensions. The test statistics for these dimensions (2365 and 2515.5, respectively) were also lower than for the motivation and administrative dimensions, indicating smaller differences in medians among the two groups.

This means that, in terms of motivation and administrative aspects of UEM collection and disposal, female participants scored higher than male participants, while there was no significant difference between male and female participants in terms of their attitude towards UEM collection and disposal and their knowledge about it. These results suggest that gender may play a role in shaping people's motivation and administrative behavior related to UEM, but not their attitude or knowledge.

Hypothesis 3
Graph H3
Here I compare two groups G3: Austrian and Slovakian participants.
S1 - Motivation; S2 - Attitude; S3 - administrative; S4 - knowledge



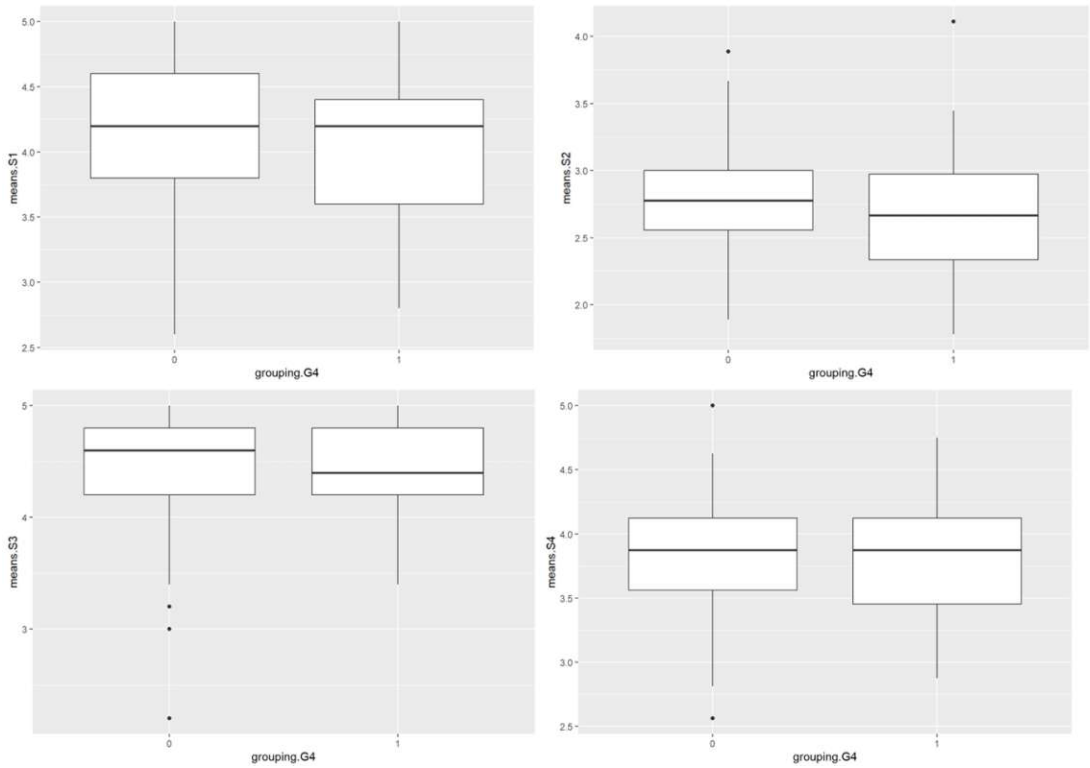
I assumed that there could be difference between Austria and Slovakia consumption behavior due to their cultural, traditional, and regulative differences, on all dimensions related to UEM collection. (Hypothesis 3 and Graph H3).

The output shows the results of Wilcoxon rank sum tests with continuity correction for four variables tested (motivation, administration, knowledge, and attitude).

There is a significant difference between Austria and Slovakia in terms of motivation related to UEM collection (p-value = 0.01505), indicating that the two countries have different levels of motivation to collect UEM. There is a significant difference between Austria and Slovakia in terms of administrative issues related to UEM collection (p-value = 0.0265), indicating that the two countries have different administrative practices when it comes to UEM collection. There is a significant difference between Austria and Slovakia in terms of knowledge related to UEM collection (p-value = 0.006579), indicating that the two countries have different levels of knowledge regarding UEM collection and disposal. There is no significant difference between Austria and Slovakia in terms of attitude related to UEM collection (p-value = 0.5815), indicating that the two countries have similar attitudes towards UEM collection.

Overall, these results suggest that there are cultural, traditional, and regulative differences between Austria and Slovakia that influence UEM collection behavior. While the two countries have similar attitudes towards UEM collection, they differ in terms of motivation, administrative practices, and knowledge.

Hypothesis 4
Graph H4
Here I compare two groups G4: with children up to 18 years old and without one's participants.
S1 - Motivation; S2 - Attitude; S3 - administrative; S4 - knowledge



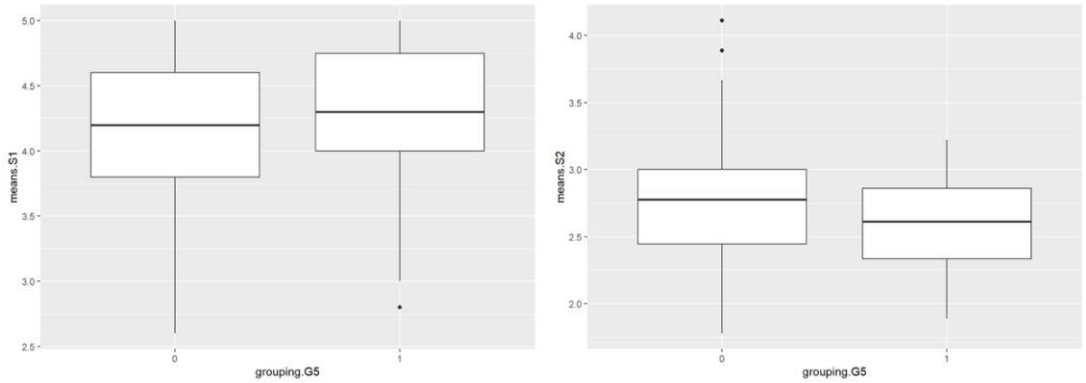
I assumed that participants who have children up to 18 years old, might be more often to visit pharmacies to purchase medication for them, therefore they are more informed about UEM collection and disposal (Hypothesis 4 and Graph H4).

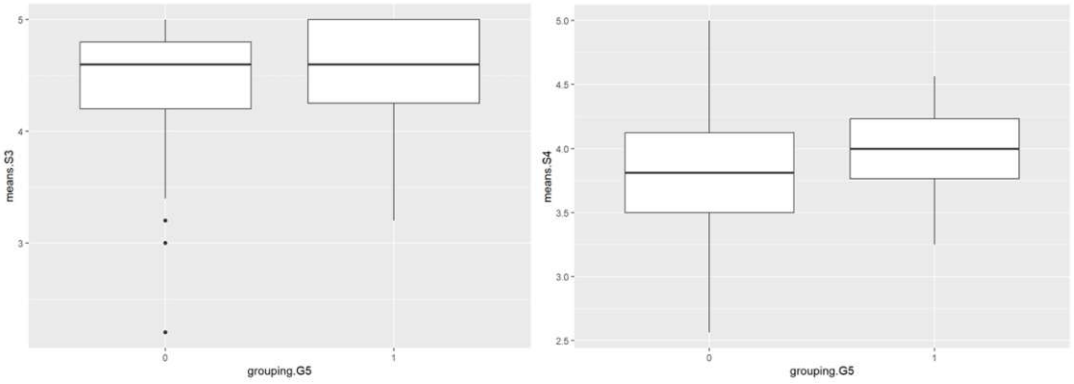
The output shows the results of Wilcoxon rank sum tests with continuity correction for four variables tested (motivation, administration, knowledge, and attitude).

The results show as following variables: motivation: W=2091.5, attitude: W=1912, and administrative=2092 and knowledge=1949.5, in all cases the p-value is greater than 0.05.

Therefore, based on the Wilcoxon rank sum tests, there is no evidence to suggest that there are any significant differences in the scores between the two groups for any of the four variables tested. This means that the hypothesis being tested, which is not explicitly stated, cannot be supported by this analysis.

Hypothesis 5
Graph H5
Here I compare two groups G5: with chronic illnesses and without one's participants.
S1 - Motivation; S2 - Attitude; S3 - administrative; S4 - knowledge





I assumed that participants with chronic illnesses are more acquainted with UEM collection due to their more often visiting pharmacies (Hypothesis 5 and Graph H5).

Based on the Wilcoxon rank sum test results, there is no significant difference between participants with chronic illnesses and those without regarding their motivation, attitude, administrative knowledge, and overall knowledge about UEM collection. The p-values for all four tests are greater than 0.05, which indicates that there is not enough evidence to reject the null hypothesis that there is no difference among the two groups. Therefore, I can conclude that Hypothesis 5 is not supported by the data.

Conclusion of the section Groups comprise

In summary, the study investigated five hypotheses related to the factors influencing UEM collection behavior among participants in Austria and Slovakia. The results showed that older participants had higher scores in UEM collection dimensions compared to younger participants, suggesting that age influences UEM collection behavior. Gender also played a role in shaping UEM collection behavior, with female participants scoring higher in motivation and administrative aspects compared to male participants. However, there was no significant difference in attitude and knowledge among genders. Additionally, the study revealed cultural, traditional, and regulative differences between Austria and Slovakia, which influenced UEM collection behavior.

Furthermore, the analysis indicated that there was no significant difference in UEM collection behavior among participants with chronic illnesses and those without. The p-values for all four variables tested were greater than 0.05, indicating that there was no evidence to reject the null hypothesis that there was no difference among the two groups. Yet, the analysis failed to support a hypothesis that was not explicitly stated. Overall, the study's findings suggest that age, gender, cultural background, and regulatory environment are important factors in influencing UEM collection behavior.

5. THESIS CONCLUSION

In recent years, the concept of a circular economy has gained significant attention as an alternative to the traditional linear economy, which relies on a take-make-dispose model. The circular economy model is designed to reduce waste and pollution by keeping resources in use for as long as possible, through practices such as product longevity and recycling. One key aspect of the circular economy is end-of-life product management, which involves collecting and processing waste materials to prevent them from being discarded in landfills or the environment.

The pharmaceutical industry is an area where effective end-of-life product management is particularly crucial, given the potential environmental and health hazards posed by unused or expired drugs. Proper disposal of pharmaceutical products and packaging is necessary to prevent contamination of waterways and landfills, and incineration is often used as the final stage of pharmaceutical waste management. Nonetheless, incineration is not always environmentally friendly and can lead to air pollution and other negative impacts.

To address these challenges, various organizations and governments are developing new approaches to end-of-life pharmaceutical product management. One such approach involves implementing circular economy principles that prioritize the recovery and reuse of materials in the pharmaceutical supply chain. This strategy can help reduce waste generation and limit the need for incineration. Another critical aspect of sustainable end-of-life product management is waste collection. Effective waste collection is essential in minimizing the environmental impact of pharmaceutical products and reducing the amount of waste that ends up in landfills or incinerators. Proper waste collection and disposal systems must be prioritized to ensure that end-of-life pharmaceutical products are handled in an environmentally friendly and sustainable manner. Innovative approaches, such as product take-back schemes and deposit-refund systems, can help incentivize consumers to participate in waste management and reduce the amount of pharmaceutical waste generated. Waste collection systems should be designed to maximize the collection of recyclable materials and minimize contamination, further reducing the environmental impact of pharmaceutical waste.

Based on the survey results, it was found that there is a lack of awareness and understanding about the proper disposal of pharmaceutical waste among different groups of participants, including their attitudes, knowledge, administrative behaviors, and motivation. While some participants do check the expiration date of medications and return unused or expired medications to a collection point, most participants do not dispose of pharmaceutical waste properly, do not regularly inventory their pharmaceutical waste, and are unsure about their behavior regarding unpacking medicine at home and delivering it to a collection location.

Responders generally recognize the importance of checking the expiration dates of their medication before taking them and have a relatively high level of awareness about the potential harm of improper disposal of pharmaceutical waste. Moreover, responders acknowledge the impact of their pharmaceutical waste on the environment, indicating that people are willing to take responsibility for it.

Environmental and personal responsibility motivations were found to be more effective than convenience and rewards/incentives for motivating people to dispose of their waste properly. Improving education and awareness, increasing accessibility and convenience, and offering incentives and rewards could be focused on to improve pharmaceutical waste collection.

The study investigated five hypotheses related to the factors influencing UEM collection behavior among participants in Austria and Slovakia. The results showed that older participants had higher scores in UEM collection dimensions compared to younger participants, suggesting that age influences UEM collection behavior.

Gender also played a role in shaping UEM collection behavior, with female participants scoring higher in motivation and administrative aspects compared to male participants. Still, there was no significant difference in attitude and knowledge among genders. Additionally, the study revealed cultural, traditional, and regulative differences between Austria and Slovakia, which influenced UEM collection behavior. Furthermore, the analysis indicated that there was no significant difference in UEM collection behavior among participants with chronic illnesses and those without. The p-values for all four variables tested were greater than 0.05, indicating that there was no evidence to reject the null hypothesis that there was no difference between the two groups. However, the analysis failed to support a hypothesis that was not explicitly stated. Overall, the study's findings suggest that age, gender, cultural background, and regulatory environment are important factors in influencing UEM collection behavior

Take also into account that according survey the connivance of the point of collections and the unpacking of pharmaceutical waste did not have a significant impact on the decisions of participants to bring their waste for the collection.

The survey also highlights the need for government involvement, and the role of schools and pharmacies in providing information and take-back rules. It is encouraging to see that participants recognize the need for proper disposal methods, suggesting that current efforts may not be sufficient in reducing the amount of pharmaceutical waste that ends up in the environment. Improving education and awareness campaigns to inform the public about the importance of proper pharmaceutical waste disposal is needed. While most participants were aware of the harmful effects of pharmaceutical waste on the environment, a significant portion were not aware of the legal requirements for disposal and the potential consequences of improper disposal. The survey results suggest that a multi-faceted approach that addresses education and awareness, accessibility and convenience, and incentives and rewards may be most effective in improving pharmaceutical waste collection and reducing the potential negative impact on the environment and public health.

Overall, the survey results provide valuable insights that can inform policies and initiatives aimed at addressing the issue of pharmaceutical waste. To address this issue, it may be necessary to increase public awareness and education about the proper disposal of pharmaceutical waste. This could include providing information about the environmental impact of pharmaceutical waste and the importance of returning unused or expired medications to a collection point

6. LIST OF ACRONYMS

UEM - Unneeded or expired medication
DFD - Design for Disassembly
DFA - Design for Assembly
DFR - Design for Recycling
DfES - Design for Environment and Sustainability
C&D - Construction and demolition
NGO - Non-governmental organization
SME - Small and Mid-size organization
GW - Gypsum waste
WRAP - The Waste Resources Action Program
DEFRA - Department for Environment Food and Rural Affairs
LCDs - Liquid Crystal Displays
CRTs - Cathode Ray Tubes
WEEE - Waste Electrical and Electronic Equipment
ICT - Information and communication technology
R&D - Research and development
EEA - European Environment Agency, https://www.eea.europa.eu
DFX - Design For X
API - Active Pharmaceutical Ingredients
BMW - Biomedical Waste Rules
UNEP - United Nations Environment Program
PCDDs - Dioxins
EPR -The Extended Producer Responsibility
OECD - Economic Co-operation and Development
TFEU - Treaty on the Functioning of the European Union
FASS - The Pharmaceutical Industry Association's Service AB, Stockholm
POPs - Persistent Organic Pollutants
MPC - Centralized Model Predictive Control

7. LINKS

Published papers:

Alcalde-Calonge, F. J., Sáez-Martínez, P., & Ruiz-Palomino. (2022). Evolution of research on circular economy and related trends and topics. A thirteen-year review. Ecological Informatics, 70, 101716. https://doi.org/10.1016/j.ecoinf.2022.101716

Ameli, M., Mansour, S., & Ahmadi-Javid, A. (2019). A simulation-optimization model for sustainable product design and efficient end-of-life management based on individual producer responsibility. Resources, Conservation and Recycling, 140, 246-258. https://doi.org/10.1016/j.resconrec.2018.02.031

Bressanelli, G., Saccani, N., Pigosso, D. C. A., & Perona, M. (2020). Circular Economy in the WEEE industry: a systematic literature review and a research agenda. Sustainable Production and Consumption, 23, 174-188. https://doi.org/10.1016/j.spc.2020.05.007.

Brodin, T., Fick, J., Jonsson, M., & Klaminder, J. (2013). Dilute concentrations of a psychiatric drug alter behavior of fish from natural populations. Science, 339(6121), 814-815. https://doi.org/10.1126/science.1226850.

Christopher J L Murray, Kevin Shunji Ikuta, Fablina Sharara, 2022. Antimicrobial Resistance Collaborators, Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet, 399, 629-655. https://doi.org/10.1016/S0140-6736(21)02724-0.

Czajczyńska, D., Anguilano, L., Ghazal, H., Krzyżyńska, R., Reynolds, A.J., Spencer, N., & Jouhara, H. (2017). Potential of pyrolysis processes in the waste management sector. Thermal Science and Engineering Progress, 3, 171-197. https://doi.org/10.1016/j.tsep.2017.06.003.

Dias, P., Machado, A., Huda, N., & Bernardes, A. M. (2018). Waste electric and electronic equipment (WEEE) management: A study on the Brazilian recycling routes. Journal of Cleaner Production, 174, 7-16. https://doi.org/10.1016/j.jclepro.2017.10.219

Dar, M. A., Maqbool, M., & Rasool, S. (2019). Pharmaceutical wastes and their disposal practice in routine. International Journal of Information and Computing Science, ISSN NO: 0972-1347. https://www.researchgate.net/publication/332275215_Pharmaceutical_Wastes_and_their_disposal_practice_in_routine

van Ewijk, S. (2018). Resource efficiency and the circular economy: Concepts, economic benefits, barriers, and policies (EV0276). UCL Institute for Sustainable Resources. https://www.researchgate.net/publication/327868697_Resource_efficiency_and_the_circular_economy_Concepts_economic_benefits_barriers_and_policies

G Ya Gerasimov 2019 IOP Conf. Ser.: Earth Environ. Sci. 272 022116 https://iopscience.iop.org/article/10.1088/1755-1315/272/2/022116/pdf

Hipólito, T., Nabais, J. L., Botto, M. A., & Negenborn, R. R. (2020). Effective Continuous-flow Supply Chains Using Centralized Model Predictive Control. IFAC-PapersOnLine, 53(2), 10855-10860. https://doi.org/10.1016/j.ifacol.2020.12.2808

Jiménez-Rivero, A., & García-Navarro, J. (2017). Best practices for the management of end-of-life gypsum in a circular economy. Journal of Cleaner Production, 167, 1335-1344. https://doi.org/10.1016/j.jclepro.2017.05.068

Jaseem, M., Kumar, P., & John, R. M., 2017. An overview of waste management in pharmaceutical industry. International Journal of Research in Pharmaceutical Sciences, 6(3), 174-179. Retrieved from https://www.thepharmajournal.com/archives/2017/vol6issue3/PartC/6-2-9-174.pdf

Law, A. V., Sakharkar, P., Zargarzadeh, A., Tai, B. W. B., Hess, K., Hata, M., Mireles, R., Ha, C., & Park, T. J. (2015). Taking stock of medication wastage: Unused medications in US households. Research in Social and Administrative Pharmacy, 11(4), 571-578. https://doi.org/10.1016/j.sapharm.2014.10.003

Mitkidis, K., Obolevich, V., Chrysochou, P., & Mitkidis, P. (2021). Harmonisation of Pharmaceutical Take-Back Systems in the EU, European Journal of Health Law, 28(5), 445-471. doi: https://doi.org/10.1163/15718093-bja10051

Elia, Maha, "Design for Circular Economy" (2019). Electronic Theses and Dissertations. 8163. https://scholar.uwindsor.ca/etd/8163

Nash, J. P., Kime, D. E., Van der Ven, L. T. M., Wester, P. W., Brion, F., Maack, G., Stahlschmidt-Allner, P., & Tyler, C. R. (2004). Long-term exposure to environmental concentrations of the pharmaceutical ethynylestradiol causes reproductive failure in fish. Environmental Health Perspectives, 112(17), 1725-1733. https://doi.org/10.1289/ehp.7209

Most, M. (2018). Designing for a circular economy - Exploring how service system design approach can support the transition towards a circular economy in Amager East. Master's thesis, Aalborg University in Copenhagen https://projekter.aau.dk/projekter/files/287516332/process_report_monikamost.pdf

Mohammed, S.A., Kahissay, M.H., & Hailu, A.D. (2021). Pharmaceuticals wastage and pharmaceuticals waste management in public health facilities of Dessie town, North East Ethiopia. PLoS ONE, 16(10), e0259160. https://doi.org/10.1371/journal.pone.0259160

Nyaga, M.N., Nyagah, D.M., & Njagi, A. (2020). Pharmaceutical Waste: Overview, Management, and Impact of Improper Disposal. Preprints, 2020100245. https://www.preprints.org/manuscript/202010.0245/v1

O'Grady, T., Minunno, R., Chong, H.-Y., & Morrison, G. M. (2021). Design for disassembly, deconstruction, and resilience: A circular economy index for the built environment. Resources, Conservation and Recycling, 175, 105847. https://doi.org/10.1016/j.resconrec.2021.105847

Martins-Rodrigues, M. C., Barbieri da Rosa, L. A., Sousa, M. J., & Godoy, T. P. (2020). Research topics in circular economy. International Journal of Engineering and Management Sciences, 5(1), 1-9. https://www.iaras.org/iaras/filedownloads/ijems/2020/007-0001(2020).pdf

Shah, Y., Rajbongshi, S., & Sajib, A. (2016). PHARMACEUTICAL WASTE MANAGEMENT: A REVIEW. European Journal of Biomedical AND Pharmaceutical sciences, 3, 192-206

Trueman, P., Lowson, K., Blighe, A., Meszaros, A., Wright, D., Glanville, J., Taylor, D., Newbould, J., Bury, M., Barber, N., & Jani, Y. (2010). Evaluation of the Scale, Causes and Costs of Waste Medicines: Final Report. York Health Economics Consortium & School of Pharmacy, University of London. ISBN 978 090 293 620 1

Unpublished papers:

Arunprasath, Kalaivani, & R, Lavanya. (2009). A Case Study of Biomedical Waste Management in Hospitals. Global Journal of Health Science. https://www.researchgate.net/publication/41940664_A_Case_Study_of_Biomedical_Waste_Management_in_Hospitals

Alev, I., Atasu, A., Toktay, L. B., & Zhang, C. (2021). Extended producer responsibility for pharmaceuticals. Manufacturing & Service Operations Management, 24(1), 524-541. https://doi.org/10.1287/msom.2020.0962

BIO Intelligence Service. (2013). Study on the environmental risks of medicinal products: Final report prepared for Executive Agency for Health and Consumers. CLIENT Executive Agency for Health and Consumers, CONTRACT NUMBER 2011 61 03

BMJ. (2016, March 1). Overspending driven by oversized single dose vials of cancer drugs. BMJ, 352. https://doi.org/10.1136/bmj.i788

CCL North. (January 2023). WEEE Recycling. Retrieved March 13, 2023, from https://www.cclnorth.com/weee-recycling

CropLife Canada. (2011). Stewardship of discontinued products in Canada: A checklist. https://www.croplife.ca/wp-content/uploads/Stewardship-of-Discontinued-Products-Canada-CHECKLIST.pdf

Corporate Finance Institute. (January 2023.). Harvest strategy. Corporate Finance Institute. https://corporatefinanceinstitute.com/resources/management/harvest-strategy/

Council of the European Union. (2008). Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives [PDF file]. Retrieved March 11, 2023, from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008L0098-20180705&from=SV

Chamberlain, M. 2019, Medical Waste Treatment Methods - Autoclave, Chemical, & More. Daniels Health, from https://www.danielshealth.com/knowledge-center/treatment-medical-waste#:~:text=Chemical%20treatment%20is%20an%20option,be%20available%20at%20every%20facility

Department for Environment, Food and Rural Affairs. (2006). Waste Electrical and Electronic Equipment (WEEE) and Batteries and Accumulators: Guidance on Producer Responsibility Obligations. Website: www.defra.gov.uk. © Crown copyright

2006. Copyright in the typographical arrangement and design rests with the Crown. This publication (excluding the royal arms and departmental logos) may be reused free of charge in any format or medium provided that it is re-used accurately and not used in a misleading context. The material must be acknowledged as crown copyright and the title of the publication specified.

Dusi, E., Rybicki, M., & Jungmann, D. (2019). The database "Pharmaceuticals in the Environment" - Update and new analysis. Final report (Project No. 97778, FB000079). GWT-TUD GmbH. Retrieved from http://www.umweltbundesamt.de/publikationen

Epstein, D. (2023, January 13). Top 15 Inventory Management Solutions. FinancesOnline. https://financesonline.com/top-15-inventory-management-solutions/

European Federation of Pharmaceutical Industries and Associations. (2020). Pharma Figures 2020. Retrieved from https://www.efpia.eu/media/554521/efpia_pharmafigures_2020_web.pdf

European Commission. (2022, October 26). Questions and Answers on the new EU rules on treating urban wastewater. https://ec.europa.eu/commission/presscorner/detail/en/QANDA_22_6281

European Parliament, & Council. (2008). Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006 (Text with EEA relevance). Official Journal of the European Union, L 353, 1-1355

European Commission. (2020). Pharmaceutical Strategy for Europe. Retrieved March 11, 2023, from https://health.ec.europa.eu/system/files/2021-02/pharma-strategy_report_en_0.pdf

Fintech Nexus. (2021, February 2). Climate Change Agenda: Circular Economy. Fintech Nexus. https://news.fintechnexus.com/climate-change-agenda-circular-economy/

FC Business Intelligence Ltd. (2018). The 2018 Supply Chain Study. Retrieved from https://img03.en25.com/Web/FCBusinessIntelligenceLtd/%7Bd4fe8682-c4c2-4bfd-8222-e1a0387febce%7D_4909_2018_Supply_Chain_Report.pdf

FEAM European Biomedical Policy Forum, Federation of Veterinarians of Europe (FVE), & European Federation of Pharmaceutical Industries and Associations (EFPIA). (2022, May 5). Pharmaceuticals in the environment: Summary report. Retrieved from https://www.feam.eu/wp-content/uploads/Pharmaceuticals-in-the-Environment-Summary-report.pdf

FASS, 2021, Läkemedelsfakta, from https://www.fass.se/LIF/menydokument?userType=0&menyrubrikId=2432

Hazardous Waste Experts. (n.d.). Regulated Medical Waste Treatment Methods, 2013, from https://www.hazardouswasteexperts.com/regulated-medical-waste-treatment-methods/

IMI (Innovative Medicines Initiative). (2017). Combating antimicrobial resistance: from research to action. https://www.imi.europa.eu/sites/default/files/uploads/documents/projects/IMI_AMR_2017_LR.pdf

IQVIA. (2020). Global medicines use in 2020: Outlook and implications. IQVIA Institute for Human Data Science. https://www.iqvia.com/-/media/iqvia/pdfs/institute-reports/global-medicines-use-in-2020

Kumar, P. (2016). Bio-Medical Waste Management Rules, 2016: overview, salient features, and implication. Department of Hospital Administration, AIIMS.

Kaisanlahti, A. (2018). New Product Development Cycle Infographic. Haltian. Retrieved from https://haltian.com/resource/new-product-development-cycle-infographic/

Lexparency (March 2023). Article 168 TFEU (Treaty on the Functioning of the European Union, from https://lexparency.org/eu/TFEU/ART_168/

Ministry of Health of the Slovak Republic. (2020). Zneškodňovanie liekov nespotrebovaných fyzickými osobami [Disposal of medicines unused by individuals]. Retrieved from //www.sukl.sk/buxus/docs/Inspekcia/Odpady/MP_105_-_2020_Zneskodnovanie_liekov_nespotrebovanych_fyzickymi_osobami.pdf

Ministerstvo životného prostredia SR. (2014). Metodické usmernenie k zaradzovaniu odpadových liekov. Retrieved from //www.minzp.sk/files/oblasti/odpady-a-obaly/odborno-metodicke-usmernenia/usmernenie-zaradovanie-odpadovych-liekov.pdf

Malsparo, March 2023, Principles of Medical Waste Management, Retrieved from https://www.malsparo.com/principles.htm

OECD (2022), Management of Pharmaceutical Household Waste: Limiting Environmental Impacts of Unused or Expired Medicine, OECD Publishing, Paris, https://doi.org/10.1787/3854026c-en.

OECD. (2018). Stemming the Superbug Tide: Just A Few Dollars More. OECD Health Policy Studies. OECD Publishing. https://doi.org/10.1787/9789264307599-en

Health and Environmental Research Online (HERO). (February 2023). Pharmaceuticals and Personal Care Products (PPCPs). Retrieved March 11, 2023, from https://www.hercenter.org/hazmat/pharma.php

Product Stewardship Institute. (2017, November 13). Awareness Campaign Targets Pharmaceutical Waste in Missouri. https://productstewardship.us/press_releases/awareness-campaign-targets-pharmaceutical-waste-in-missouri/

Austrian Standards International. (2020). ÖNORM S 2104:2020-07-01 - Pharmaceuticals - Collection and disposal of pharmaceutical waste from human medicine [PDF file]. Retrieved from https://www.ris.bka.gv.at/Dokumente/Bundesnormen/NOR40226726/II_409_2020_Anlage_6_OENORM_S_2104.pdf

ResouTech. (February 2023). Intelligent disassembly. https://www.resoutech.com/isl-group/resoutech/intelligent-disassembly/

State of Green. (January 2023). 10 examples of circular economy solutions. Retrieved from https://stateofgreen.com/en/news/10-examples-of-circular-economy-solutions/

Stockholm Convention, 2004

Ellen MacArthur Foundation. (2013). Towards the circular economy: Vol. 1: An economic and business rationale for an accelerated transition. https://emf.thirdlight.com/file/24/xTyQj3oxiYNMO1xTFs9xT5LF3C/Towards%20the%20circular%20economy%20Vol%201%3A%20an%20economic%20and%20business%20rationale%20for%20an%20accelerated%20transition.pdf

UNEP Chemicals. (1999). Dioxin and furan inventories: National and regional emissions of PCDD/PCDF. Geneva, Switzerland.

Viau, B. (2020, October). Examples of Brand Repositioning & Renewed Company Growth. Market Veep. https://blog.marketveep.com/examples-of-brand-repositioning-renewed-company-growth

World Resources Institute. (2017, November 20). 5 Opportunities for the Circular Economy. Retrieved from https://www.wri.org/insights/5-opportunities-circular-economy

WRAP. (2021). WEEE collection guide. Retrieved from https://wrap.org.uk/sites/default/files/2021-04/WEEE-collection-guide-March2021.pdf.pdf)

World Health Organization. (2018, September). Health care waste. Fact Sheet. Retrieved from https://www.who.int/news-room/fact-sheets/detail/health-care-waste#cms

World Health Organization. (1999). Guidelines for Safe Disposal of Unwanted Pharmaceuticals in and after Emergencies. https://apps.who.int/iris/bitstream/handle/10665/42238/WHO_EDM_PAR_99.2.pdf?sequence=1

BOOK
Nelson, H. G., & Stolterman, E. (2012). The Design Way: Intentional Change in an Unpredictable World. MIT Press. https://doi.org/10.7551/mitpress/9188.001.0001

Appendix A

LimeSurvey

Thank you for your interest in this study. This study helps us to understand and define the main challenges of pharmaceutical waste collection. This is important, as improper disposal of pharmaceuticals can have negative impact on the environment and public health. The results of this study will help to derive practical implications for the disposal of pharmaceutical waste within the EU.

The survey will only take you about 5 minutes. All responses remain anonymous; only aggregated data is being analyzed; no individual responses will be investigated.

Section A: About you

A1. Gender

- ☐ female
- ☐ male
- ☐ diverse

A2. Age

☐☐

A3. Where do you live right now?

- ☐ Austria
- ☐ Slovakia
- ☐ Other

Other

A4. Do you have child/children up to 18 years old?

- ☐ Yes
- ☐ No

A5. Do you have any chronic illnesses?

- ☐ Yes
- ☐ No

Section B:

B1. What best describes your attitude to the pharmaceutical waste collection?

	1 - do not agree	2	3	4	5 - fully agree
I check the expiration date only before taking the medicine.	☐	☐	☐	☐	☐
I usually dispose the pharmaceutical waste in (sewage, bins, toilets)	☐	☐	☐	☐	☐
The pharmaceutical waste produced by me as a person is so insignificantly small that I can neglect its impact on the environment	☐	☐	☐	☐	☐
I believe that if I take my medications orally, they shouldn't be harmful to the environment	☐	☐	☐	☐	☐
I consider it is a waste of time and additional costs (parking a car, gasoline, etc.) to hand over pharmaceutical waste to special collection points	☐	☐	☐	☐	☐
I usually visit pharmacies when I or a family member gets sick, and I don't remember bringing pharmaceutical waste at that situation	☐	☐	☐	☐	☐
I do inventory of my pharmaceutical waste regularly during a year	☐	☐	☐	☐	☐
I always return unused or expired medications to my neighborhood pharmacy or another location for collection	☐	☐	☐	☐	☐
I unpack medicine at home and deliver it to a collection location	☐	☐	☐	☐	☐

Section C:

C1. In how far do you agree with the following statements: I think that...

	1 - do not agree	2	3	4	5- fully agree
…governments should financially support the incineration and collection of pharmaceutical waste	☐	☐	☐	☐	☐
...awareness should be raised in society about environmental problems caused by pharmaceutical waste inappropriate disposal	☐	☐	☐	☐	☐
...education provided in schools is important in developing pharmaceutical waste awareness	☐	☐	☐	☐	☐
…pharmacies should provide an information about pharmaceutical waste take-back rules	☐	☐	☐	☐	☐
...societies do not have the required level of information about pharmaceutical waste	☐	☐	☐	☐	☐

Section D:

D1. In how far do you agree with the following statements: I think that...

	1 - do not agree	2	3	4	5- fully agree
...pharmaceutical waste increases environmental pollution	☐	☐	☐	☐	☐
...pharmaceutical waste increases health problems	☐	☐	☐	☐	☐
...pharmaceutical waste transfers of compounds within the food chain	☐	☐	☐	☐	☐
...pharmaceutical waste increases antibiotic resistance level	☐	☐	☐	☐	☐
...pharmaceutical waste collection methods are the same for all types of waste	☐	☐	☐	☐	☐
...pharmaceutical waste requires special kind of packaging for waste collection and storage	☐	☐	☐	☐	☐
...the most important stage of pharmaceutical waste management is collection from public and hospitals	☐	☐	☐	☐	☐
...collection of pharmaceutical waste is done by licensed firms	☐	☐	☐	☐	☐
...incineration of pharmaceutical waste reduces pharmaceutical active ingredients (API) content in aquatic environment and negatively influence on fish, daphnia, algae etc	☐	☐	☐	☐	☐
...incineration of pharmaceutical waste increases energy consumption	☐	☐	☐	☐	☐
...incineration and collection of pharmaceutical waste creates jobs for people	☐	☐	☐	☐	☐
...incineration of pharmaceutical waste factories should have special filtration system	☐	☐	☐	☐	☐
...incineration of pharmaceutical waste is done by licensed plants at the approximately 1000 degree of Celsius	☐	☐	☐	☐	☐
...pharmacies are obliged to take-back pharmaceutical waste from public	☐	☐	☐	☐	☐
...pharmaceutical waste bins are not reachable by public because of security measures	☐	☐	☐	☐	☐
...that I evaluate my knowledge about pharmaceutical waste problem	☐	☐	☐	☐	☐

Section E:

E1. Where would be a convenient place for you to return expired and/or unused medicine?

- Pharmacies ☐
- Doctors ☐
- Nearby stores, gas stations, etc. ☐

Other

Other

E2. **How would you prefer the most to return unused and/or expired medicines? I would rather:**

- hand them over openly
- put them in a bag that isn't transparent
- leave them in a collection box

Section F:

F1. **What would motivate you most to bring pharmaceutical waste to a collection point?**

	1 - do not agree	2	3	4	5- fully agree
Environmental concerns: Proper disposal of pharmaceutical waste helps to protect the environment and prevent contamination of soil and water sources					
Legal requirements: In many jurisdictions, it is illegal to dispose of pharmaceutical waste in regular trash or down the drain. Collection points provide a legal and safe way to dispose of these materials					
Personal responsibility: Some people may feel a sense of personal responsibility to dispose of their waste properly and do their part to protect the environment					
Convenience: Collection points are often located in convenient locations, making it easy for people to drop off their pharmaceutical waste					
Rewards or incentives: Some collection programs may offer rewards or incentives to encourage people to bring in their waste					

F2. **What is your reason to take action?**

F3. **What is your reason to NOT take action?**