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Faculty of Science and Technology

Root Cause Analysis of fire in waste facilities

A case study of Tromsø municipality

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Preface

This master's thesis is submitted to fulfill the Master's degree in Technology and Safety in the High North at UiT – The Arctic University of Norway. This thesis has been carried out in the period from January to May 2021.

I am thankful to all the people who have contributed to this research with their engagement and feedback. Special thanks to my supervisor, Javad Barabady, for his guidance and continuous support through each stage of my work. I also wish to thank Abbas Barabadi, my co-supervisor, for his advice, guidance, and helpful feedback.

I would like to thank Remiks Miljøpark AS and the employees for welcoming me into their office and providing me all the required information and resources. I would also like to express my sincere appreciation to Sigve Daae Rasmussen, the HSE and Quality manager at Remiks Miljø AS, for investing his time and energy in supporting my work.

Abstract

The amount of waste produced in Norway has been increased considerably in the past decades as a result of population and economic growth. Therefore, the role of waste management companies in society has become more important. One of the significant challenges in the waste facilities is the fire that occurs regularly and causes various problems for the waste management companies. Several causes can ignite the fire in waste facilities, such as friction, improper storage of waste, technical and electrical failure, and human error.

This master's thesis investigates the main source of fire and its root causes at Remiks waste facility located in Tromsø municipality in Norway. Fire has become a frequent problem at Remiks waste facility, and a total of 31 fire incidents have been recorded in the past five years. For identifying the main source of fire and its causes at Remiks, historical data of fire incidents at Remiks together with expert judgment are collected and analyzed. All causes of fire at Remiks are identified and classified using the cause-and-effect chart. The identified causes of fire are further analyzed through the Root Cause Analysis to determine the root causes of fire at Remiks. Further, several measures are proposed to reduce the number of fire incidents at Remiks waste facility.

Abbreviations

DSB: Direktoratet for Samfunnssikkerhet og beredskap

EE: Electricals and Electronics

HW: Hazardous waste

HSE: Health, Safety, and Environment

MSW: Municipal Solid Waste

RCA: Root Cause Analysis

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Introduction

In this chapter, brief information about the background, problem statement, the aim and objectives of the thesis, research questions, limitations, and an overview of the structure of the thesis are provided.

1.1 Background

In the European Union Legislation (Council Directive 75/442/EEC on waste), the term waste has been described as “any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force” (Council Directive, 1975). The amount of produced waste in the world has been steadily rising as a result of the growing population and urbanization. The greatest share of the generated waste is from industrial activities, manufacturing processes, and Municipal Solid Waste (MSW) (Kan, 2009). MSW can be explained as “waste durable goods, nondurable goods, containers and packaging, food scraps, yard trimmings, and miscellaneous inorganic wastes from residential, commercial, and industrial sources” (Demirbas, 2011).

Waste management is considered one of the world’s foremost environmental concerns (Demirbas, 2011). Fire in waste facilities is a major problem that occurs frequently, and it has numerous environmental impacts (Mikalsen et al., 2021; Mikalsen et al., 2019). Earlier studies have shown that high emissions levels are produced annually due to the fire in municipal waste (Mikalsen et al., 2021). Moreover, it can usually be challenging to extinguish fires occurring in waste storage facilities. Some of the reasons are that there are several sources of ignition and considerable amounts of fuel available in the waste facilities. Therefore, fire in waste facilities can cause significant pollutions to the environment. It can affect surrounding residential areas and other societal functions due to significant emissions over a long period. So, smoke emissions, as well as a run-off of extinguishing water, can have negative consequences for the environment. (Lönnermark et al., 2008; Mikalsen et al., 2019).

Fire risk management in waste facilities is essential. This is due to the fact that waste facilities represent an essential societal function, and fire in waste facilities can affect the whole society. By avoiding fire, interruptions in production can be avoided both at the waste facilities and nearby businesses. Preventing fire in waste facilities and handling it in a proper manner can also contribute to environmental sustainability with fewer emissions to the air and reduce health consequences for the inhabitants in the neighborhood (Mikalsen et al., 2019).

In Norway, numerous fires in waste facilities have been reported in the past few years (Mikalsen et al., 2019). Therefore, the Norwegian Environment Agency (miljødirektoratet) and the Norwegian Directorate for Civil Protection and Emergency Planning (DSB) cooperate to reduce the number of fires in waste facilities (Mikalsen et al., 2019). Since the requirements for waste facilities in various municipalities or regions can be different in Norway, the same set of requirements and solutions cannot be established for the waste facilities all over Norway. Yet, the aforementioned authorities work on developing safety recommendations that could be utilized in the entire waste industry in Norway (Mikalsen et al., 2021; Mikalsen et al., 2019).

1.2 Problem statement

In Remiks waste facility, fire is a major problem, and it occurs frequently. Fire at Remiks has negative economic impacts on the company, and it exposes the staff to health problems. Fire damages the conveyor belts, raises the costs repairs, and increases the personnel's risk of injuries. Additionally, fire at Remiks represents a challenge for the rescue services and fire departments. However, most of the ignitions are extinguished before creating a major fire. If the fire lasts for a long period, it can release high emissions into the air and affect the surrounding environment. (Remiks, personal communication, 2021).

1.3 Aim and objective of the research

This research aims to provide knowledge about the main source of fire at Remiks waste facility and identify its root causes. Further, it aims to suggest measures to minimize the fire incidents occurring due to the identified root causes at Remiks waste facility.

The objectives of this thesis are to:

- Review the historical data of fire incidents at Remiks and identify the main source of fire
- Provide an understanding of how the identified main source leads to fire at Remiks
- Identify the causes of the main source of fire at Remiks
- Determine the root causes of the main source of fire at Remiks
- Provide suggestions for minimizing the number of fire incidents at Remiks occurring due to the identified root causes

1.4 Research questions

The following research questions are defined to ensure this study is directed toward achieving the aim and objectives of the research:

- What is the main source of fire at Remiks, and what are its causes?
- What are the root causes of the main source of fire at Remiks?
- Which solutions can be implemented to reduce fire incidents at Remiks due to the identified root causes?

1.5 Limitations

The following limitations were set up for this research that was mostly due to limited time and required resources:

- This thesis only focused on investigating the main source of fire at Remiks waste facility and did not analyze the other sources of fire
- The efficiency of extinguishing techniques used at Remiks waste facility is not studied
- The compliance of activities at Remiks regarding fire with the Norwegian laws and regulations are not investigated
- The extent of environmental impacts from the fire at Remiks waste facility is not studied
- While conducting the Delphi method, the questionnaires were sent out to all the experts involved in the research, but only four out of seven experts participated. So, the results of this thesis are based on the opinion of a limited number of experts at Remiks.

1.6 Structure of the thesis

This thesis consists of five chapters: introduction, literature review, methodology, results and discussion, and conclusion and recommendations.

Chapter 2 presents the required theoretical knowledge to understand the methodology in this study. This chapter provides information about waste management, fire in waste facilities, Risk management, and risk assessment techniques.

Chapter 3 describes the methodology in this study and the approach that has been taken to achieve the final results. It presents the various steps taken to conduct the root cause analysis, such as problem understanding, data collection and analysis, root cause identification, root cause determination, and providing recommendations.

Chapter 4 presents the results of the methodology of the thesis and holds a discussion of how this study has answered the research questions. In this chapter, the flow chart of the waste management process at Remiks, the customer survey results, the fishbone diagram for the main source of fire at Remiks, the final results of the Delphi method, and the suggestions and recommendations to be implemented are presented and discussed

Chapter 5 provides a summary of the results of this study and the conclusion made from this thesis. This chapter also includes the suggestions made for future work.

Moreover, the customer surveys and the questionnaires used for conducting the Delphi method are attached in the appendix. The references, including all the sources used throughout this study, are presented in the end.

2 Literature review

This chapter presents information about waste management, fire in waste facilities, risk management, and risk assessment techniques. The information presented in this chapter has been used to conduct the analyses in this research.

2.1 Waste management

Waste management consists of “collection, transport, processing, recycling or disposal, and monitoring of waste materials” (Demirbas, 2011). The aim of waste management is to create sanitary living conditions in order to minimize the amount of waste that enters and leaves society while also encouraging the reuse of waste (Kan, 2009). It also aims to recover resources from waste through biological reprocessing, physical reprocessing, and energy recovery (Demirbas, 2011). The goals of a waste management concept are (Kan, 2009):

- Decrease the total amount of generated waste and recycling produced waste
- Developing suitable categories of substances that can be utilized as the energy carrier or secondary raw material in production cycles
- Re-entering the biological waste into the cycle of nature
- Reducing the total quantities of residual waste which should be disposed on landfills
- Considering the variations in waste quantities and the household waste composition and developing a flexible concept

The waste management system includes the entire set of activities regarding handling, treating, recycling, or disposing of generated waste. The four main components of the waste management system are (Demirbas, 2011):

- Generation or production of waste
- Collection and transportation
- Treating the waste
- Recycling and disposing of waste

Each component of waste management consists of various subparts (Demirbas, 2011). The various steps of the waste management system are presented in Table 1.

Table 1 - Main steps of the waste management system (Demirbas, 2011).

Main components	Subparts
Production of materials	Waste sources Source separation Internal collection Production rates Waste types
Collection and transport	Collection Transport Transfer
Treatment or reprocessing	Physical reprocessing: Shredding, sorting, compacting Thermal processing: Incineration, gasification Biological reprocessing: Anaerobic digestion, aerobic composting
Final disposition	Recycling Landfilling

Within the waste management system, minimizing the total waste quantities is the top priority. Next comes recycling (Demirbas, 2011). The process of recovering the material and reusing the sources in the waste is generally called recycling. In fact, the material recovered from the waste through recycling is utilized as raw material for different purposes than the one they were originally generated. Recycling can be carried out using different methods. For instance, one can extract and reprocess the raw material in the waste or use the energy content of the waste to produce electricity (Wilson et al., 2009; Demirbas, 2011).

It is not possible to eliminate large amounts of waste. Still, using the waste in a more sustainable manner can reduce its environmental impacts. This is called waste hierarchy (Demirbas, 2011). The waste hierarchy (figure 1) is a term for referring to the efforts taken to reduce, reuse, and recycle waste. There are six different categories of environmental impacts for the hierarchy of disposal options, namely landfill and incinerate, compost, recycle, reuse, and reduce (from high to low) (Siddique et al., 2008). The purpose of the waste hierarchy is to maximize the benefit extracted from the waste and minimize waste generation quantities (Demirbas, 2011).

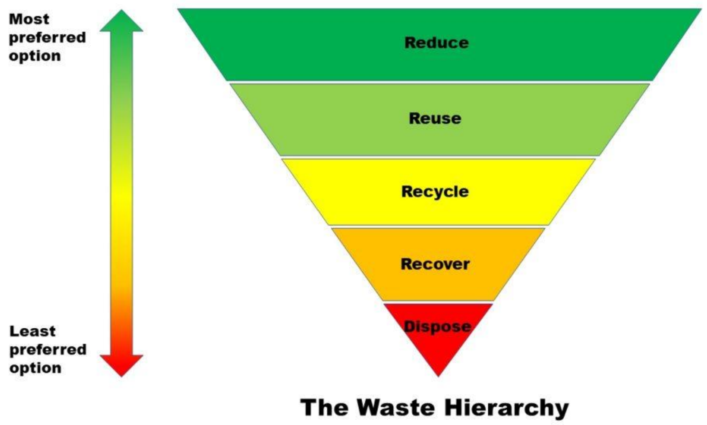


Figure 1 - Waste management hierarchy (Garbera, 2021).

2.1.1 Waste management in Norway

The responsibility of municipal waste management in most of the western European countries is on related municipalities. However, in some countries, such as the UK, Spain, Italy, and Ireland, the provinces and municipalities split the waste management services (Torsteinsen & van Genugten, 2016). In Norway, municipalities are responsible for providing waste management services for collecting household waste. Anyone who aims to collect household waste in Norway must acquire the consent of the municipality. The activities of the municipalities regarding waste management are regulated by The Norwegian Environment Agency (Miljødirektoratet) to ensure the municipalities comply with the laws. The Norwegian Environment Agency can also decide if the municipalities should collect special waste or the manufacturer of this type of waste should deliver it to a treatment station in the municipality (Torsteinsen & van Genugten, 2016).

Among all the European countries, Norway has the greatest length, which is 1752 km. Besides, the population of Norway is around 5 million. The relatively small population of Norway that is spread in different directions in a large area increases the challenges of waste management (Kjær, 2013). Figure 2 shows the map of the average household waste generation per capita per kilogram in various municipalities in Norway.

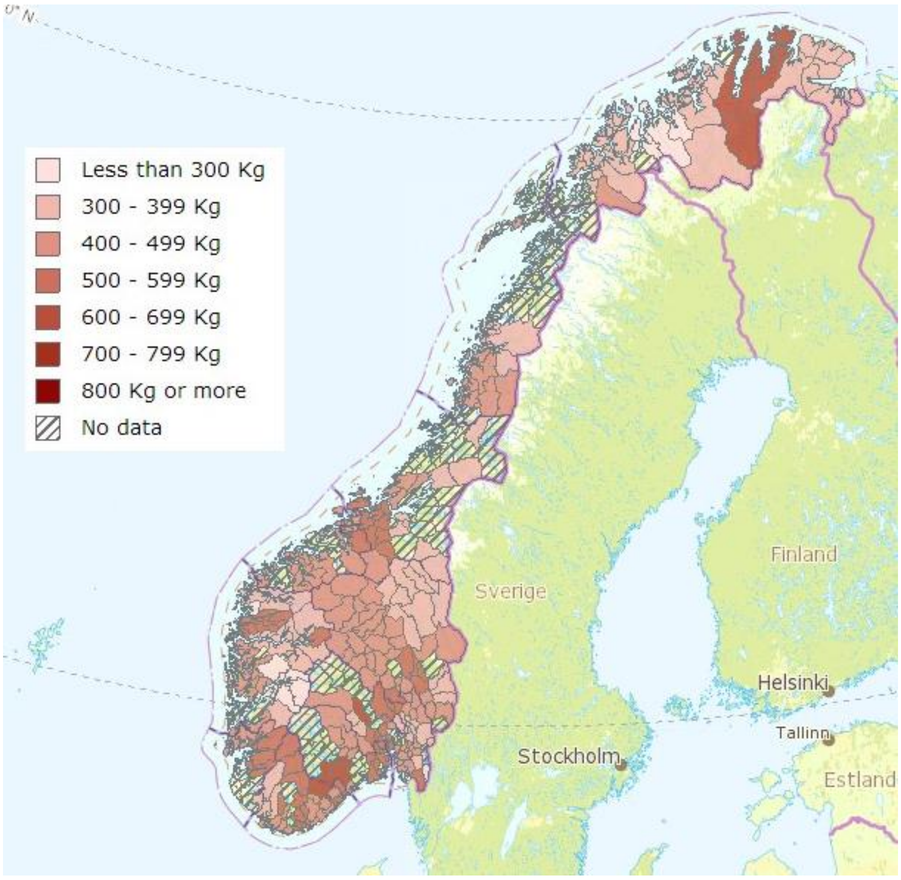


Figure 2 - the average household waste per capita in kilograms within each municipality in Norway (Environment Norway, 2021a)

The amount of municipal waste produced in Norway has increased by 41% in the timespan 2001-2010. (Kjær, 2013). One reason for the rise in quantities of generated municipal waste in Norway could be the economic growth in the country. The statistics show that the amount of generated municipal waste in Norway in 2019 reached 12.2 million tonnes. Figure 3 illustrates the rising trend of total waste quantities generated in Norway in timespan 1995-2019. (Environment Norway, 2021b).

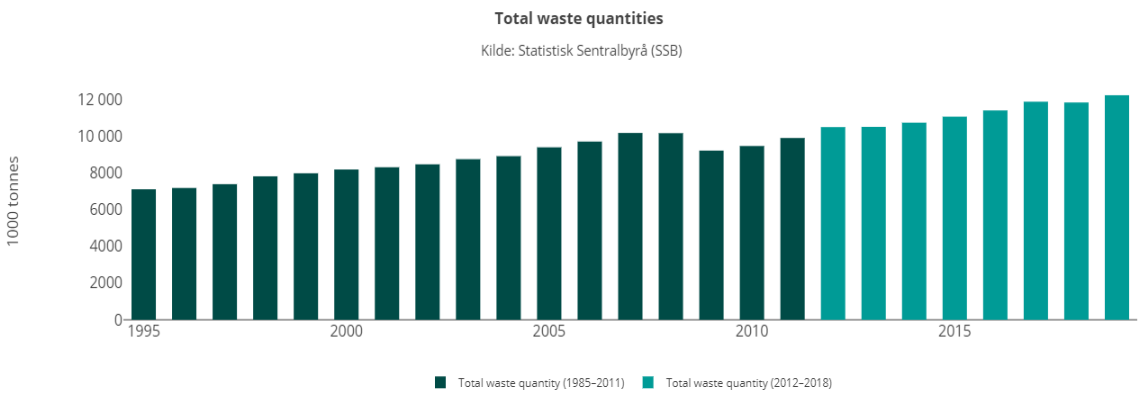


Figure 3 - The rising trend of total waste quantities generated in Norway from 1995 to 2019 (Environment Norway, 2021b).

Today, the construction industry is generating the largest share of waste in Norway. The quantities of household waste in Norway have been relatively stable in the past few years, while the amount of waste generated by the industry sector has increased. In 2019, the amount of waste produced by each Norwegian was 776 kg which was 274 kg more than the average amount in 27 EU countries (Environment Norway, 2021b).

The waste management system in Norway has been changed during the past decades. The largest part of the waste in Norway was disposed of in the form of landfilling around 20-30 years ago. This form of waste disposal has the most serious impacts on the environment. This is because hazardous substances in the waste leach out in the water as it moves through landfills, and the sources of water can be contaminated by the polluted water from landfills. Moreover, various resources in waste will not be used when it is disposed of in landfills. The rate of waste recovery in Norway has increased in the period 1995 to 2011, and it decreased after 2011. The reason for the decline in waste recovery was a change in the Norwegian regulations, which allowed landfilling of bricks and concrete. Statistics show that around 71% of total ordinary waste in Norway was recovered in 2019, and 41% of the recovered waste was recycled (Environment Norway, 2021b). Figures 4 and 5 illustrate the proportion of waste recycled in Norway from 1995 to 2019, and the map of recycled household waste in various municipalities in Norway in 2015, respectively.

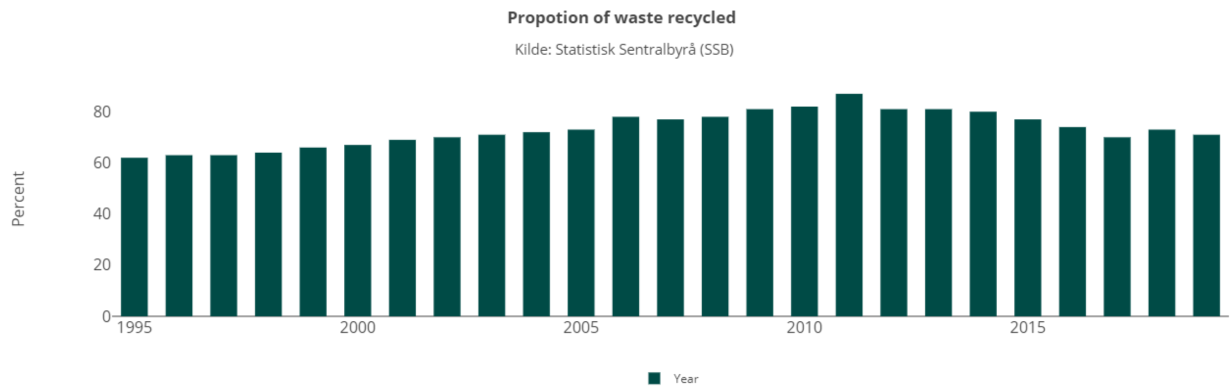


Figure 4 - Proportion of waste recycled in Norway from 1995 to 2019 (Environment Norway, 2021b).

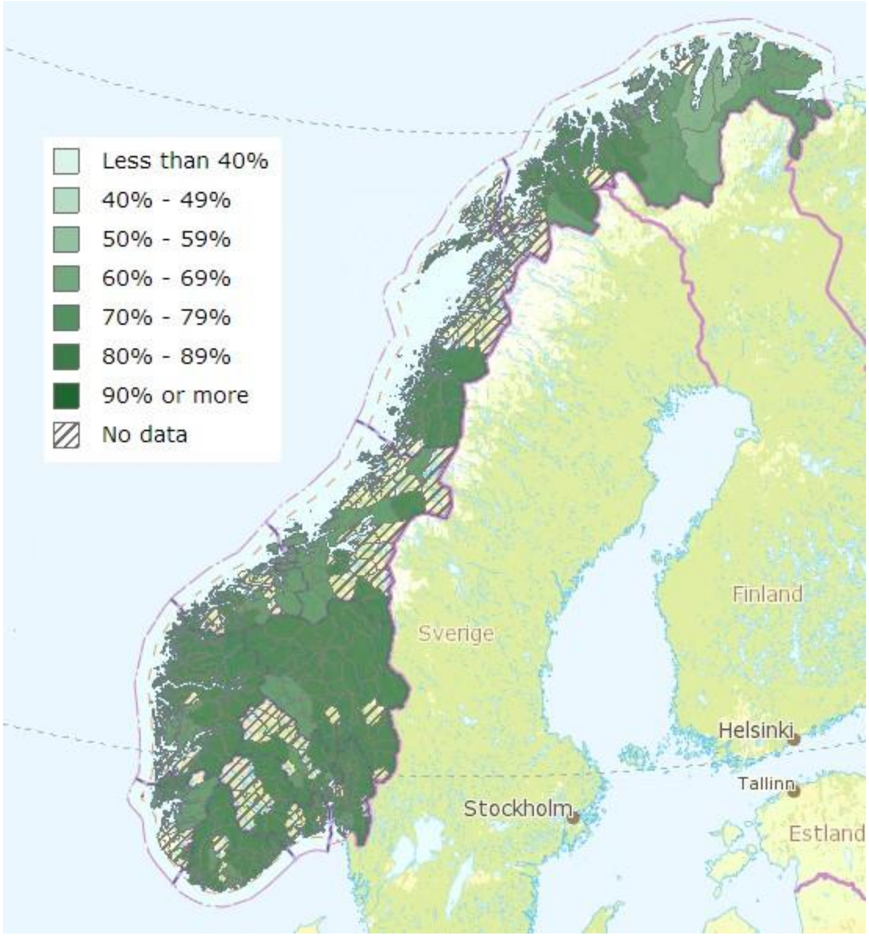


Figure 5 - Proportion of recycled waste in various municipalities in Norway in 2015 ((Environment Norway, 2021a)

According to the statistics, the greatest amount of waste generated in Norway is treated and disposed inside of the country. Yet, a share of the generated waste is exported to other countries for the purpose of energy recovery or recycling (Environment Norway, 2021b). Figure 6 illustrates the amount of treated waste in Norway and the type of treatment from 2012 to 2019.

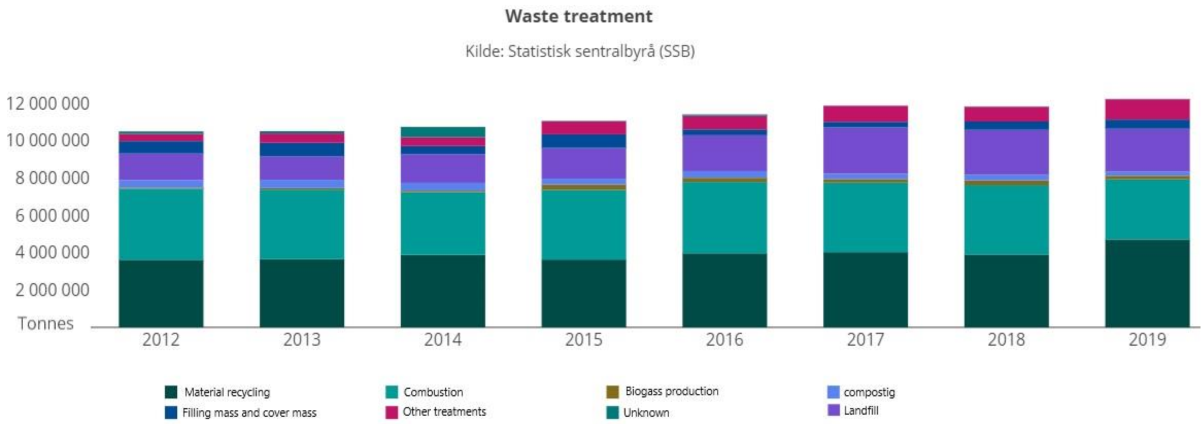


Figure 6 - the amounts of treated waste in Norway from 2012 to 2012 (Environment Norway, 2021b).

2.1.2 Waste management at Remiks Miljøpark As

Remiks is a waste management company that collects, handles, and treats waste in northern Norway. Remiks offers waste management services for the industry community and households in Tromsø and Karlsøy municipalities, and it has around 120 employees in total (Remiks, 2021a). Figure 7 represents a general view of the waste management process at Remiks. The process of waste management at Remiks starts with collecting the waste from household and industry customers. Then, the collected waste is sorted, and different types of waste are sent for further treatment (Remiks, personal communication, 2021). In the following sections, a more detailed description of Remiks waste management processes will be presented.

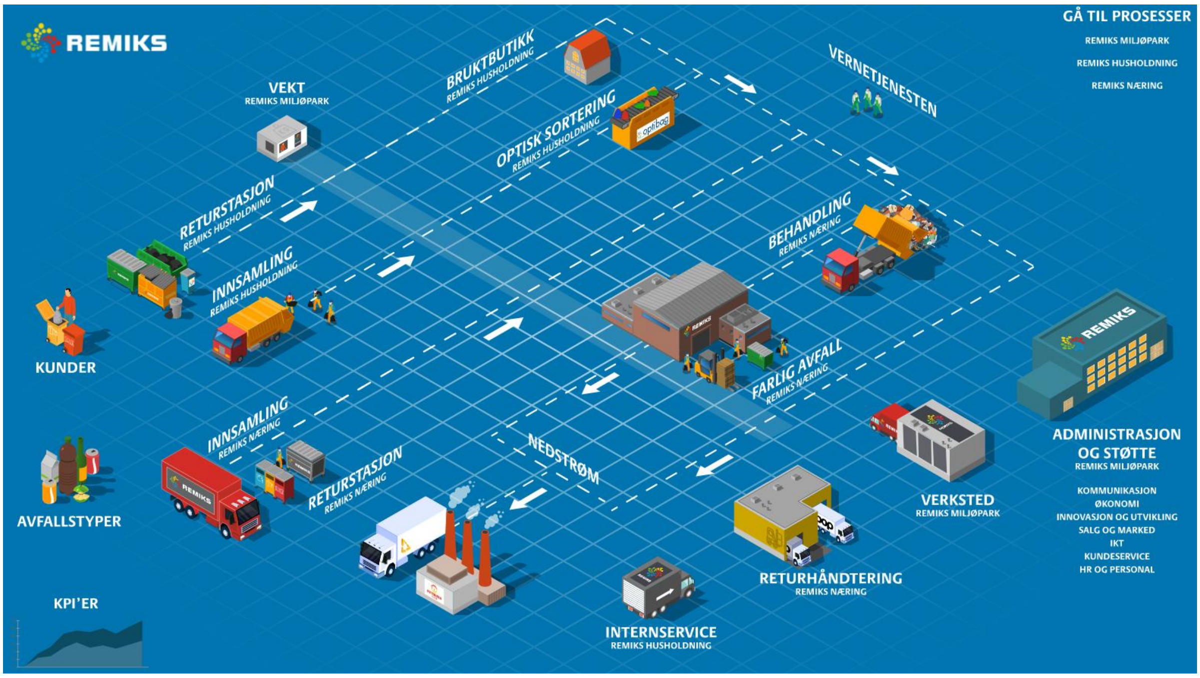


Figure 7 - A general view of the waste management process at Remiks (Landax, 2021)

2.1.2.1 Household

Remiks collects the domestic waste from the household at the customers' place. The household customers must sort out their waste into bags of five different colors, as illustrated in figure 8. Usually, each customer has two different trash bins at home. One trash bin is for the sorted waste in the bags, and the other one is for the glass and metal packaging waste (Remiks, personal communication, 2021).

Figure 8 - Sorting guide for the household customers (Johnsen, 2021b)

As shown in figure 8, the type of waste that can be recycled should be sorted into colorful bags, and the remaining waste should be sorted into white- or neutral-colored bags. The suitable waste to be sorted in each bag is (Johnsen, 2021a):

- **Green:** the food waste should be sorted into green bags. It can include meal leftovers, fruit, vegetables, eggshells, flour, and baking items, coffee filters, tea bags, milk products, small amounts of flowers, and small amounts of kitchen towels and egg trays.
- **Blue:** the plastic packaging waste should be sorted into blue bags. It can include all plastic packaging, plastic bags, films, bottles, beakers, containers, coffee bags, and boxes.
- **Red:** paper and light packaging cartons should be sorted into red bags. It can consist of newspapers, writing paper, magazines, egg cartons, and any other light packaging cartons.
- **Orange:** beverage carton should be sorted into orange bags. It can include all light packaging cartons that are used to contain liquid, such as juice and milk cartons.
- **White (or neutral-colored):** residual waste or the type of waste that cannot be sorted in any of the mentioned bags should be packed into white- or neutral-colored bags. However, dangerous waste such as electrical components, batteries, paint, etc., should not be thrown as residual waste.

The household customers can put their sorted waste into the trash bins at their homes. They should also place glass and metal packaging waste into a trash bin specifically for glass and metal waste at home. Afterward, Remiks will empty the trash bins and collect the waste regularly. Figure 9 shows the normal domestic trash bins for sorted waste on the right and metal/ glass bins on the left (Remiks, personal communication, 2021).

(a) (b)

Figure 9 – (a) Trash bins for the sorted household waste, (b) Trash bins for glass and metal (Remiks, 2021b).

In addition, Remiks offers other types of waste containers for household customers, such as underground containers and waste suction systems. The underground containers have the same function as the normal bins, with the difference that they are buried under the ground and do not occupy a large space in the streets or the public areas in the city. Figure 10 illustrates the underground bins. Remiks collects the waste inside the underground containers frequently using special machinery (Remiks, personal communication, 2021).

Figure 10 - Underground waste containers (Remiks, 2021b)

The waste suction system is illustrated in figure 11, and it is an innovative method for collecting waste in urban areas. This system consists of ports, an underground pipeline system, and underground containers. The household customers can throw their bags of sorted waste into the suction system through the ports in different spots in the city. The ports are connected to an underground pipeline system. Then, the bags of waste are sucked up from the end of the pipeline system by specific machinery. Although the waste suction system increases the efficiency of waste collection, it decreases the waste quality. This problem is because machinery utilizes a considerable amount of power to suck up the bags lying in the whole pipeline system, and plenty of bags cannot tolerate the tension force and get torn. The spilled-out waste from the torn bags will be treated the same as the remaining waste later in the process. It would also make the other bags dirty and cause difficulties for the further sorting process (Remiks, personal communication, 2021).

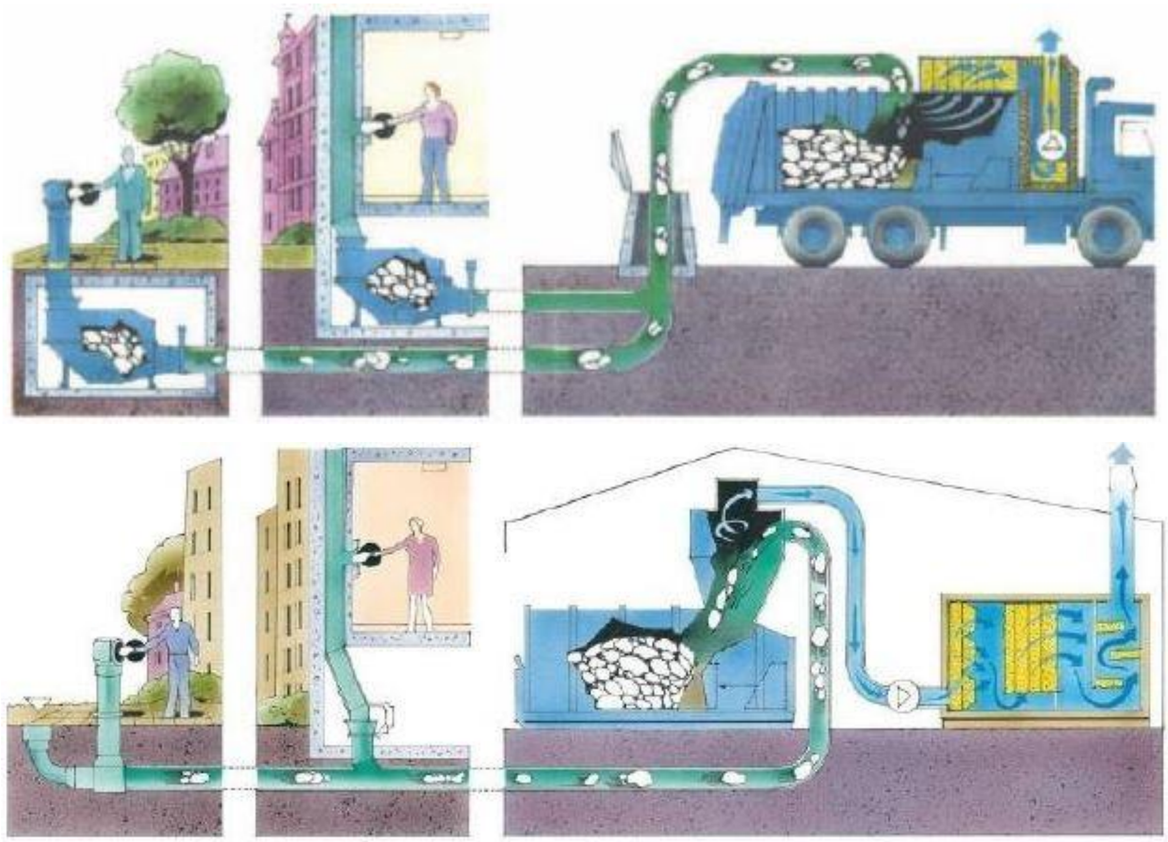


Figure 11 - The waste suction system in Tromsø municipality (Remiks Miljøpark As, 2021)

Remiks also has a delivery station at Tromsø where household customers can deliver other types of waste, which can be sorted neither in the bags nor in glass and metal trash bins, such as (Johnsen, 2021a):

- **Electrical/ electronic (EE) waste:** EE equipment such as TV, refrigerators, computers, electrical toys, hairdressers, etc., can be either delivered to the Remiks' delivery station or to the store that sells such equipment.

- **Dangerous waste:** this type of waste should be directly delivered to the Remiks' delivery station. Some dangerous waste examples are glue, oil, paint, cell phone battery, car battery, spray cans, thinner, varnish, cleaning fluids, etc.
- **Garden waste, construction waste, furniture, and textile:** trees and roots, branches, grass, leaves, sand, soil, stone, non-usable furniture, and textiles can be delivered to the Remiks' delivery station.
- **Residual waste:** other types of waste which do not suit any of the mentioned fractions.

In the delivery station at Remiks, customers should sort out their waste by themselves and dump it into the proper fractions. The operators working at delivery stations provide instructions for the customers and control what is being dumped in different fractions. The dangerous waste and EE waste delivered by customers need to be handled safely. Therefore, they are checked out and placed on the shelves by the operators. (Remiks, personal communication, 2021). In this thesis, all the electrical/ electronic waste, batteries, and dangerous waste are classified in one general category called Hazardous Waste (HW).

2.1.2.2 Industry sector customers

The industry sector customers can rent waste containers from Remiks to manage more significant amounts of waste. The waste containers are available in different sizes depending on the customers' needs. Customers should specify which type of waste they will dump into the containers. Regardless of the selected type and size of the container, the customers are not allowed to dump dangerous and EE waste into the containers. These types of waste must be delivered safely either to operators who visit the worksite or to the delivery stations at Remiks. Furthermore, industry customers can choose to rent open access or secured containers. Also, they can select to either deliver the full containers to the Remiks recycling center or ask Remiks to empty their full containers at their worksite. Moreover, Remiks offers the service to pick up the full containers, transport them to the recycling center, and bring back the clean and empty containers. The content of containers is controlled by the operators at Remiks. If the container's content does not comply with the contents mentioned in the renting contract, the customer will get a non-compliance warning together with a penalty invoice (Remiks, personal communication, 2021).

2.1.2.3 Waste treatment

After collecting the waste from the household trash bins and waste suction systems, the waste is transported to the recycling center at Remiks. At this stage, the household waste goes through the Opti-bag system. The Opti-bag system is an automatic machine that uses optical sensors to identify bags of the correct color and activate a mechanical arm to sort out the bags into the proper fractions. This system has an accuracy of 95-97 %, and it is programmed to recognize and sort out green, blue, orange, and red bags. The poor quality waste coming from the waste suction system would further decrease the efficiency of the Opti-bag system as the dirty bags might not get recognized by the Opti-bag system (Remiks, personal communication, 2021).

The waste which is not sorted by the Opti-bag system and is left on the conveyors will be thrown into the residual waste fraction. Afterward, the residual waste from the industry sector, delivery station, and household waste will go through the waste grinder. Eventually, ground residual waste will be transferred to the Kvittebjørn Varme AS to be burnt and produce energy. Also, the sorted waste from the households, industry, and delivery station will be sent to the external companies for recycling (Remiks, personal communication, 2021).

2.2 Fire in waste facilities

According to the fire statistics from waste facilities in Sweden and Norway, numerous fires occur at waste facilities in these countries annually. The Norwegian fire and rescue service has recorded 141 fires in the timespan 2016-2018. However, most of them were small fires that had been extinguished quickly (Mikalsen et al., 2021). Yet, the appropriate risk reduction measures should be implemented to limit the environmental impacts caused by the fire in waste facilities (Stenis and Hogland, 2011). The quantities of waste will most likely not decrease in the future based on historical evidence, and it can be very difficult to control and extinguish fires in waste facilities. Therefore, there is an obvious need to evaluate the challenges regarding the fire. (Mikalsen et al., 2021).

The studies conducted to find the main reasons for fire in waste facilities in Norway and Sweden shows that self-ignited fires, re-ignited from previous fires, electrical and technical failures, and human activities (both human error and arson) are standing out as the main factors of fire. However, the cause of numerous fires has remained unknown. Figure 12 represents the opinion of waste industries in Norway about the waste fractions in which fires can have the most remarkable consequences. (Mikalsen et al., 2021).

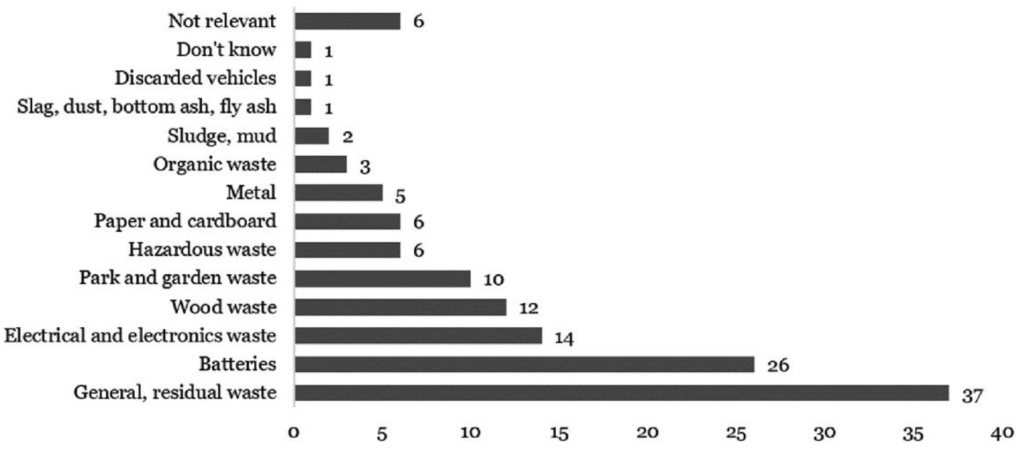


Figure 12 – The waste fractions that can cause the greatest consequences if a fire occurs in them based on the opinion of waste industries in Norway (Mikalsen et al., 2021).

Mikalsen et al., 2021, have assessed fire risk in Norwegian and Swedish waste facilities in their research. The results of the fire risk assessment for various risk fractions are presented in Table 2. The fractions with the total highest risk are marked with red. The total risk reduces as it comes down to orange, yellow, and tan, which is representing the lowest risk. The frequency of fire in each fraction is ranked as Very rarely, Rarely, Regularly, and often. Further, the consequences of fire in each fraction are ranked as Low, Medium, and High (Mikalsen et al., 2021).

Table 2 – Total assessment of fire risk for different waste fractions (Mikalsen et al., 2021).

Waste fraction, sorted by fire risk	**Ignition frequency**	**Qualitative assessment of potential consequences**	**Comment to assessment of consequences**
General, residual waste	Often	High	Large quantities, damage on equipment, pollutants
Batteries*	Often	-	Depends on waste fraction*
Electrical and electronic waste	Regularly**	High	Pollutants
Paper and cardboard	Regularly**	High	Large quantities, damage on equipment
Hazardous waste	Rarely	High	Pollutants
Wood waste	Very rarely	Medium	Large quantities
Park and garden waste	Rarely	Medium	Large quantities
Plastic waste	Rarely***	Medium	Energy density, pollutants
Rubber	Very rarely	Medium	Energy density, pollutants

Organic waste	Rarely	Low	None stands out
Discarded vehicles	Rarely	Low	None stands out
Metal	Rarely	Low	None stands out
Sludge. mud	Rarely	Low	None stands out
Slag	Rarely	Low	None stands out
Glass	Very rarely	Low	None stands out
Slightly contaminated masses	Very rarely	Low	None stands out
Concrete/ bricks	Very rarely	Low	None stands out
Textile	Very rarely	Low	None stands out

"* All battery-related fires included. Batteries are not a separate waste fraction but are highlighted in this table to show their inherent fire
** Not as frequent in Sweden as in Norway
*** Not as frequent in Norway as in Sweden, where recycled plastic (bales) regularly cause fire" (Mikalsen et al., 2021).

2.2.1 Example of a fire in Norway

A significant fire in a waste facility in Re municipality in Norway was recorded in 2014. It was recognized as a self-ignited fire that occurred in a pile of treated electrical and electronics waste with total quantities of 1230 000 kg. Foam and water were utilized to extinguish the fire, and the process took around 36 hours. The discharge of water used for extinguishing was directed to a small stream in the neighborhood through the plant's sewer system. The amount of oxygen in the stream was reduced considerably due to the discharge of the foam, and the water was contaminated by metal. The level of contamination was much higher than the limit for the aquatic animals, resulting in fish death. Moreover, the contaminated water destroyed all or a share of the nearby farmers' crops (Mikalsen et al., 2021).

2.2.2 Impacts of fire

In the past 25 years, several fire incidents with considerable environmental impacts have occurred and resulted in the rise in awareness of fire and its dramatic effects on the environment (Simonson et al., 2011). Before, the focus of studies related to the environmental impacts of fire was mainly on the fire emissions into the air, soil, and water. Nowadays, the dimensions of sustainability have been extended to include social, economic, and ecological factors. The definition of sustainability is "the ability to meet present needs without compromising the ability of future generations to meet their needs" (Mikalsen et al., 2021). Figure 13 illustrates the potential impacts of fire on three dimensions of sustainability.

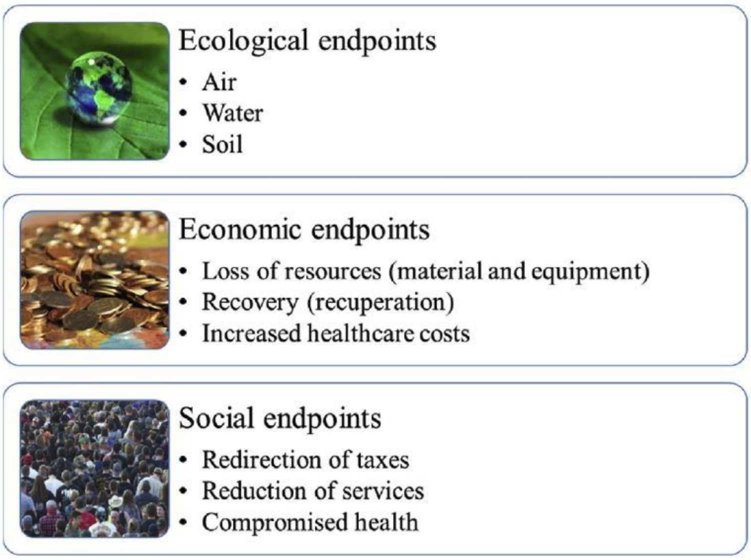


Figure 13 - The possible impacts of fire on various dimensions of sustainability (Mikalsen et al., 2021).

The impacts of fire on different dimensions of sustainability are (Mikalsen et al., 2021):

- **Ecological impact:** fire causes emissions to the air, soil, and water. These emissions are caused due to fire itself and all other activities to avoid fire, limit its extent, and fire extinguishing activities.
- **Economic impact:** fire can cause severe damages to buildings and equipment, and it can destroy the resources that could be utilized for providing energy. It also increases the cost of repair, rehabilitation of the environment or resources, implementation of preventing measures, and response activities.
- **Social impact:** fire can have adverse effects on the psycho-social and physical health of people exposed to emissions. Therefore, taxes should be redirected to recovering resources and the environment.

2.3 Regulations and laws

This section provides a review of regulations, laws, guidelines, and standards regarding fire safety in waste facilities. The review only includes those parts that are considered relevant to this study, and it is not a complete overview of the regulations.

2.3.1 Fire and Explosion Protection Act with regulations

The Fire and Explosion Protection Act (Brann- og eksplosjonsvernloven, 2002) regulates fire safety at a higher level. Neither the law nor the regulations set specific requirements for fire safety for specific industries, businesses, or facilities. Therefore, no specific requirements for fire safety for waste facilities were found. The sections of §6 and §19 in the law describe the owner's- and the company's obligations to implement necessary fire protection measures, respectively. These laws are applied to all businesses, buildings, areas, production equipment, and other facilities (Brann- og eksplosjonsvernloven, 2002).

According to section §9 of the Fire and Explosion Act, it is the municipality's responsibility to ensure the implementation and operation of the fire service that can take care of preventive and emergency preparedness tasks in accordance with the law in an efficient and safe manner. The tasks are described in section §11 of the Act, and they include the efforts needed when the fire occurs, information, supervision, and preventive task regarding the handling of dangerous substances (Brann- og eksplosjonsvernloven, 2002; Standard Norge, 2011).

Since the Fire and Explosion Protection Act is not directed toward some specific industries, the waste industry needs to adapt by law in the same way as all other industries and business owners. Chapter §4 of the Act provides the rules for businesses that handle hazardous and explosive substances. It gives an overview of the security, emergency preparedness, registration, and reporting of accidents. According to chapter §6 of the Act, the facility owner is responsible for the necessary safety measures to prevent and limit fire, explosion, and other accidents. Moreover, it is mentioned in chapter §6 of the Act that both the owner and the user of the facility have the responsibility to further control the implemented security measures will work at the time it is needed. The security measures comprise both technical and organizational measures (Brann- og eksplosjonsvernloven, 2002).

Regulations on handling hazardous substances (Forskrift om håndtering av farlig stoff, 2009) apply to all waste facilities that handle hazardous substances, regardless of their quantity. When the dangerous substances and goods are taken out of their value chain, they turn out to hazardous waste and need to be disposed/ treated. Different waste facilities treat hazardous waste in various ways. According to the regulations on handling hazardous substances, the waste facilities must report the hazardous waste treatment to DSB if they handle quantities above the given threshold. (Direktoratet for samfunnssikkerhet og beredskap, 2021).

2.3.2 Regulations on industrial protection

Regulations on industrial protection (Produktforskriften, 2004) ensure that companies have robust industrial protection, which can limit the consequences of adverse events on life, health, environment, and assets. The regulations have different business codes for different types of businesses, and waste facilities are registered as industry code 38.2 treatment and disposal of waste. The regulations apply to those companies that have around 40 employees in a year on average. According to the regulations, companies must have an overview of undesirable events, and this shall be used as a decision basis for the organization. Further, companies must have a written contingency plan where the first tasks to execute in the event of any undesirable event are clarified. Also, the tasks should be exercised at least every six months (Produktforskriften, 2004).

2.4 Risk management

Risk management is defined as “coordinated activities to direct and control an organization with regard to risk” (International Organization for Standardization, 2018). The aim of risk management is to make sure that proper measures are implemented to protect humans, assets, and the environment from the adverse outcomes of activities being executed. It also aims to consider important aspects, such as costs and HSE (Health, Safety, and Environment), and make a balance between them. The measures implemented by risk management are both to prevent a hazard from occurring, and to mitigate their potential consequences. It is commonly accepted that the elimination of risk is not possible. Instead, risk must be managed within an organization in order to achieve high-performance levels. (Aven and Vinnem, 2007).

2.4.1 Risk management framework

The fact that how well the organizations integrate risk management into their governance, decision-making, and management will determine the effectiveness of risk management. For obtaining higher efficiency levels, organizations can follow the risk management framework, which consists of the following components (International Organization for Standardization, 2018):

- **Integration:** the organization should make risk management a part of its governance, strategy, leadership, operations, purposes, objectives, and commitment. Managing risk within an organization is everybody’s responsibility, and every part of the structure of an organization should contribute to managing risk.
- **Design:** the first step in designing the risk management framework is that the organization should investigate its context, both external and internal. Next, the management board in the organization should express their commitment to risk management and assigning responsibilities and roles within the organization. Then, enough resources should be allocated to risk management, and proper consultation and communication must be established.

- **Implementation:** at this stage, appropriate plans for resources and time should be developed, and proper decisions should be taken within the organization. If the risk management framework is designed and implemented across the organization properly, it can be ensured that risk management is involved in all the activities undertaken in the organization.
- **Evaluation:** the organization should periodically evaluate the performance of the risk management performance to make sure of its effectiveness.
- **Improvement:** any changes in the internal or external context of the organization must be monitored, and the risk management framework must be adapted accordingly. Additionally, the organizations should enhance the efficiency, sustainability, and adequacy of the risk management framework continuously.

Figure 14 - Risk management framework (International Organization for Standardization, 2018).

Figure 14 illustrates the components of the risk management framework. The organization using this framework can customize the components of the framework according to their needs. (International Organization for Standardization, 2018).

2.4.2 Risk management process

Risk management is considered an iterative process that encompasses several steps. The organization can improve its performance and decision-making through undertaking the steps in sequence. In fact, a viable management practice involves the risk management process as an integral part of the organization and ensures that risk management is an element of its governance (Aven and Vinnem, 2007). The organization can customize the risk management process and utilize it for various applications. Further, the organization should consider the dynamic nature of culture and human behavior across the risk management process. Figure 15 demonstrates different steps of the risk management process (International Organization for Standardization, 2018).

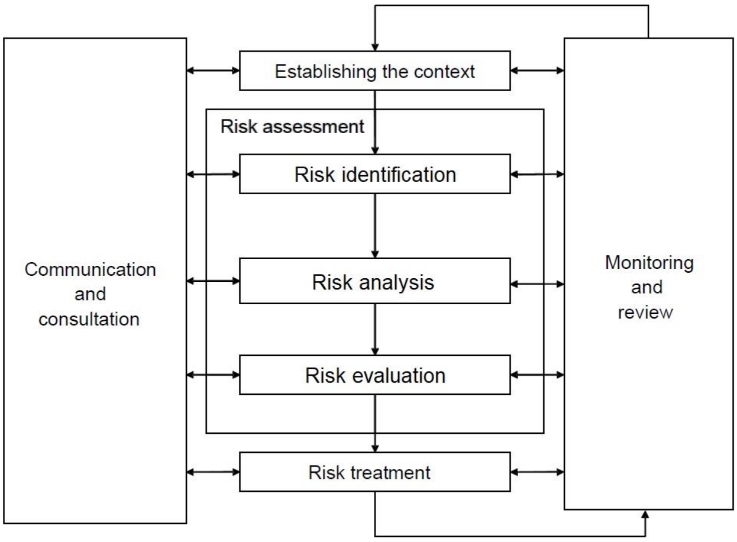


Figure 15 - Risk management process (IEC/ISO, 2009).

- **Communication and consultation:** this is an essential element of all the steps across the risk management process. Through communication and consultation, organizations and stakeholders can obtain a common understanding of risk, the basis of decision-making, and the purpose of actions being undertaken. While communication involves increasing the stakeholders' understanding of risk, the consultation aims to promote the exchange of feedback and information that is important for making decisions (International Organization for Standardization, 2018).
- **Establishing the context:** in this step, the organization can customize risk management according to its needs and provide a basis to conduct the risk assessment and risk treatment effectively. In order to establish the context, the organization should define its scopes of risk management, specify the internal and external context, and define the risk criteria (International Organization for Standardization, 2018).
- **Risk assessment:** this step encompasses risk identification, risk analysis, and risk evaluation (International Organization for Standardization, 2018).
    - Risk identification aims to assist the organization in finding, understanding, and portraying the potential risks that might affect the organization's objectives. To carry out this step, it is important to obtain up-to-date and relevant information and utilize appropriate tools.

  - The aim of risk analysis is to help the organization understand the nature of the risks and their features. The organization decides the degrees of complexity and details of risk analysis based on the goal of analysis, available resources, and information.
  - At the risk evaluation step, the results of the risk analysis are compared with the risk criteria to provide a basis for making appropriate decisions. Based on the outcomes of the risk evaluation, the organization can recognize if they need to consider risk treatment alternatives, carry out further analysis to better recognize the risks, maintain their current controls, consider the objectives again, or take no further actions.
- **Risk treatment:** this is an iterative process where various options for addressing risk are selected and implemented. The risk treatment process consists of selecting the options, planning and implementing the options, evaluating the effectiveness of options, deciding if the risk is acceptable, and if not, implement further treatments (International Organization for Standardization, 2018).
- **Monitoring and review:** the aim of monitoring and review is to ensure the effectiveness and quality of the entire risk management process, including the design, implementation, and results. It is essential to carry out the monitoring and review in all stages of the risk management process (International Organization for Standardization, 2018).

2.5 Risk assessment techniques

Within the risk assessment process, various techniques can be utilized to carry out each step. Several factors influence the selection of appropriate risk assessment techniques, such as available data and resources, the timeline of the assessment, the objectives of the risk assessment and requirements to satisfy them, the required level of expertise, and the degree of the problem's complexity (IEC/ISO, 2009).

In the following sections, information about the risk assessment techniques used to carry out this research is presented. Since the available data regarding the fire at Remiks waste facility was limited, there was a need to utilize experts' opinions to conduct the analysis. Therefore, those risk assessment techniques that could be utilized to collect the experts' opinions in a time-efficient manner were selected for this research study.

2.5.1 Root cause analysis

The Root Cause Analysis (RCA) is a technique to analyze a significant loss that has occurred in the organization due to different sorts of failures and utilize the results to avoid reoccurring the loss. The purpose of this technique is to point out the root causes rather than removing the existing symptoms. This technique can be utilized in a wide range of contexts, such as safety-based RCA, System-based RCA, Production-based RCA, and process-based RCA (Andersen and Fagerhaug, 2006; IEC/ISO, 2009).

To carry out the RCA, a group of experts who have the required knowledge about the occurred loss should be selected to analyze the loss and provide recommendations. The RCA can be executed by using different methods, but the following steps are similar in all the methods (Andersen and Fagerhaug, 2006):

- Setting up a group of experts
- Defining the objectives and scope of the RCA
- Understanding the problem
- Collecting data and evidence regarding the loss
- Identifying the root causes through conducting a structured analysis
- Providing solutions and developing recommendations
- Implementing the solutions and recommendation
- Testing the effectiveness of the implemented solutions

Various techniques can be used to carry out the structured analysis, such as the "5 Whys" technique, Fishbone or Ishikawa diagrams, fault tree analysis, Pareto analysis, and failure mode and effects analysis. The RCA involves the people who are working in a team, and it considers all the potential hypotheses. Yet, there might not always be enough time and resources to execute RCA, and it might not be possible to implement a sufficient number of recommendations. (Andersen and Fagerhaug, 2006; IEC/ISO, 2009).

2.5.2 Cause-and-effect analysis

The cause-and-effect analysis is a procedure to point out potential causes of a problem or an unwanted event. This technique classifies the causal factors into wider categories, and by this, it considers all probable hypotheses. This technique can be used together with RCA to identify the root causes of a problem. For organizing the information in the cause-and-effect technique, the Fishbone (Ishikawa) or a tree diagram can be utilized. The structure of the Fishbone/

Ishikawa diagram is similar to the fish skeleton. The effect is placed in the head of the fish, and the causal factors are classified into main categories represented by the backbones of the fish. The branches and sub-branches illustrate the secondary or more detailed causes in each category. Figure 16 shows an example of a Fishbone diagram (IEC/ISO, 2009).

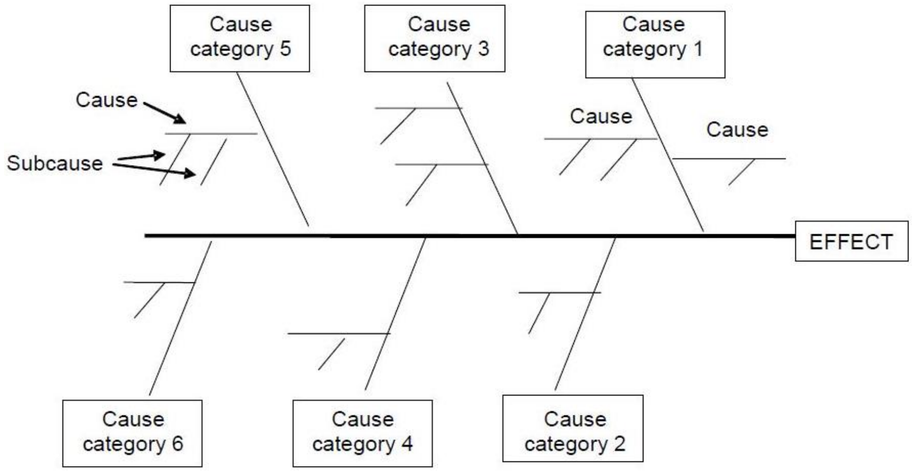


Figure 16 - An example of a Fishbone diagram (IEC/ISO, 2009).

The basic steps to carry out a cause-and-effect analysis are (IEC/ISO 2009):

- Identify the effect that should be analyzed
- Specify the main categories of causes
- Write down the potential causes in related categories
- Review the diagram to make sure that all of the causes lead to the effect
- Point out the most probable causes according to the views of the participants

The results of this analysis should be tested and verified before proposing any recommendations (IEC/ISO, 2009).

2.5.3 Brainstorming

Brainstorming sessions are conducted among a group of people who have enough knowledge about the topic of the discussion, organization, process, and system. The purpose of brainstorming is to identify risks, criteria for decision-making, potential failure modes, and risk treatment alternatives by encouraging participants to a free-flowing conversation. The facilitation of the session influences the effectiveness of this technique. Brainstorming facilitation includes encouraging the discussion at its start, directing the group of participants toward other relevant aspects periodically, and catch the issues that might arise during the discussion (IEC/ISO, 2009).

Brainstorming can be utilized along with other risk assessment techniques. It can be conducted at any stage of the risk assessment process to stimulate creative thinking among those involved. It can be used for developing a more detailed review for high-level discussions where the main issues are pointed out. It also can be utilized at a detailed stage for solving a specific problem. Brainstorming can be carried out both formally and informally. While formal brainstorming follows a clear structure, informal brainstorming is considered less structured and unprepared. In the formal brainstorming, the participants usually get information about the purpose and outcome of the sessions, and they prepare for the discussion in advance. The facilitator at formal brainstorming prepares appropriate plans to prompt the thinking pattern of the participants and direct them toward the context. Further, the rules and objectives of the session are defined and explained to the participants. Next, the facilitator kicks off the session by providing a train of thoughts, and all participants point out as many issues they can come up with. At this point, there should not be any discussion about whether the ideas mentioned should be listed or not, and none of them should be criticized. This session is considered as a free-flowing process, and all the inputs are accepted (IEC/ISO, 2009).

The brainstorming technique has some strengths and limitations. One of the strengths of this technique is that it encourages imaginative thinking, which might result in novel solutions, or it might contribute to identify new risks. Further, it is pretty easy and quick to set up the session, and it improves the communication between the organization and stakeholders. However, the effectiveness of the brainstorming is highly dependent on the knowledge and skill level of the participants. Moreover, some participants with novel ideas might not get the chance to share their opinion if others are dominating the discussion (IEC/ISO, 2009).

2.5.4 Structured or semi-structured interviews

In the structured interview, a set of questions are asked from the interviewees individually. The questions are prepared in a way to direct the participants toward considering the situation from a different view and point out the risks from that point of view. The semi-structured interview gives the interviewees the chance to express their opinions through a conversation. The interview (both structured and semi-structured) technique can be applied when gathering all the experts at the same time is difficult or in situations where having a free-flowing discussion is not a viable option. This technique can be used at any stage of the process to provide appropriate inputs. The questions should be clear and straightforward, and if possible open-ended.

Additionally, follow-up questions can be asked wherever clarification is needed (IEC/ISO, 2009).

2.5.5 Delphi

The Delphi technique is a reliable method for getting agreement on a specific topic from a group of experts. This technique is widely utilized to describe any sort of brainstorming. However, its original formulation is that each participant can share their opinion anonymously and at the same time get information about other participants' views along the process. The Delphi technique can be used at any stage across the risk management process where an agreement of opinions from experts is required (IEC/ISO, 2009).

To conduct the Delphi method, a semi-structured questionnaire should be asked from the experts, and they should respond to the questionnaire individually without meeting the other participants. Then, the results of the first round questionnaire should be analyzed and combined, and the second round questionnaire should be sent out to the participants individually. This procedure continues until agreement from the experts is obtained (IEC/ISO, 2009).

The Delphi method is a rather time-consuming procedure, and it requires the experts to express their views clearly. Nevertheless, it gives the participants the chance to share their opinions freely, and it can be carried out without having the participants physically available in one place (IEC/ISO, 2009).

3 Methodology

In this chapter, the methods used to carry out this research have been explained. Further, an overview of the methodology, as well as the research procedure, is presented.

3.1 Overview

The principal analysis of this research is conducting a root cause analysis in order to find the main source of fire at Remiks and its root causes. In this study, a combination of qualitative and quantitative approaches has been applied to carry out the various steps of the root cause analysis. Combining the qualitative and quantitative methods has helped acquire information from different parties involved in the process, such as customers, employees, and the management board. It also has contributed to provide a holistic picture of the problem and obtain comprehensive results.

3.2 Research process

The process of this thesis started in September 2020, where the topic of the thesis was discussed with the representatives from Remiks. The author was in contact with Remiks, and the main topic of the research was specified through the final discussion in January 2021. Fire incidents in waste facilities were found to be a major problem and a broad topic. Therefore, it was decided to narrow down the research. After discussions with Remiks in the planning phase, it was agreed to look at the main reasons for the fire in waste facilities in this research. In order to keep control of the progress in this study, a timetable was developed, which is presented in Table 3. Although the schedule was followed throughout the entire research, there have been some minor adjustments to the plan.

Table 3 - Timetable for conducting the entire research

Activity	**Start**	**End**
Planning	04.01.21	31.01.21
Project description	20.01.21	15.02.21
Research questions	20.01.21	15.02.21
Table of content	30.01.21	20.02.21
Data collection	01.02.21	15.03.21
Writing the thesis	16.02.21	17.05.21
Theory section	16.02.21	05.03.21
Main body	28.02.21	31.03.21
Analysis and results	15.03.21	16.04.21

Discussion and conclusion	13.04.21	11.05.21
Review	30.04.21	31.05.21
Delivery	31.05.21	01.06.21

3.3 Root cause analysis

The root cause analysis process in this research consisted of several steps, namely problem understanding, data collection and analysis, root cause identification, Delphi method, and recommendations. The various steps of the RCA are explained in the following sections in more detail.

3.3.1 Problem understanding

The first step of the root cause analysis was to understand the problem for which causes are being searched. For this purpose, the Remiks' facilities were inspected to understand the flow of activities in the waste management process at Remiks. Afterward, the inspection results were discussed with the HSE (Health, Safety, and Environment) expert at Remiks to make a flowchart of waste management at Remiks. First, the inputs and outputs of the whole process were defined. Then, the customers of Remiks in different sectors were identified. Next, all the tasks and activities undertaken throughout the process to produce the outputs from inputs were identified. Subsequently, the process of waste management at Remiks was mapped in a flowchart. Last, the flowchart was reviewed by the HSE expert at Remiks to ensure that it represents a realistic picture of the waste management process at Remiks.

3.3.2 Data collection and analysis

During root cause analysis, various techniques and tools have been used to collect data, such as previous fire incident reports at Remiks, brainstorming sessions with the experts at Remiks, semi-structured interviews with experts, and customer surveys. In the following sections, each tool is explained in more detail.

3.3.2.1 Incident reports

In order to collect data about the sources of the previous fire incidents at Remiks, the fire incident reports have been collected and reviewed. Remiks requires all its employees to send fire incident reports via a digital platform if they observe a fire in Remiks' facilities. Nevertheless, plenty of previous fire incidents have not been recorded. A total of 31 fire incidents have been reported in the timespan 07.2015-02.2021. The incident reports include various information, such as the description of the event, description of the causes, immediate actions that were taken after incidents, and preventive measures. When the fire occurs in the waste grinder, the employees at Remiks have difficulties identifying the precise type of waste that starts a fire. The reason could be that the specific waste that ignites a fire is usually burnt off before the operators take it out of the pile of waste. Therefore, they often guess the type of waste that created a fire and write it on the fire report. So, the fire incident reports at Remiks could mainly represent the major categories of causes of fire.

After collecting and reviewing the incident reports, a Pareto chart has been made to indicate the frequency of causes of fire. The results of the Pareto chart are used to identify the main source of fire in Remiks waste facility.

3.3.2.2 Brainstorming

Two brainstorming sessions were carried out to investigate the causes of fire in Remiks facilities in the past few years. A week before the brainstorming sessions, the participants had received brief information about the objectives of the session, different steps of the root cause analysis method, a draft of the Fishbone diagram with main categories of causes. The author was the facilitator in both of the brainstorming sessions. At the beginning of each session, the facilitator provided a short presentation about the topic, the objectives of the sessions, and the rules and procedures of the session for the participants. Afterward, the participants shared their ideas. The unstructured brainstorming approach for sharing opinions was chosen in order to encourage more spontaneous ideas. Hence, each participant could freely explain their inputs. The following experts at Remiks participated in the brainstorming sessions:

- HSE and quality manager
- Project manager of the innovation department
- Operation coordinator of the delivery stations
- Household services department manager

The focus of the brainstorming sessions was to identify different causes of the main source of fire at Remiks. During the discussion, participants agreed to consider all different stages of waste management in Remiks facilities in the investigation, such as waste collection, waste transportation, waste reception, waste treatment, and grinding the waste. The main categories of causes discussed in the brainstorming were manpower, method, management, and wrong-sorted waste. Additionally, an open category, named other, was defined to let the participant share their inputs which do not fit in any other category.

3.3.2.3 Interview with experts

The interview sessions with three experts at Remiks were conducted to collect more detailed data about how the identified causes in the brainstorming can lead to fire at Remiks. The interview sessions were conducted by the author. The questions for the interview were prepared in advance of the session. The semi-structured interview method was chosen for this step. Thus, interviewees could express their opinions through a conversation rather than only answering the questions. During all three interviews, the same questions were asked from the following experts at Remiks:

- Operation coordinator at the waste treatment department
- Department manager of the waste treatment department
- Operation manager of the Remiks Næring As

The focus of the interview sessions was to obtain precise information about the routines and methods of waste management at Remiks that can lead to a fire. However, other causes of the problem and possible solutions for reducing fire incidents were also discussed in the interview sessions.

3.3.2.4 Customer surveys

After the brainstorming and interview sessions, it was found that the largest share of the wrong-sorted hazardous waste comes from the industry sector customers. In order to trace the main reasons for this problem, a questionnaire consisting of six questions was sent out to the industry sector customers. A total of 83 customers responded to the questionnaire. The questionnaire is attached in the appendix.

3.3.3 Root cause identification

At this stage, all data collected from various sources during the previous steps were analyzed to create a list of causes for the fire at Remiks. The cause-and-effect chart or the Fishbone diagram has been chosen to investigate the relationship between the problem and its causes. The first step to create the fishbone diagram was to describe the problem clearly. Since most of the fire incidents at Remiks are due to the hazardous waste that ends up in the waste grinder, the problem was defined as hazardous waste in the waste grinder. Then, the main categories of causes of the problem were identified, namely manpower, method, management, wrong-sorted waste, and other. Figure 17 illustrates the basis of the fishbone diagram and the identified categories.

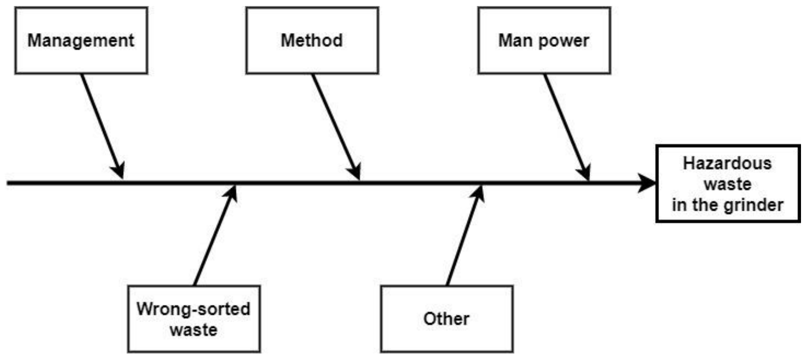


Figure 17 - The main categories of causes of hazardous waste in grinder

After identifying the main categories, the results of brainstorming sessions, interview sessions, and customer questionnaires were analyzed, and all causes of the problem were set in the related categories in the diagram. Finally, the identified causes in the chart were analyzed to determine the root causes. At this stage, a list of potential root causes was identified, and they were classified into more general groups.

3.3.4 Root cause determination

After identifying the potential root causes, various causes have been ranked based on their importance by the experts. For this purpose, the Delphi method has been used to collect the agreement from the experts. The author was the facilitator of the Delphi method. The Delphi method carried out in this research consisted of two steps. First, a questionnaire was sent to all participants involved in conducting the RCA. In the first round of the questionnaire, the participants were asked to choose to what extent they agree that each cause could result in hazardous waste in the waste grinder. There were three alternatives, strongly agree, agree, and disagree. The results of the questionnaire were anonymous, in a way that other participants could not see other participants' answers. Yet, the author had access to the name of the participants and their answers. After getting the outcomes of the first round of the questionnaire, the results were analyzed, and the average score for each question was calculated. Then, the second-round questionnaire was prepared. The questions for the second round were the same as the first round, but they included an anonymized summary of the average score for each question from the first round. Thus, the experts had the opportunity to revise their answers by knowing how the rest of the participants have answered the questions. The Delphi method was carried out in two rounds. Eventually, those causes that received the highest ranks at the end of the second round were determined as the root causes for hazardous waste in the waste grinder.

3.3.5 Recommendations

After identifying the root causes of hazardous waste in the grinder, a list of recommendations for eliminating the root causes or minimizing their impacts was prepared. The recommendations and suggestions made are primarily based on the information from the brainstorming and interview sessions. Since an unstructured approach was taken to hold the brainstorming and interview sessions, plenty of the participants expressed their opinions about the potential solutions throughout the free-flow conversations. Further, the author proposed a number of suggestions based on the discussions with the HSE expert at Remiks, acquired understanding of the problem throughout the analysis, and available resources.

4 Results and discussion

In this chapter, the final results of the analysis are presented, and the research questions of the thesis are discussed. The chapter consists of three sections. In the first section, the main sources of fire at Remiks and its potential causes are discussed. The second section discusses the root cause of the main source of fire at Remiks. In the last section, recommendations for eliminating the root causes and reducing the number of fire incidents at Remiks are provided.

4.1 The main source of fire and its potential causes

In this section, the result of the Pareto chart, flowchart, customer surveys, and the Fishbone chart have been presented and discussed. First, the main source of fire is identified by analyzing the results of the Pareto chart. Next, the flowchart of waste management activities has been presented and analyzed. Then, the outcomes of the customer surveys are studied, the Fishbone chart is presented, and the causes of the main source of fire at Remiks are discussed.

4.1.1 Identification of the main source of fire at Remiks

To find the main source of fire at Remiks waste facility, the data from reviewing the fire incident reports, brainstorming, and interview sessions have been analyzed. A Pareto chart created based on the 31 fire incident reports at Remiks in timespan 07.2015-02.2021 is presented in figure 18. It can be seen from the Pareto chart that more than 90% of fires at Remiks have occurred due to the hazardous waste that goes through the waste grinder. Other sources of fire are technical failures and human error.

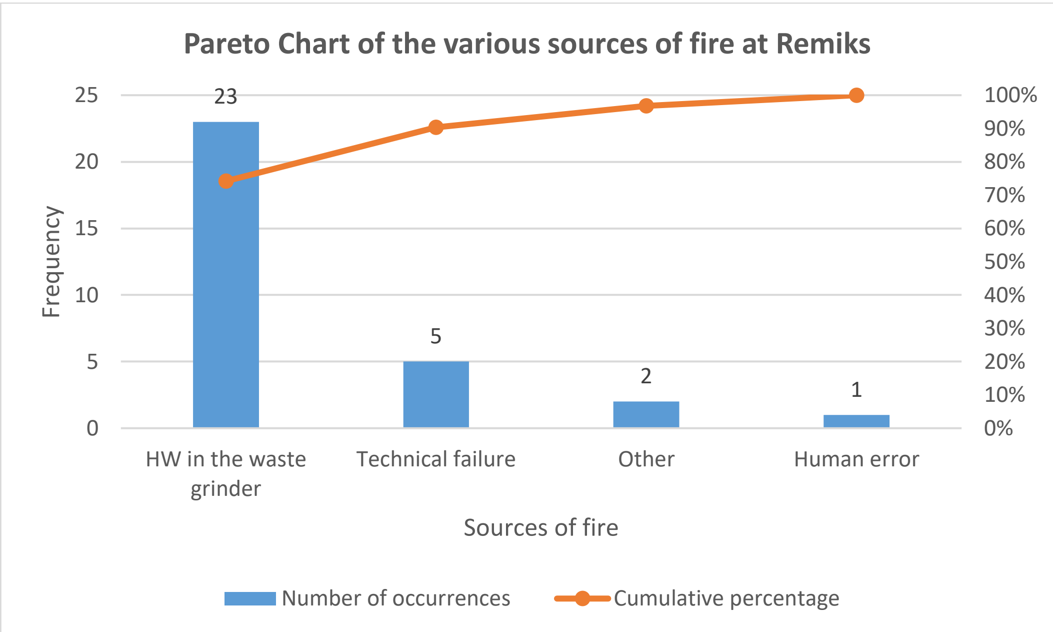


Figure 18 - Pareto chart of the fire incident reports at Remiks in the timespan 07.2015-02.2021

In the brainstorming and interview sessions, the participants agreed that most of the fires occurring at Remiks are ascribed to hazardous waste that ends up in the waste grinder and ignites a fire. Since the experts at Remiks have the same opinion about the main source of fire as the Pareto chart shows, it is validated that hazardous waste that ends up in the waste grinder is the primary source of fire at Remiks.

4.1.2 Flow chart

It is crucial to recognize how hazardous waste can end up in the waste grinder to identify the causes of hazardous waste in the waste grinder. For this purpose, the flow of activities conducted in the waste management process at Remiks is mapped and represented in figure 19. The waste management process at Remiks starts with waste generation by the household and industry customers in Tromsø municipality. The generated waste is then either collected by Remiks or delivered to the delivery stations by customers. The flow chart shows that only generated residual waste from household and industry customers goes through the waste grinder. Hence, hazardous waste that is disposed in the same fraction as residual waste ends up in the waste grinder. According to figure 19, hazardous waste can end up in the waste grinder in the following ways:

- It is dumped into the bags of residual waste by the household customers
- It is left into the residual waste fractions at the delivery station
- It is disposed in the residual waste containers at companies' workplaces
- It is dumped into the residual waste that businesses deliver to Remiks

The flow chart shows that the employees at Remiks control the content of residual waste that is either delivered to Remiks by industry customers or delivered to the delivery stations by the household customers. If the employees find any hazardous waste in the pile of residual waste, they pick it out and return it to the hazardous waste department at Remiks. Thus, insufficient control by any means may result in ending up the hazardous waste in the waste grinder. So, it is important to investigate both why customers dump their hazardous waste in the same fraction as residual waste and why hazardous waste is not being prevented from ending up in the waste grinder through the controlling process at Remiks.

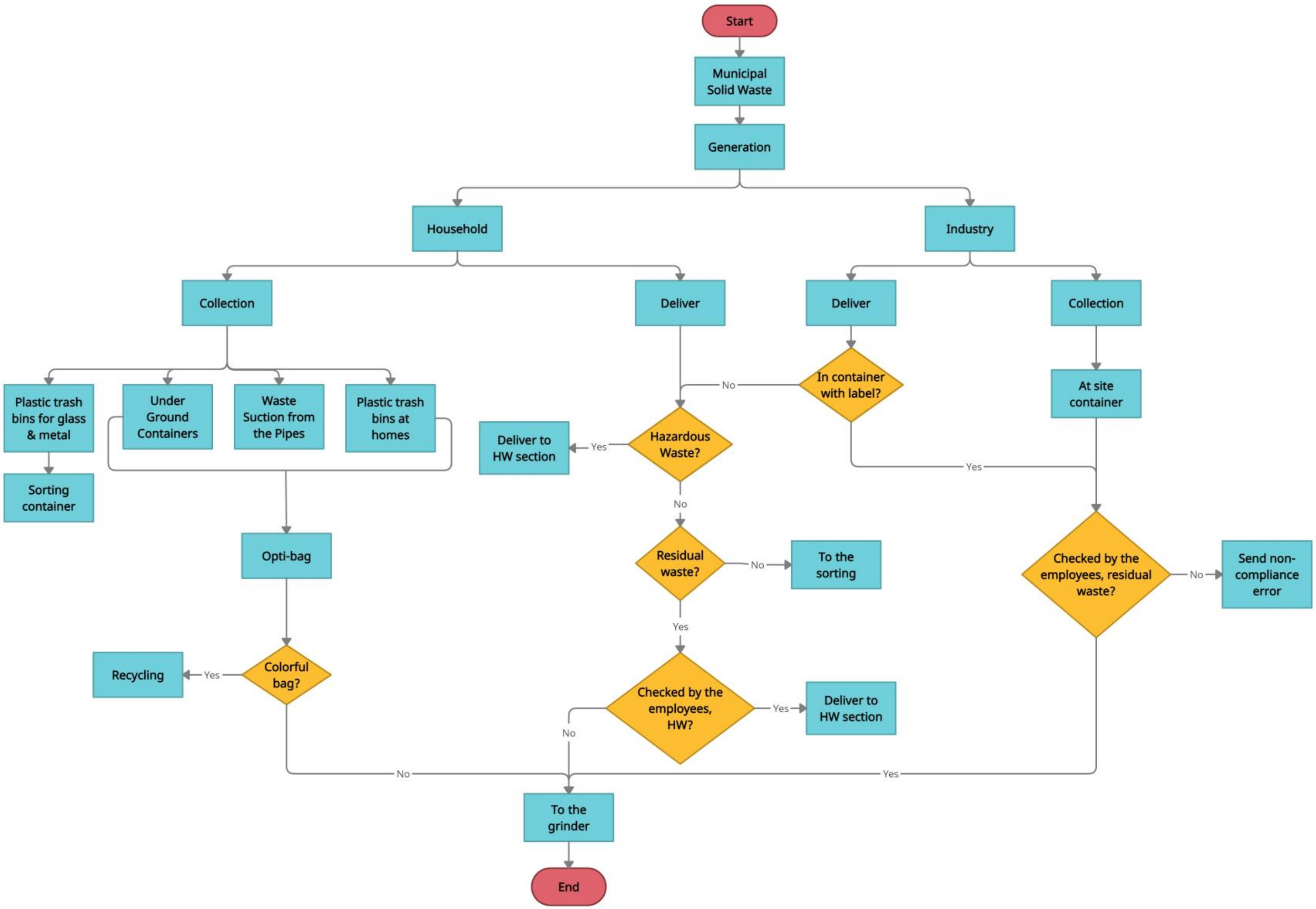


Figure 19 - Flow chart for activities in the waste management process at Remiks

4.1.3 Customer surveys

This section aims to investigate why some customers dump their hazardous waste in the same fraction as residual waste. For this purpose, the results of customer surveys are presented in figure 20 and discussed.

According to figure 20 (a), around 46% of the industry customers at Remiks have not received information about how to dispose of hazardous waste at their workplace. Also, around 17% of the participants have received insufficient information. Moreover, figure 20 (d) shows that about 29% of the participants feel unsure about how to dispose of hazardous waste appropriately. Further, around 15% of the industry customers do not provide any training regarding the disposal of hazardous waste for their employees at all (figure 20 (e)). This shows that some of the staff at workplaces do not receive any information regarding hazardous waste disposal. Thus, the lack of information among the customers of Remiks is a major problem. The customers may choose the improper solutions for disposal of their hazardous waste due to lack of information.

Regarding the challenges of the disposal of hazardous at Remiks (figure 20 (d)), around 15% of the customers believe that delivering hazardous waste to the delivery stations at Remiks is a time-consuming process. Further, approximately 8% of the participants think that disposing of hazardous waste is too expensive, and about 10% of the participants experience other challenges regarding the disposal of hazardous waste. These results show that disposal of hazardous waste might not be easy enough for the customers of Remiks.

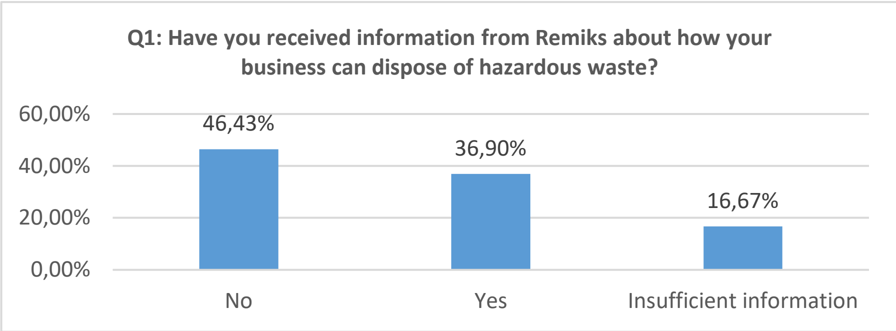
Based on figure 20 (e), about 39% of the participants have experienced that people outside of the company dump waste into their containers even though it is not allowed for them to do so. This means that there is a lack of control over the content of waste that is dumped in the waste containers of some industry customers.

It can be seen from figure 20 (c) that the majority of the industry customers generate electrical and electronic waste as well as batteries by about 62% and 56% of the participants, respectively. Next comes oil and liquid hazardous waste by around 42%, paint by around 36%, glue by around 27%, and gas containers by around 24% of the participants. Moreover, 25% of the participants have said they generate other types of hazardous waste, and about 5% have mentioned they do not produce any of the above alternatives.

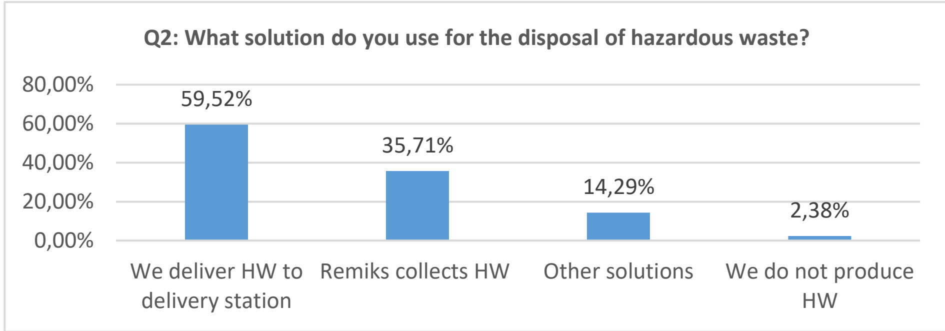
Results of figure 20 (b) illustrate that more than 59% of the participants deliver hazardous waste to the Remiks's delivery stations. Also, Remiks collects the hazardous waste from the workplace of almost 36% of the participants, and roughly 14% of the participants use other solutions to dispose of hazardous waste. Around 3% of the participants do not generate hazardous waste.

The results of the customers' survey are further utilized to complete the Fishbone diagram, which is presented and explained in the following section.

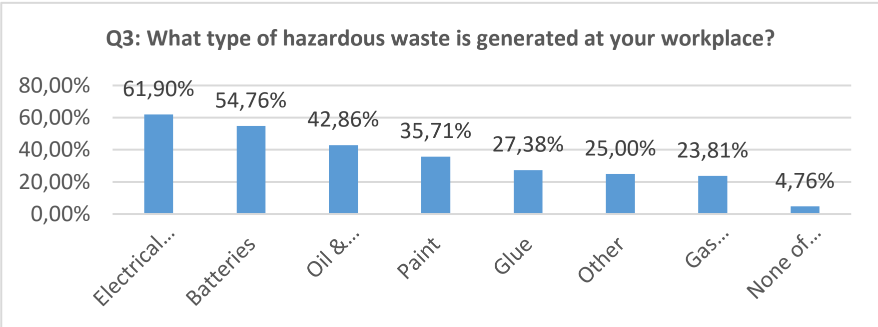
(a)



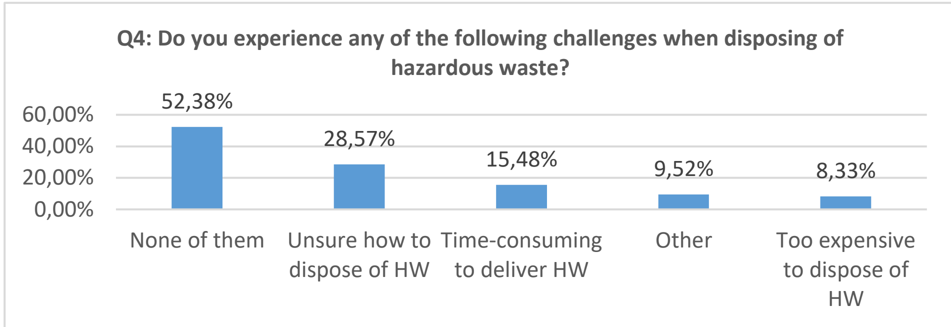
(b)



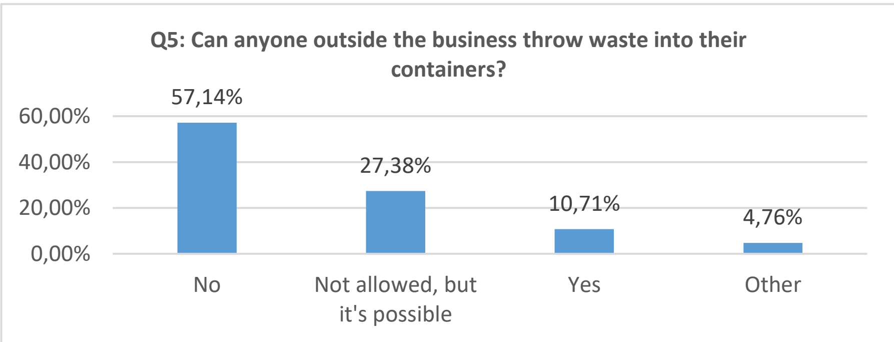
(c)



(d)



(e)



(f)

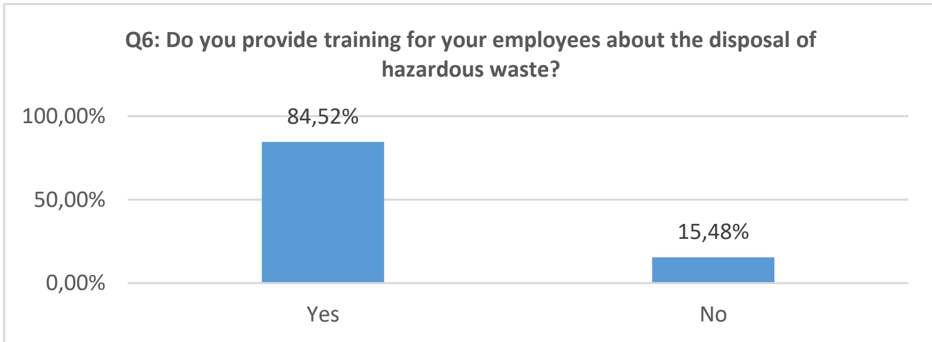


Figure 20 - The results of customer surveys

4.1.4 Causes of the main source of fire at Remiks

The various causes of hazardous waste in the waste grinder have been explored through brainstorming sessions, interview sessions, and customer surveys. The summary of all the causes found through different data collection methods is represented in the Fishbone diagram (figure 21). There are five principal categories of causes in the Fishbone diagram, namely wrong-sorted waste, manpower, method, management, and other. Table 4 represents the abbreviations used in the Fishbone diagram.

Table 4 - The list of abbreviations used in the Fishbone diagram

Abbreviations	
DS:	Delivery station
HH:	HouseHold
HP:	Hazardous Products
HW:	Hazardous Waste
Info:	Information
SH:	Stor Hallen
SS:	Sorting Systems

Wrong-sorted waste: this category includes numerous causes of hazardous waste in the grinder. The wrong-sorted waste can be either from the industry customers or household customers. The industry customers experience the following challenges regarding disposal of hazardous waste:

- Many industry customers do not have information regarding the disposal of hazardous waste or have insufficient information.
- Plenty of industry customers believe that it is not easy to dispose of hazardous waste
- Several industry customers acknowledged that they do not have control over what is dumped in their containers as they have open access containers, and too many people use the containers at the workplace.
- Some of the industry customers use only one container at work as it would be more expensive to pick out the hazardous waste and dispose it separately
- Many foreigners are working in various industries in Norway, and they do not understand the information in Norwegian, nor are familiar with sorting waste

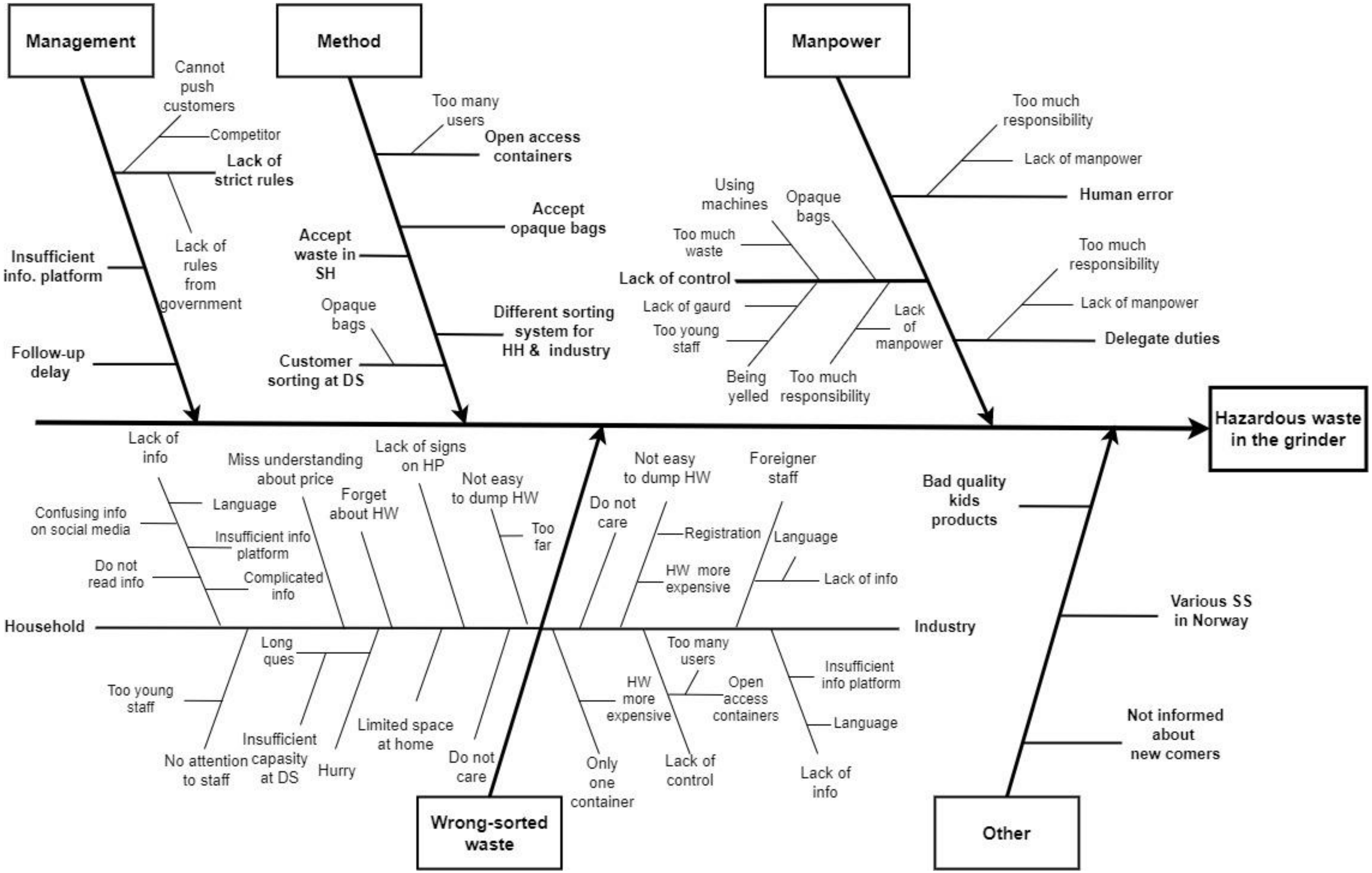


Figure 21 - The Fishbone diagram for hazardous waste in the waste grinder

Moreover, disposing of hazardous waste is accompanied by various challenges for the household customers, such as:

- The delivery station is located too far out of the city center, and it has poor access to public transportation services
- Customers do not get sufficient information regarding waste management and especially the disposal of hazardous waste
- Household customers often have limited space at home, and they need to make their own system for keeping the various type of hazardous waste, whereas Remiks provides bags of different colors for other types of waste
- The delivery stations do not have enough capacity for handling customers during the high seasons, and people need to wait in long queues. Then, they need to hurry up, and it increases the chance of wrong sorting

Manpower: the investigation shows that there is a lack of manpower in delivery stations at Remiks, and the staff has too much responsibility. This problem has the following consequences:

- The employees cannot control the content of all residual waste
- Having too much responsibility increases the probability of making human error
- Due to having too much responsibility, some employees may pass over their duties

Method: this category includes the causes of hazardous waste in the grinder that are related to the procedures at Remiks, such as:

- Remiks allows customers to dump their residual waste in bags that are not transparent
- Industry customers can have open-access containers at the workplace
- Remiks allows industry customers to deliver their residual waste in the workshop, next to the waste grinder
- Remiks allows customers to sort out their waste in the delivery station by themselves
- The waste sorting system for industry and household customers are different

Management: This category describes the causes of hazardous waste in the waste grinder related to the management of Remiks, such as:

- There are not strict policies to prevent customers from dumping hazardous waste into residual waste containers.
- Remiks do not have sufficient platforms to provide information for the customers.
- The management board does not usually take immediate actions regarding contacting the customer after hazardous waste is found in the container.

Other: This category includes some causes that do not fit in any other categories, such as:

- The waste sorting system is different in different municipalities in Norway
- Remiks cannot get information about the people who move to Tromsø for living in order to inform them about the proper way of domestic waste disposal
- There are some poor-quality products for kids that use a battery (e.g., shoes, toys), and when they lose their functionality, people dispose of them as residual waste

4.2 Root causes of hazardous waste in the waste grinder

In this section, the outcomes of the Delphi method are presented and discussed. At the end of the Delphi method, the root causes of hazardous waste in the waste grinder are identified.

After analyzing the Fishbone diagram and all causes of the hazardous waste in the waste grinder, it was found that some of the causes repeat in more than one category in the Fishbone diagram. Through a discussion with the experts at Remiks, the identified critical causes were classified into the following eight categories:

- Lack of control over the content of residual waste
- Lack of information among the customers regarding the disposal of hazardous waste
- It is not easy for customers to dispose of hazardous waste
- Lack of rules and regulations to prevent customers from sorting waste wrong
- Industry customers need to pay extra for the disposal of hazardous waste
- Industry customers do not have control over what is dumped in their waste containers
- Insufficient capacity in delivery stations, especially during the high season
- Different waste sorting systems in each municipality in Norway

The first round of questionnaires containing the above categories was sent to seven experts involved in the brainstorming and interview sessions to rank them. Four people out of the seven experts responded to the first round. After analyzing the results, the second round of questionnaires with the average score of each category in the first round was sent to those four experts again. The results of the final round of questionnaires in the Delphi method are presented in Table 5.

Table 5 - The results of the final round of questionnaire in the Delphi method

Root causes identified	**The percentage of the alternatives**		
	Strongly agree	**agree**	**disagree**
Lack of control over the content of residual waste	25%	75%	-
Industry customers do not have control over what is dumped in their waste containers	-	100%	-
It is not easy for customers to dispose of hazardous waste	50%	50%	-
Lack of information among the customers regarding the disposal of hazardous waste	-	50%	50%
Industry customers need to pay extra for the disposal of hazardous waste	-	50%	50%
Lack of rules and regulations to prevent customers from sorting waste wrong	-	25%	75%
Insufficient capacity in delivery stations, especially during the high season	-	25%	75%
Different waste sorting systems in each municipality in Norway	-	25%	75%

The outcomes of the Delphi method show that the three first categories in table 5 got the highest ranks at the end, and they represent the root causes of hazardous waste in the waste grinder. Since the "Lack of information among the customers regarding the disposal of hazardous waste" was identified as a significant problem while analyzing the results of customer surveys, this category was also determined as a root cause of the hazardous waste in the waste grinder. Thus, the root causes of hazardous waste in the waste grinder are:

Lack of control over the content of residual waste: this is a significant problem at Remiks, and many factors cause the lack of control. Remiks receives around 300 tons of residual waste from both the households and industry sectors every day. According to the data collected in the brainstorming and interview sessions, the greatest part of the hazardous waste that ends up in the waste grinder is from the industry sector. The industry customers can dump their residual waste on the floor in the workshop, where an operator transfers the waste into the grinder using a loader. So, the operator cannot see the content of waste on the ground. Thus, if there is any hazardous waste in the pile of waste, it will most probably be moved to the waste grinder. Additionally, the content of residual waste in the containers from the industry sector is not often controlled before it is directed to the waste grinder. In the delivery stations, the staff to customer ratio is too low, and each operator has many responsibilities. Therefore, there is limited control over the waste that people dump into different fractions due to the lack of human resources. Moreover, the customers are allowed to dump their residual waste in bags that are not transparent, and it makes it difficult for staff to control the content of bags.

Lack of information among the customers regarding the disposal of hazardous waste: the customer survey results show that many of the industry customers do not have enough information about the proper way of hazardous waste disposal. The information provided by Remiks is mainly in Norwegian. Therefore, the foreign staff working in industrial workplaces cannot understand the information. Further, a share of the industry customers has indicated in the customers' survey that they do not provide training for their staff regarding hazardous waste disposal. Thus, the lack of information among the customers can lead to choosing the wrong solution for hazardous waste disposal, for instance, dumping hazardous waste in the residual waste container. According to the brainstorming and interview sessions, many household customers do not have enough information about hazardous waste disposal. In fact, some of them do not know that empty batteries, empty hairsprays, and empty gas bottles are still considered hazardous waste. This problem is because many products lack signs that indicate they should be disposed as hazardous waste when they have lost their functionality. Also, the waste facilities give complicated information to the customers about sorting their waste. There are many different fractions that customers should think about when sorting out their waste. Moreover, local media and newspapers share confusing information about the waste facilities. Remiks informs the customers about the waste management system through its webpage, Facebook page, commercial TV programs, digital events in spring and fall, pop-up stands at university, and Remiks visiting tours for the pupils. Since the information is mainly in Norwegian, some foreign residents, students, and tourists cannot understand the information. However, many customers do not read the information, and some of them, especially older people, do not have access to online platforms.

It is not easy for customers to dispose of hazardous waste: the household customers need to deliver their hazardous waste to the Remiks' delivery stations. They need to make their own system for keeping hazardous waste at home. Some of them have limited space at home and cannot keep their waste until they deliver them. So, the easiest way for them is to dump their hazardous waste into the residual waste bags. Since the household customers do not get a specific packaging for the hazardous waste, they put it together with the remaining waste and forget to deliver them separately at the delivery stations. A big challenge for delivering hazardous waste is that Remiks' delivery stations are located far from the city center with poor public transportation services. Hence, household customers should usually drive a long way and spend so much time to get rid of their hazardous waste. Then, people who do not have a private car and have a busy schedule will get rid of their waste into the remaining bags. The industry customers need to pay extra for disposing of hazardous waste. Additionally, they are required to register the type and quantities of hazardous waste they produced if they deliver it separately. Hence, some industry customers prefer to pay extra to dump both residual and hazardous waste in one container as it is more convenient.

Industry customers do not have control over what is dumped in their waste containers: The industry sector customers often use open access containers at the workplace. The outcome of customers' survey illustrates that in some companies, people outside of the company can dump their waste into the containers as the containers are unsecured. Thus, there is a chance that people outside of the company dump hazardous waste into the residual waste containers. Furthermore, in some companies, numerous users dump waste into one common container, and there are several foreign staff who are not familiar with hazardous waste disposal. For instance, Tromsø shipyard has open access containers, and many Russian boats dump their waste into the containers over the night. Hence, it is difficult for the company to keep control over the content of waste that is dumped into the container.

4.3 Recommendations for solutions

The principals and experts at Remiks have accepted the fact that fires that are ignited by the hazardous waste in the waste grinder cannot be prevented. Yet, various measures can be implemented to reduce the number of fire incidents due to hazardous waste in the grinder at Remiks. Similarly, eliminating the root causes of hazardous waste in the waste grinder (presented in section 4.2) seems to be extremely difficult. Thus, this section aims to provide a number of suggestions to help to reduce the fire incidents at Remiks occurring due to the identified root causes. The measures suggested are based on the information obtained from brainstorming and interview sessions, meetings, inspections, and surveys. Table 6 presents the suggested measures for each root cause identified.

Table 6 - The recommendations and suggestions made for each root cause identified

Root causes	**Recommendations**
Lack of control over the content of residual waste	Increasing human resources Transparent bags
Lack of information among the customers regarding the disposal of hazardous waste	Training for the industry customers Developing a smartphone application Providing information in different languages
It is not easy for customers to dispose of hazardous waste	Hazardous waste reclaim system Pick-up services
Industry customers do not have control over what is dumped in their waste containers	Pre-sorting Labeling containers and waste

Lack of control over the content of residual waste: by increasing control over whatever goes through the waste grinder, the number of fire incidents can be reduced. The content of residual waste delivered by industry customers and those returned to the delivery station requires the most attention. The following suggestions can be considered for raising the control over the content of residual waste:

- Increasing the human resources: Remiks may increase the number of staff who mainly focus on controlling the content of residual waste delivered by the industry customers. The control can be carried out through a pre-sorting system at the main workshop before grinding the waste. Even if the implemented pre-sorting system has a medium or low accuracy, many hazardous wastes can be picked out before creating a significant fire in the waste grinder. Additionally, Remiks may increase the number of staff in delivery stations or recycling centers. If there are enough human resources to ensure that customers sort out their waste into the proper fractions at delivery stations, the probability of ending up the hazardous waste in the waste grinder can be decreased.
- Transparent bags: Remiks can make a rule to only accept waste in transparent bags at delivery stations. The employees at the delivery station can better control the content of the residual waste if it is packed in transparent bags. Hence, if they detect any hazardous waste in the bags, they can pick it out and prevent it from ending up in the waste grinder.

Lack of information among the customers regarding the disposal of hazardous waste: one of the most important steps in reducing the number of fire incidents due to hazardous waste in the waste grinder is informing the customers about the proper way of hazardous waste disposal more effectively. In order to so, the following suggestions can be considered:

- Training for the industry customers: Remiks can provide frequent training sessions for the employees of companies at their workplace. By doing so, Remiks can ensure that everyone at a workplace, including those who have recently started their job, gets enough information about hazardous waste disposal. The training sessions can be held in English for the foreign staff who do not understand Norwegian.
- Developing smartphone applications: a smartphone application can represent a technological opportunity to make the source of information available and accessible for the customers. Various waste management services can be offered through mobile applications, such as digital membership account, payments, personalized offers. The information in the mobile application can be provided in different languages. Thus, those customers who do not understand Norwegian can still get the information and use the application. Moreover, a mobile application gives the customers the opportunity to have a reliable source of information everywhere, whereas conventional sources of information, such as papers and magazines, cannot be available all the time.
- Providing information in different languages: the information regarding the sorting systems and hazardous waste disposal can be provided in other languages, such as English, to help the customers who do not understand Norwegian and tourists to understand the information thoroughly.

It is not easy for customers to dispose of hazardous waste: If Remiks can make hazardous waste disposal easier for the household and industry customers, the probability that they dump hazardous waste in residual waste fractions can be decreased. The following suggestions can be considered to make hazardous waste disposal more convenient:

- Hazardous waste reclaim system: a sorting reclaim system can be designed for electrical and electronic waste and batteries. In this way, the customers can get motivated to return the hazardous waste separately and get their money back. Various reclaim stations can be built in different spots of the city to make the delivery process more convenient for the customers. A reclaim system for hazardous waste can be beneficial to both the waste facilities and customers. The waste company can collect hazardous waste more efficiently and safely. Also, fire incidents due to wrong-sorted hazardous waste can be reduced significantly.

- Pick-up services for hazardous waste: Remiks can offer to pick up the hazardous waste at customers' places. The biggest challenge with pick-up services will be the risk of reaction between different types of waste, such as chemicals, electrical, and flammable fluid waste. The transportation of high volumes of hazardous waste in the city could also be dangerous. Thus, Remiks can provide the pick-up service for only those types of hazardous waste that can be transported safely, such as batteries, empty gas bottles, electrical and electronic waste.

Industry customers do not have control over what is dumped in their waste containers: for the industry sector customers with many employees, it can be challenging to control the content of waste that is dumped in the containers at the workplace. Moreover, using a secured container at a workplace might not be practical. Therefore, the following measure can be implemented to minimize the wrong sorted hazardous waste in the waste grinder:

- Pre-sorting: Remiks can identify the industry customers where many users dump residual waste in a common waste container. Then, the content of residual waste in the waste container from those specified companies can be pre-sorted at Remiks before it goes through the grinder. By implementing the pre-sorting solution, not only the hazardous waste can be picked out of the residual waste, but also it might help to pick out other sources in the waste that can be used for recycling. However, implementing a pre-sorting system requires extra human resources and related facilities.
- Labeling the containers and waste: Remiks can label the residual waste containers by the name of the customer and grind the waste of one container at a time. By doing so, the source of the fire can be tracked if any fire arises during the grinding. Then, the customer can be contacted, and proper follow-up actions can be taken. In this way, Remiks can further identify the needs of those specific customers for training or pre-sorting.

5 Conclusion & future study

In this chapter, the conclusion of this study, together with the suggestions for further research on the topic of this thesis, is presented.

5.1 Conclusions

In the waste industry, fire is a frequent problem, and ongoing efforts aim to prevent fire in waste facilities, reduce the number of fire incidents, or limit the extent of fires. Fire in waste facilities can occur due to various reasons, such as friction, self-ignition, technical failure, human error. The record of fire incidents at Remiks waste facility shows that the main reason for fires occurring at Remiks is the wrong sorted hazardous waste that ends up in the waste grinder and initiates a fire. According to the flow chart of waste management at Remiks, the residual waste from the household and industry customers are the only type of waste that is ground at Remiks. Thus, the hazardous waste must be wrong sorted in the residual waste fraction in order to end up in the waste grinder. The outcomes of the cause-and-effect analysis show that there are many factors regarding the manpower working at Remiks, methods, and procedures at Remiks, management, and customers that cause hazardous waste in the waste grinder. The different causes were analyzed through the Delphi method to identify the main causes. Amongst all the causes of hazardous waste in the waste grinder, the following causes were found to be the most critical ones:

- Lack of control over the content of residual waste that is arrived at Remiks
- Lack of information among the customers regarding the disposal of hazardous waste
- It is not easy for customers to dispose of hazardous waste
- Industry customers do not have control over what is dumped in their waste containers

In order to help to eliminate the causes identified or reduce their impacts, plenty of solutions can be suggested. To increase the control on the residual waste delivered to the delivery stations, Remiks can ask the customers to use transparent bags for dumping the residual waste. Additionally, Remiks can increase the number of employees at delivery stations to ensure that the content of residual waste in the delivery station is controlled. Remiks can provide the information in various languages for the customers, provide training sessions for the industry customers at their workplace, and utilize more efficient information platforms such as a smartphone application. Further, Remiks can develop a hazardous waste reclaim system to encourage the customers to deliver their hazardous waste properly. Also, Remiks can offer a pick-up service of hazardous waste to make the disposal of hazardous waste easier for the customers. Finally, Remiks can identify the industry customers where many users dump residual waste in a common container and design a pre-sorting system for picking out the hazardous waste from the residual waste. Moreover, labeling the waste containers and grinding the waste of one container at a time could provide the possibility for follow-up actions if a fire initiates from the residual waste of a container.

5.2 Future study

The following suggestions are made to conduct further research on the topic of this thesis:

- An analysis can be conducted to measure the viability of each recommendation made for the elimination of the main causes of hazardous waste in the waste grinder. This analysis can compare the required costs, time, and resources with the benefits of each recommendation.
- The extent of various impacts of fire on Remiks waste facility, such as economic and environmental impacts, can be studied.
- The fire extinguishing techniques and tactics to control fires at Remiks can be studied, and suggestions for improvement can be made.
- The compliance of activities at Remiks with regulations, laws, and standards regarding fire safety at waste facilities can be reviewed.
- The fire detection and monitoring systems at Remiks can be reviewed and improvement points can be discussed.

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Appendix A – Customer surveys

In this section, the customer surveys that were sent to the industry customers are listed below.

Avhending av farlig avfall

1. Har du mottatt informasjon fra Remiks om hvordan din virksomhet kan avhende farlig avfall?

- ◯ Ja
- ◯ Nei
- ◯ Ikke tilstrekkelig informasjon

2. Hvilken løsning benytter dere for avhending av farlig avfall?

- ☐ Vi leverer farlig avfall til returstasjonen
- ☐ Remiks henter farlig avfall hos oss
- ☐ Vi genererer ikke farlig avfall
- ☐ Andre løsninger (spesifiser)

3. Hvilken type farlig avfall genereres hos dere?

- ☐ Batterier (fra mobiltelefoner, el-sykler, håndverktøy, startbatterier, m.m.)
- ☐ Elektrisk og elektronisk avfall
- ☐ Gassbeholdere
- ☐ Maling e.l.
- ☐ Lim e.l.
- ☐ Olje eller annen type flytende farlig avfall
- ☐ Andre (vennligst spesifiser)
- ☐ Ingen av disse - Vi genererer ikke farlig avfall

4. Opplever dere noen av de følgende utfordringene ved avhending av farlig avfall?

- ☐ Vi kan være usikre på hvordan farlig avfall skal avhendes
- ☐ Det er for dyrt å ha en avtale om henting av farlig avfall
- ☐ Det er tidkrevende å måtte levere farlig avfall på Remiks sin returstasjon
- ☐ Nei - ingen av disse
- ☐ Andre (vennligst spesifiser)

5. Kan noen utenfor virksomheten kaste avfall i deres containere?

- ◯ Ja
- ◯ Nei
- ◯ Det er ikke tillatt, men teoretisk mulig
- ◯ Annet svar

6. Gir dere ansatte opplæring i avhending av farlig avfall?

- ◯ Ja
- ◯ Nei

Ønsker dere evt. bistand fra Remiks til dette?

Appendix B – the Delphi method questionnaires

In this section, the questionnaires used in the first round and second round of the Delphi method are presented. Since the second round of questionnaires included personal information, an anonymized version of the second round questionnaire is attached.

The first round questionnaires in the Delphi method:

Hazardous waste (FA) in the waste grinder

Finding the root causes for why hazardous waste ends up in the waste grinder

This questionnaire is a part of the research for the master's thesis in collaboration with the Remiks Miljøpark AS. This study aims to find the main causes of fire in Remiks facilities. In order to find the causes of fire, data has been collected through investigating the incident reports, brainstorming sessions, interview sessions, and customer surveys. The data analysis results showed that fire is mostly due to the hazardous waste that ends up in the waste grinder and ignites a fire. In this study, we are looking for:

"the root causes for why the hazardous waste can end up in the waste grinder?"

In this questionnaire, participants should choose to which extent they agree that each cause can result in hazardous waste (farlig avfall) in the grinder (strongly agree, agree, or disagree).

* 1. Please write your name in the box below:

* 2. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"Not enough control over the content of residual waste (Restavfall) coming from the customers, especially industry customers"

○ Strongly agree

○ Agree

○ Disagree

* 3. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"Customers of Remiks do not have enough information about how to dispose of hazardous waste (farlig avfall)

- Remiks do not have sufficient information platforms
- It is complicated for the customers to know what is considered as hazardous waste and what is not
- Information is not available in different languages (only in Norwegian)"

◯ Strongly agree

◯ Agree

◯ Disagree

* 4. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder:

"Disposing of hazardous waste (farlig avfall) is not easy enough for the customers:

- The delivery station (Returstasjon) is too far out
- Poor public transportation system near the delivery station (Returstasjon)
- Customers should make their own system for storing the hazardous waste"

◯ Strongly agree

◯ Agree

◯ Disagree

* 5. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"There are not enough rules and regulation to prevent customers from wrong sorting"

◯ Strongly agree

◯ Agree

◯ Disagree

* 6. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"Industry customers should pay extra money for disposing of hazardous waste (farlig avfall)"

◯ Strongly agree

◯ Agree

◯ Disagree

* 7. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"Industry customers do not have control over what is thrown into their containers"

- ◯ Strongly agree
- ◯ Agree
- ◯ Disagree

* 8. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"The delivery stations at Remiks (Returstasjon) do not have enough capacity for the customers at high seasons"

- ◯ Strongly agree
- ◯ Agree
- ◯ Disagree

* 9. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"The waste sorting systems in each municipality in Norway is different, and it makes people confused"

- ◯ Strongly agree
- ◯ Agree
- ◯ Disagree

The second round of questionnaires in the Delphi method:

Hazardous waste (FA) in the waste grinder [redacted]

Finding the root causes for why hazardous waste ends up in the waste grinder

[redacted]

This questionnaire consists of the same questions as the previous questionnaire. In each question, you can see a table. In the table, you can see what was the average result in the first round, and what was your answer.

Now you have the chance to change your answer.

If you do not want to change your answer please choose the same alternative as you did in the first round.

Please choose to which extent they agree that each cause can result in hazardous waste (farlig avfall) in the grinder (strongly agree, agree, or disagree).

* 1. Please write your name in the box below:

* 2. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

“Not enough control over the content of residual waste (Restavfall) coming from the customers, especially industry customers"

Average result:	[redacted]
Your answer:	[redacted]

-If you <u>want to</u> change your answer: **Choose a new answer below**

-If you <u>do not want to</u> change your answer: **Choose** [redacted]

◯ Strongly agree

◯ Agree

◯ Disagree

* 3.
Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"Customers of Remiks do not have enough information about how to dispose of hazardous waste (farlig avfall)

- Remiks do not have sufficient information platforms
- It is complicated for the customers to know what is considered as hazardous waste and what is not
- Information is not available in different languages (only in Norwegian)"

Average result:	[redacted]
Your answer:	[redacted]

-If you <u>want to</u> change your answer: **Choose a new answer below**

-If you <u>do not want to</u> change your answer: **Choose** [redacted]

◯ Strongly agree

◯ Agree

◯ Disagree

* 4. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder:

"Disposing of hazardous waste (farlig avfall) is not easy enough for the customers:

- The delivery station (Returstasjon) is too far out
- Poor public transportation system near the delivery station (Returstasjon)
- Customers should make their own system for storing the hazardous waste"

Average result:	[redacted]
Your answer:	[redacted]

-If you <u>want to</u> change your answer: **Choose a new answer below**

-If you <u>do not want to</u> change your answer: **Choose** [redacted]

- ◯ Strongly agree
- ◯ Agree
- ◯ Disagree

* 5. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"There are not enough rules and regulation to prevent customers from wrong sorting"

Average result:	[redacted]
Your answer:	[redacted]

-If you <u>want to</u> change your answer: **Choose a new answer below**

-If you <u>do not want to</u> change your answer: **Choose** [redacted]

- ◯ Strongly agree
- ◯ Agree
- ◯ Disagree

* 6. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"Industry customers should pay extra money for disposing of hazardous waste (farlig avfall)"

Average result:	[redacted]
Your answer:	[redacted]

-If you <u>want to</u> change your answer: **Choose a new answer below**

-If you <u>do not want to</u> change your answer: **Choose** [redacted]

- ◯ Strongly agree
- ◯ Agree
- ◯ Disagree

* 7. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"Industry customers do not have control over what is thrown into their containers"

Average result:	[redacted]
Your answer:	[redacted]

-If you <u>want to</u> change your answer: **Choose a new answer below**

-If you <u>do not want to</u> change your answer: **Choose** [redacted]

- ◯ Strongly agree
- ◯ Agree
- ◯ Disagree

* 8. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"The delivery stations at Remiks (Returstasjon) do not have enough capacity for the customers at high seasons"

Average result:	[redacted]
Your answer:	[redacted]

-If you want to change your answer: **Choose a new answer below**

-If you do not want to change your answer: **Choose** [redacted]

- ◯ Strongly agree
- ◯ Agree
- ◯ Disagree

* 9. Do you agree that the following condition can result in hazardous waste (farlig avfall) in the grinder?

"The waste sorting systems in each municipality in Norway is different, and it makes people confused"

Average result:	[redacted]
Your answer:	[redacted]

-If you want to change your answer: **Choose a new answer below**

-If you do not want to change your answer: **Choose** [redacted]

- ◯ Strongly agree
- ◯ Agree
- ◯ Disagree