Sustainable Handling of Water from Coating Process

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Preface

The work described in this master thesis was performed at McNeil AB in Helsingborg. I would like to thank all the people that have been involved in this work. First, I would like to thank my supervisors Ann Andersson and Daniella Cheng for all the support and guidance during this time. I would also like to thank all people that I came in contact with, in order to collect the desired data and samples, for finding the time to help me and for explaining everything in detail when necessary.

I would also like to thank my supervisor Mats Galbe for all support that I received. Another thanks to Per Falås that was not involved in this work but helped me with my laboratories and answered all my questions related to wastewater treatment anyways.

I am now officially an engineer, and it has been a fantastically fun, educative and sometimes challenging to study at Lund University. I am thankful to all professors and teachers that were part of my education for sharing their experience and knowledge. Even though there are new possibilities and challenges waiting ahead, I will surely miss the university from time to time.

Thank you!

Abstract

McNeil AB, located in Helsingborg, Sweden, is a production site for smoking cessation products under the trademark Nicorette®. The biggest process on site is the coating of chewing gums and lozenges, which have the highest production volumes.

The production is expected to increase in the future, and the volumes of process waters are also expected to increase with it. With focus on environment and sustainability, McNeil is interested to investigate how the increase of biochemical oxygen demand (BOD) in the wastewater can be reduced in the future. The increased BOD-load have been identified to come from the coating process where sugar suspensions with high organic content are used. To reduce the BOD-load in the wastewater, the residues of the coating solutions are now collected in the containers and sent for incineration.

The solutions in the collected containers are mostly composed of water and the incineration of these is an energy-intensive process that also required a lot of transportation. The handling today is therefore not sustainable. The goal of this project was to find a more sustainable handling alternative for these waters. By performing analyses on the contents of the containers and evaluating the overall situation regarding the environmental parameters and handling today, the goal of this project can be achieved. By collecting information about the coating process, the substances used and the data for handling today, identification of the possible solutions was performed. The alternatives were then evaluated regarding sustainability, economy and the possibility of implementation.

The performed study has identified a more suitable handling alternative and a proposal for wastewater treatment that can reduce the BOD-load. Unfortunately, one of the considered solutions has shown to be impossible to implement now. Upon further studies and analyses, however, this solution might be implemented in the future.

Sammanfattning

McNeil AB är en producent av rökavvänjningsprodukter Nicorette® belägen i Helsingborg, Sverige. Tuggummi och tabletterna är produkter med högst produktionsvolym och drageringsprocessen av dessa produkter är den största på siten.

Produktionen förväntas att öka i framtiden och med det även utsläpp av processvatten. Med fokus på miljö och hållbarhet är McNeil intresserade av att undersöka hur ökningen av biokemisk syreförbrukning (BOD) i avloppsvatten kan minskas i framtiden. Ökningen har identifierats till drageringsprocessen, där socker lösningar som innehåller mycket organiskt material används. För att minska BOD i avloppsvatten samlas numera dessa lösningar upp i behållare och skickas sedan vidare till förbränning.

Sammansättningen i behållarna varierar, men generellt är vattenhalten hög. Förbränningen av vatten kräver mycket energi och transport. Hanteringen idag är därför inte hållbar. Målet med examensarbetet var att hitta mer hållbara alternativ för hanteringen genom att undersöka innehållet i behållarna och utvärdera situationen med hänsyn till miljöparametrar och hanteringen. Genom att samla information om drageringsprocessen och vilka ämnen som används där, samt genom att samla statistik kring hanteringen, har möjliga alternativ identifierats. De identifierade alternativ utvärderas sedan med hänsyn till hållbarhet, ekonomi och möjlighet för genomförande.

Genom utförandet av examensarbetet har ett mer hållbart hanteringsalternativ identifierats och dessutom har ett förslag kring avloppsvattenrening föreslagits. Ett av alternativen som har undersökts har tyvärr visat sig omöjligt att tillämpa i nuläget men genom att utföra fler analyser och studier kan även detta alternativ tillämpas i framtiden.

Abbreviations

AOP	Advanced Oxidation Process
AP	Aqua Purificata
BOD	Biochemical Oxygen Demand
C	Coater
CIP	Cleaning-In-Place
COD	Chemical Oxygen Demand
CT	Tablet Coater
DM	Dry Matter
EC	Effective Concentration
EU	European Union
GMP	Good Manufacturing Practice
HPMC	Hypromellose
IAAB	Integrated Anaerobic-Aerobic Bioreactor
M	Mixer
MU	Mobile Unit
N	Nitrogen
OD	Oxygen Demand
P	Phosphorus
POME	Palm Oil Mill Effluents
PU	Preparation Unit
RBC	Rotating Biological Contractor
SBR	Sequencing Batch Reactor
SS	Suspended Solids
TU	Toxicity Unit
UAF	Up-flow Anaerobic Filter
UMAS	Ultrasonic-Membrane Anaerobic System

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1 Introduction

The history of McNeil AB started in the beginning of 19th-centuary when Leo AB was founded with Leo-pills against constipation being the first product which was later followed by the painkiller Albyl.[1] Over the decades, the company has been through different mergers and ownership changes but has received its current name in 2006 when it was sold to Johnson & Johnson. The company has since 1995 its focus towards production of non-prescription drugs with its smoking cessation products under the trademark Nicorette® being the most manufactured product. Today, the company has a portfolio of seven different types of Nicorette® products selling them to over 80 countries.[2]

McNeil is concerned about the environment and takes responsibility in protecting it by minimizing the industry's impact on it. A risk assessment is performed in each step with respect to environment, health and safety. From 2017, McNeil is certified as carbon dioxide neutral as a result of a seven-year long process of minimizing energy use and environmental impact. The last step resulting in minimization of the environmental impact and reduction of energy use was the transition from natural gas to biogas.[3]

As the company is the pharmaceutical industry, it is obliged to follow the regulations that are put on pharmaceutical industry by the Swedish government and European Union. Furthermore, as most of the products are classified as pharmaceuticals, the whole production site is under strict regulation of Good Manufacturing Practice (GMP) requiring the products to be of consistent high quality, appropriate for intended use and be able to meet the requirements of marketing or clinical trial authorisation.[4] The production volumes and emissions to the environment are also regulated by the County administrative board, Länsstyrelse, from which McNeil AB receives a permit regarding the production capacity with terms and conditions that must be fulfilled.[5]

One of the major sources of emissions is the process water, and Biochemical Oxygen Demand (BOD) is a widely used criteria for assessment of the water quality, giving an indication of organic pollution with readily biodegradable organic matter.[6] Over the last few years there have been an increase in the BOD in the waters released to the municipal wastewater system. During 2018, the increase has been identified to come from the coating process where a lot of organic material is used. To decrease the values, some of the solutions with high content of organic matter used for the coating process are now collected into separate containers and sent to an external contractor for incineration.[5]

With further market expansion and growing production volumes, an increase in the collected volumes is to be anticipated. Considering that the collected solutions are mainly composed of water, the handling alternative of today does not provide a sustainable solution since the incineration of water is an energy intensive process.

The goal of this project was to evaluate if there is a better handling alternative that can be implemented for these waters or if there is a possibility to avoid the collection of these without affecting the environment. The goal was to be achieved by answering the following questions:

- What is collected in the containers?
- How does the situation look today?
- How the collected waters influence the environmental parameters?
- What can be done to change the handling?

2 Product portfolio

At McNeil, the production of different products takes place[7] where coated products include chewing gums and lozenges. Both chewing gums and lozenges under trademark Nicorette® are used as smoke cessation products and contain nicotine in concentrations of 2 or 4 mg.[8] These products fall therefore under the category of medicated chewing gums and medicated lozenges. Since the problem with high BOD-load is associated with the coating process, only a description of medicated gums and lozenges produced on site is given below.

2.1 Medicated chewing gums

The composition of the chewing gums varies a lot depending on the product recipe, which is often considered as a trade secret. The various ingredients that can be used are polyols or sugars, different gum bases and sweeteners, aromas and colours.[9,10,11] The chewing gum in general consists of two phases – gum base as a discontinuous phase, and a continuous water-soluble phase.[9]

Different types of chewing gums are generally classified into four groups:[9,11]

i. Sugar chewing gums
ii. Sugar-free chewing gums
iii. Coated chewing gums
iv. Medicated chewing gums

The main difference between sugar and sugar-free gums is the components used for the production. While sugar chewing gums use sugar and glucose syrup, the polyols and high intensity sweeteners are used in the sugar-free gums to achieve the same effect.[9,11] It is also proved that the dental health is improved by using the sugar-free gums since the polyols do not provide sufficient calorific value and thus are not metabolised by the oral bacteria.[11]

The coating of the chewing gums can be made from a polymeric film, sweeteners and sugars, waxes, flavours, and colours, and is often seen as a third phase.[9,10,11] There are different coating methods such as encapsulation, extrusion, and dipping, which are chosen depending on the desired characteristics of the end product.[11]

In the medicated chewing gums, a nutraceutical or pharmaceutical compound is incorporated in either the core or the coating allowing for slow and controlled drug release during chewing. The uses of medicated chewing gums include treatment and prevention of dental caries, nausea, and motion sickness.[9,10,11] The major use is however associated with the smoking cessation products. The global market for the medicated chewing gums is expanding primarily due to the addiction to smoking of a large part of the population and the effects that it causes on the oral hygiene.[11] There is however a growing interest in the implementation of this drug delivery system because of its many advantages, including easiness of administration and faster metabolism.[9,10,11]

2.2 Medicated lozenges

The oral route for drug administration is the most common and accepted route.[12] As there are some patients that experience issues with swallowing the tablets or capsules, the lozenges provide a better alternative as they are intended to be held and sucked in the mouth, slowly releasing the pharmaceutical compounds.[12,13]

Lozenges are solid, flavoured, medicated dosage forms with the pharmaceutical compound covered in the sweetened base. The lozenges are usually classified into two major classes with various subclasses according to:[12,13]

i. The site of action
    a. Local effect
    b. Systemic effect
ii. The texture and composition
    a. Chewy or caramel based
    b. Compressed tablets
    c. Soft
    d. Hard

The classification based on the site of action is self-explanatory as the lozenges with local effect soothe the throat or oral cavity, while the lozenges with systemic effect reach longer in the body through the bloodstream and act directly on the specific organ. Examples of lozenges with local effect are antiseptics and decongestants, while vitamins and nicotine containing lozenges are examples of lozenges with a systemic effect.[12,13]

For the classification based on texture and composition, there may be specific reasons for choosing one form over another. As for example in the case of compressed tablets, where the active ingredient is heat sensitive and thus other forms are not possible to implement due to heating involved in the preparation method. The chewy or caramel-based lozenges are highly flavoured caramel lozenges often formulated based on glycerinated gelatine and having a candy base of a mixture of sugar and corn syrup. The soft lozenges can be made from a variety of different compounds such as polyethylene glycol, sugar-acacia, and chocolate. These lozenges can be chewed or left in the mouth for slow drug release. Lastly, the hard lozenges can be seen as solid sugar syrups as they are made from mixing sugar with other carbohydrates. When placing these in the mouth, they should dissolute slowly and uniformly.[12,13]

In the next section, a general description of the coating process is given to provide a better understanding of the process and the problems associated with it.

3 Coating process

Summarizing the production volumes over the course of the last five years in figure 1, the production of the coated gums has increased during the last two years while the production of lozenges has slightly increased over time. The coated chewing gums contribute the most to the production volumes, and therefore the coating process is considered the biggest at the site.[14]

Figure 1: The production volumes of coated smoking cessation products for the period 2017-2021. It should be noted that only the products relevant for this work are shown.

As mentioned before, the increase of BOD in the wastewater has been identified to the coating process. Thus, a better understating of the process and substances used are important for the problem evaluation.

The main purpose of the coating is the protection of the active ingredient in the core from humidity, oxidation, and light, resulting in the prolonged shelf life of the product.[9,10] Furthermore, the coating is done to improve some of the product properties such as taste, function, and visual impact. By providing a smooth surface, not only does the visual impact improve, but also the functionality of the product since the coating is uniformly dissolved. As some of the medications have an unpleasant taste, the flavour aspect is especially important for patient compliance.[9,10,11] For the chewing gums, the coating also provides the crunching sensation when chewed.[11]

The coating process at McNeil can be divided into four separate steps where each solution is prepared in a batch. Although the steps below are presented in a specific order, this is often not the case, as the preparation times for different solutions vary. To ensure that all solutions are ready for the main step in the coater, some of the solutions may be prepared in advance.[15] This order is only used to simplify the description of the process.

1. Production of film emulsion
2. Production of sugar suspension or gloss solution
3. Coating and drying
4. Storage and/or conditioning

The film emulsion primarily containing hypromellose, and flavour is prepared as the first step of the process. For this step, there are three separate stations to produce the coating film named preparation units (denoted PU) available. Two of these are used to produce the gum film, the last one is used for lozenge film. On site, there are also six mobile units (denoted MU) available for transportation of the gum film to the coaters.[15]

Depending on the product to be coated, there are two different solutions that can be prepared. For the gum coating, a suspension is prepared by mixing xylitol with water and pigment to the desired sugar content. When the suspension is prepared, it is pumped to the holding tank of the gum coater. For this step, there are three mixers (denoted M) available. Each of the mixers prepares the suspension to at least two gum coaters (denoted C). The suspension is not used for the coating of lozenges. Instead, the sugar is already mixed in the film emulsion and a gloss solution in a separate tank is prepared.[15]

When both solutions are transferred to the coater, the loading of the gum or lozenge cores to the coater can start. The coating is then performed by spraying and drying the solutions on the rotating cores inside the coater. There are five gum coaters and one lozenge coater on site. One of the gum coaters can be used to coat the lozenges when required.[15]

After finishing the coating process, the gums or tablets are transferred to containers and sent to the conditioning or storage for a required period. After that, the products can be sent to packaging.[15] The figure 2 below summarizes the coating process.

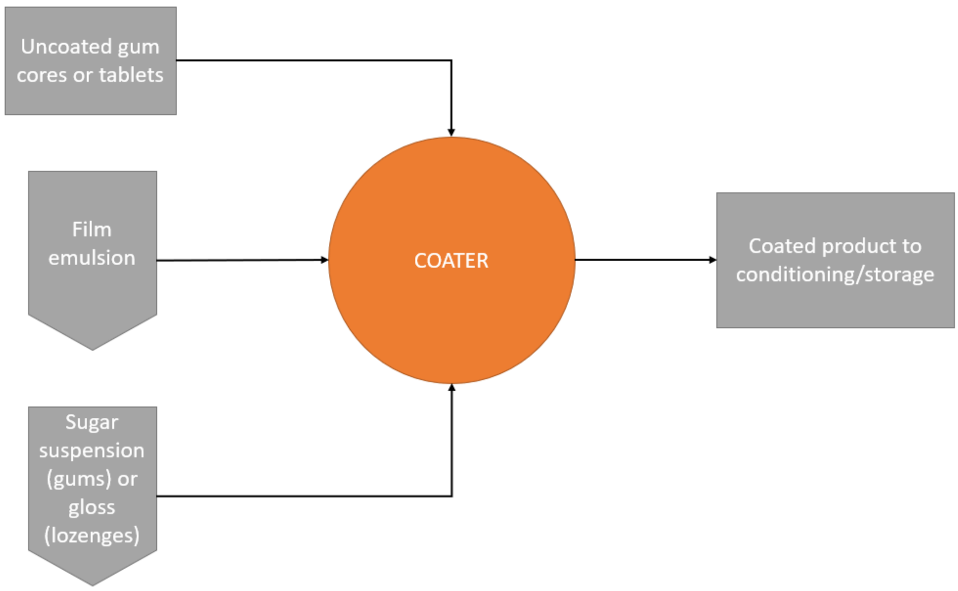

Figure 2: A simplified representation of the coating process.

3.1 Coating substances

There are small differences in the recipes, depending on the product to be coated. The main composition of the solutions is however the same and is summarised in the table 1 below.[16] The main component used for sugar suspension is xylitol while the main component in film emulsions is hypromellose. For gum film, the concentration of flavouring oils is also high.

Table 1: The composition of different solutions used in the coating process, sorted with substances with highest concentrations presented first

Type of solution	Ingredient
Sugar suspension	
	Xylitol
	AP-water
	Corn starch/Gum Arabic
	Titanium dioxide
	Colouring agent
Gum film emulsion	
	AP-water
	Flavour
	Hypromellose
	Sucralose
	Others
Lozenge film emulsion	
	AP-water
	Hypromellose
	Titanium dioxide
	Sugar substitutes
	Flavour
	Others

Further in this section, an explanation for the purpose of each substance used and the relevant properties of the substances are presented. Since the high BOD-load in the wastewater led to the installation of collection containers, the relevant properties are pH, solubility and biodegradability. The substances are presented in the same order as in the table above. As both gum and lozenge films use the same components, these components will be described in the same section.

For the preparation of all solutions, the *Aqua Purificata* or AP-water is used. This is the requirement for the GMP production to ensure the quality and safety of the product as AP-water is purified and is free from microorganisms and contaminants.[17]

The gloss in the lozenge coating is used to give the tablets a shiny finish. A solution with low concentration of approximately 0.5 % is enough to give the desired effect. This solution is not mentioned in the table since the residues of this solution are only present in very small concentration in the container. This component has no hazards associated with its handling and disposal, and it does not have any effect on the quality of the wastewater.[18]

3.1.1 Sugar suspension

Xylitol

Xylitol is a sugar-alcohol also known as pentitol with a chemical formula $C_5H_{12}O_5$. It can be found in some fruits and vegetables in very small quantities. The main uses of xylitol are related to the food and pharmaceutical industries where it is used as sugar substitute due to its tooth friendliness compared to glucose or sucrose. This is due to xylitol's nature as it has a lower calorific value but provides an equivalent sweetening power.[19]

Xylitol is also used in the food industry as a preservative as it prolongs the shelf life of the product and improves its colour and taste. Since it is a chemically inert compound, products containing xylitol cannot mold or ferment. In the confectionery production of sugar-free products it is used together with other sugars or exclusively by itself.[19]

Xylitol has found its highest application in the production of sugar-free chewing gums. In many of the chewing gums it is used as a coating because of its fast crystallization and drying properties. When such a coating melts in the mouth, it provides a cooling effect due to xylitol's negative heat of dissolution.[19] It also masks the taste of the active ingredient, such as nicotine.[9,10,11,19]

Corn starch

Corn starch is a high-polymeric carbohydrate derived from corn grains. Starch is found in many plants but there are only a few plants that are used for its commercial production, with corn (*Zea mays L.*) being the major production source. It has many applications ranging from industrial and food processing uses to uses in cosmetics and pharmaceuticals.[20]

The starch in the production of chewing gums is used as a filler and binder. In combination with xylitol, the desired characteristics in terms of strength and elasticity of the chewing gums can be achieved. It is also used in aiding the processing of suspension as it can swell in cold water thus eliminating the need of preparing the starch paste.[18]

Gum Arabic

Gum Arabic, also known as Acacia gum, is an exudate from *Acacia Senegal* and *Acacia Seyal* and has been used for many different purposes dating back to Ancient times. Both exudates are complex polysaccharides with a low content of nitrogenous material. The main uses of gum Arabic are associated with food processing industries where it is used as emulsifier, glazing agent and flavour carrier.[18,21] In the production of medicated gums, it has the same function as corn starch and is used as filler and binder.[18]

Titanium dioxide

Titanium dioxide is an oxide of titanium that is mined from rutile beach sand. It is considered the whitest material as it has the highest refractive index. When ground to a fine powder it has many industrial applications where it is mostly used as a pigment and opacifier. It can be found in paints, paper, building materials, cosmetics, pharmaceuticals and food.[22]

The European Food Safety Authority has re-evaluated the safety of using titanium dioxide as food additive and it is no longer considered safe due to being unable to exclude the genotoxicity of it. This results in a ban of its use as food additive. As many of the pharmaceuticals use titanium dioxide, this ban will not affect the pharmaceutical industry to avoid medication shortages, but the development of alternatives should be considered, as the ban for the pharmaceutical use can follow.[23] McNeil is already searching for other alternatives that can be used in the production.

Colouring agent

The colour in the suspension is used to improve the visual impact of the product and to distinguish the products from each other.[9,10,11] As the colouring used in the suspension solution is used in very small concentrations, no further mention of its qualities and possible effects will follow.

The table 2 below summarizes the relevant properties of the components used in the production of sugar suspension.

Table 2: The properties of the components used in the production of sugar suspension[18]

Compound	Formula	pH	Solubility in water	Biodegradability
Xylitol	$C_5H_{12}O_5$	5 – 7	642 g/l at 25 °C	Easily biodegradable
Corn starch	$(C_6H_{10}O_5)_n$	4.5 – 7	Soluble	Readily biodegradable
Gum Arabic	$C_5H_{20}NNaO_4$	4.1 – 4.8	Soluble	-
Titanium dioxide	TiO_2	7	Insoluble	Inorganic substance

3.1.2 Gum and film emulsion

Hypromellose

Hydroxypropyl methylcellulose, also known as hypromellose (HPMC) is a cellulose derivative with a linear polysaccharide cellulose chain and ether-linked methoxy and hydroxypropyl groups. It is semi-synthetically prepared by treating the naturally available cellulose with sodium hydroxide.[24]

There are different commercially available types of HPMC with various chemical structures, molecular weights, particle sizes and viscosities and the different types are generally identified by codes. The codes distinguish between the substitution degrees indicating the average percentages of methoxy- and hydroxypropoxy- groups. The viscosity of the polymer is also denoted in the product name. It is a polymer widely used in the pharmaceutical industry since it forms a gel layer upon swelling providing a controlled drug release.[24]

HPMC has many applications and there are many studies related to its use in different areas. In the production of the chewing gums and tablets, it is used as a coating film protecting the active ingredient and controlling its release.[10,18,24]

Sucralose

Sucralose is a substituted disaccharide derived from sucrose through its selective chlorination. By altering the properties of sucrose, the sucralose provides a 600 times greater sweetness with zero calories. Because of its high stability, the sucralose is an attractive sweetener for food and beverage industries where high temperatures and elevated pH are used. By providing high stability, the sweetness of the product can be maintained throughout the entire shelf-life.[18,25]

Sucralose can be found in many of the food products such as cereals, desserts, gums, soft drinks and sauces. Since the sucralose is calorie free, it can be found in many of the sugar-free products where it acts as sugar substitute by providing sweetness similar to glucose and sucrose. It is also better for tooth health compared to glucose and sucrose by maintaining the teeth mineralization.[26]

By replacing the sugars with high intensity sweeteners such as sucralose, the properties of the chewing gums such as release of flavours and product texture are also affected. Sucralose also aids in the moisture retention and taste improvements by masking the unpleasant taste of the active ingredient present in the medicated chewing gums.[9,11]

Flavour

Flavour is one of the most important qualities of the product giving a direct substantial effect even if present in low concentrations in some products. By incorporating flavour in the product formulation, the palatability is improved, and the taste of the active ingredient is masked.[9,10,11,12] For both film emulsions different flavours are used. The flavours are, in most cases, mixtures of different components resulting in the desired properties. What is common for most of the flavours is their hazards towards health and environment. The concentrated flavours can cause skin irritation, allergic reaction and are also toxic to the aquatic life.[18]

Others

To aid the mixing of the of the components, an emulsifier is added. It also helps with incorporation of flavours and provides an even flavour distribution.[10] Furthermore, an additional sweetener is added to provide taste more similar to sucrose and to make a product more palatable.[9,11] Some of the components used in the production of film are not readily biodegradable, but their concentration in the solution is low.

The table 3 below summarizes the relevant properties of the components used in the production of film solutions.

Table 3: The properties of the components used in the production of film emulsions[18]

Compound	Formula	pH	Solubility in water	Biodegradability
Hypromellose	$C_{56}H_{108}O_{30}$	5 - 8	Soluble	Expected to biodegrade very slowly
Sucralose	$C_{12}H_{19}Cl_3O_8$	7	Complete 30% w/v at 25 °C	Readily biodegradable

4 Situation today

In order to further understand the problem, a better understanding of the situation today is required. As the first step of the problem evaluation, the permit and regulations at McNeil are analysed to understand what requirements are imposed by the county and municipal authorities. Furthermore, the situation is further evaluated based on the handling today and how it affects the environmental parameters.

4.1 Permits and regulations

The production volumes and emissions to the environment are regulated by Länsstyrelse from which McNeil receives a permit regarding the production capacity with terms and conditions that must be fulfilled. Among other things, the terms regulate the permitted emissions to air and water. Other terms include the sound levels with risk for noise, the release of odours to the air and the handling and sorting of the waste.[5] The permitted production volumes and environmental parameters can be seen in the tables 4 and 5 below.

Table 4: The yearly permitted and actual production volumes for different types of products[5]

Type of product	Permitted production	Production 2021
Mixtures/Ointments	2 000 tons	97 tons
Effervescent/Tablets	2 000 tons	180 tons
Smoking cessation products (Gum)	4 600 tons	3793 tons
Smoking cessation products (others)	750 million units	82 million units

Table 5: The permitted environmental parameters[5]

Parameter	Permission
Organic solvents, VOC	10 ton/year
Dust	5 mg/Nm^3
NO_x	60 mg/MJ
BOD_7	300 ton/year
BOD_7/COD	> 0.4
pH	6.5 – 10

The emissions are mainly categorized in two different types of emissions – emissions to air and to water. The site is located close to the city centre and operates in a limited space. Due to its closeness to residences, the emissions to air are especially emphasized as the site uses flavouring agents and solvents.[5] The parameters that are important for this work are the ones associated with emissions to water. These include pH, Biochemical Oxygen Demand (BOD_7), and BOD_7/COD ratio with COD standing for Chemical Oxygen Demand.

The measurement of Oxygen Demand (OD) is an important indicator used for evaluation of the organic pollution in the water. It gives an indication of how the combination of conditions and substances affects the oxygen availability for the aquatic life. Both the BOD and COD indicate the organic pollutions in water. While BOD gives an indication of the biodegradable fraction, the COD gives an indication for the fraction that can only be oxidised chemically. The BOD/COD ratio on the other hand indicates how much of the total organic material in water is biodegradable.[27]

4.2 Connection to the municipal treatment plant

All water is supplied to Helsingborg from Sydvatten and the Bolmen lake in Småland. The water from Bolmen is led to Ringsjöverket where it is treated and then transported to Örby field in Helsingborg. Here, the water is passed through gravel and filtered. After a period of three weeks, the water is pumped to the water supply network after ultraviolet treatment ensuring that the water is free from bacteria. All the facilities in Helsingborg, Höganäs and Ängelholm connected to the municipal water network can then use the water.[28]

The emissions to water come from the generated sanitary wastewater, process, cooling, storm and drainage waters. McNeil is connected to the municipal wastewater system and the water from production, offices and laboratories is diverted to the local wastewater treatment plant, Öresundsverket.[5] Here, the water is first mechanically treated in a grid chamber, removing materials larger than 3 mm. The water is then further cleaned from gravel and stones in a sand trap. To further separate larger particles from water and produce an easily degradable source of coal, the water is further led to the sedimentation basins. After the mechanical treatment, the water is then biologically treated in an activated sludge process with aerobic and anoxic zones. With the aid of microorganisms, the organic material present in water is degraded and nitrogen and phosphorus that are required for the growth of microorganisms are also removed. The excess of microorganisms that follows with the stream to the next step is separated through sedimentation and the water is passed through a final sand filter before it is released to the Öresund.[29]

The wastewater from the industries can be diverted to the nearby watercourse and stormwater runoff or to the municipal wastewater network. To divert the wastewater to the wastewater network, the water must be treatable since a diversion of clean wastewater results in unnecessary load to the wastewater treatment plant. The wastewater is considered treatable if it has enough organic material, nitrogen or phosphorus. The criteria that define the water as treatable are the concentration of BOD higher than 10 mg/l, nitrogen higher than 10 mg/l or phosphorus higher than 0.3 mg/l. The water is considered treatable if one or more of the criteria are fulfilled. In other cases, and if no other harm is expected, the wastewater is considered clean and can thus be diverted to the nearby watercourse or stormwater runoff.[30] The concentrations are therefore measured on a monthly basis to ensure that the water is treatable and enable quick response if any changes are detected.[5]

The analyses are performed by the accredited laboratory and the parameters measured are BOD_7, COD, pH, suspended solids (SS), total nitrogen (N), and total phosphorus (P).[5] If the measured values exceed the normal content, a fee over the normal content is paid according to the table 6 below.[30,31] The override fees are adjusted each year to match the costs of ongoing projects but also consider the new investment costs to provide funds for development of the water and sewage services.[31]

Besides the measurements of BOD and COD, suspended solids are also measured. This is of importance for the wastewater treatment plant as it indicates the concentration of particles present in wastewater and thus the quality of the water. The higher the concentration of SS, the higher the load to be expected in the wastewater treatment plant. If the load is high, more oxygen is required to remove the particles. By measuring the SS at the source, the wastewater treatment plant can get an understanding of how the stream will affect the total load of the plant and it also helps to quickly react if any changes are detected.[32]

Table 6: The override fees for emissions to water, inclusive taxes[31]

Pollution	**Normal content (mg/l)**	**Override fee 2021 (SEK/kg)**	**Override fee 2022 (SEK/kg)**
BOD_7	260	4.45	5.01
SS	260	5.34	6.00
Total-N	52	97.66	109.88
Total-P	10.5	53.26	59.93

The samples for the monthly report are taken once a month during a randomly chosen week from the site's two connection points S1 and S5. Five collective samples from each connection point for the whole week are then sent for an analysis. The BOD and COD are analysed every month while total nitrogen and total phosphorus are analysed every third month. The S1 point receives wastewaters from the production of the nasal and mouth sprays while the S5 point receives wastewaters from the production of lozenges, nasal spray Rhinocort®, the coating process and the packaging of gums.[5] The measured parameters for the past three years are presented in the table 7 below. Since the production differs over the course of the year, the composition and volume of the wastewater varies as well, and the averages of the measurements are thus shown.[33]

Table 7: The monthly averages of the measured parameters reported to the municipality[33]

Year	Point	pH	Flow (m^3)	BOD_7 (mg/l)	SS (mg/l)	Total-N (mg/l)	Total-P (mg/l)	BOD/COD
2019								
	S1	8.1	2771	1259	195.6	26.3	4.3	0.4
	S5	8.3	1455	9089	278.8	15.5	1.2	0.6
2020								
	S1	7.8	1678	860	72.0	11.3	4.7	0.4
	S5	8.6	2116	6258	184.2	4.7	0.6	0.6
2021								
	S1	7.6	358	1819	35.3	7.9	4.7	0.4
	S5	8.4	1969	7060	163.0	7.3	1.1	0.6

The figure 3 below gives a better representation of the variations in the measurements. As the focus of this work is the BOD-load, only the variations in the flow from the connection points and BOD parameters are shown. The variations that are seen are, in some cases, the results of faulty flow meters or the issues with the sampling.

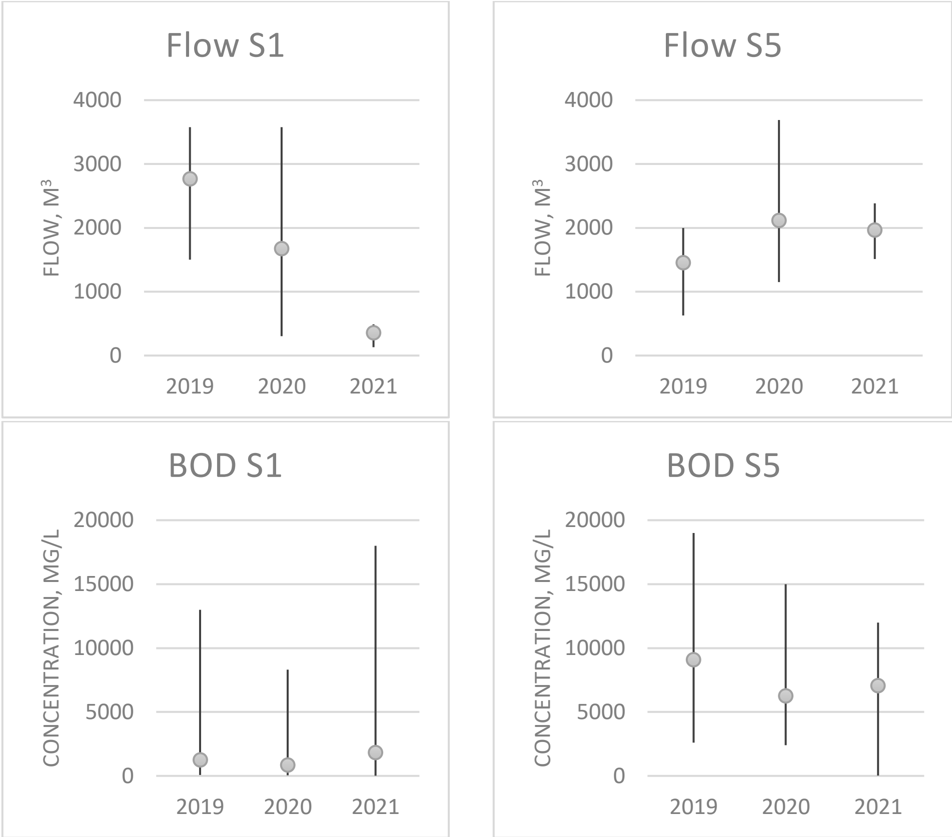

Figure 3: Visual representation of the variations in the flow and the BOD measurements for S1 and S5 connection points. The graphs represent the highest and lowest measured values as well as the calculated averages (grey circle).

Based on the measurements taken at the connection points, the total BOD-load during a year can be calculated. The yearly load is calculated as a sum of the monthly loads that are in turn calculated from the flow and BOD-concentration. The BOD-load from S1 is 4 tons for 2021 while the BOD-load from S5 is 171 tons, resulting in the total amount of 175 tons.

Table 8: The calculated BOD-loads from the S1 and S5 connection points over a period of three years

Connection point	2019	2020	2021
S1	36 tons	26 tons	4 tons
S5	149 tons	147 tons	171 tons

From the tables 7 and 8 above it can be seen that the major contribution to the BOD-load is generated from S5. This is also consistent with the decision to collect the solutions in the coating process, as these were earlier sent to the municipal wastewater treatment plant through the S5 point. It can also be seen that suspended solids, nitrogen and phosphorus are only present at low concentrations and the pH is in the acceptable range.

A peak during 2018 in figure 4, that represents the BOD-load during the last five years, is when the problem with BOD-load was identified for the first time. This year however, an issue with the sewer system with faulty connections was also discovered and resulted in the increase of the load. This year there were also issues with the flow meters resulting in the estimation of the flows for the monthly measurements.[5] After the issues were resolved, the BOD-load returned to its more normal linear trend. Considering this, the value for 2018 should have probably been around 170 tons. Of most importance in this graph is the value for 2021. With start of the collection by the end of 2020, the overall BOD has decreased after the installation of the containers. It proves that the urgency of the issue has been slightly reduced.

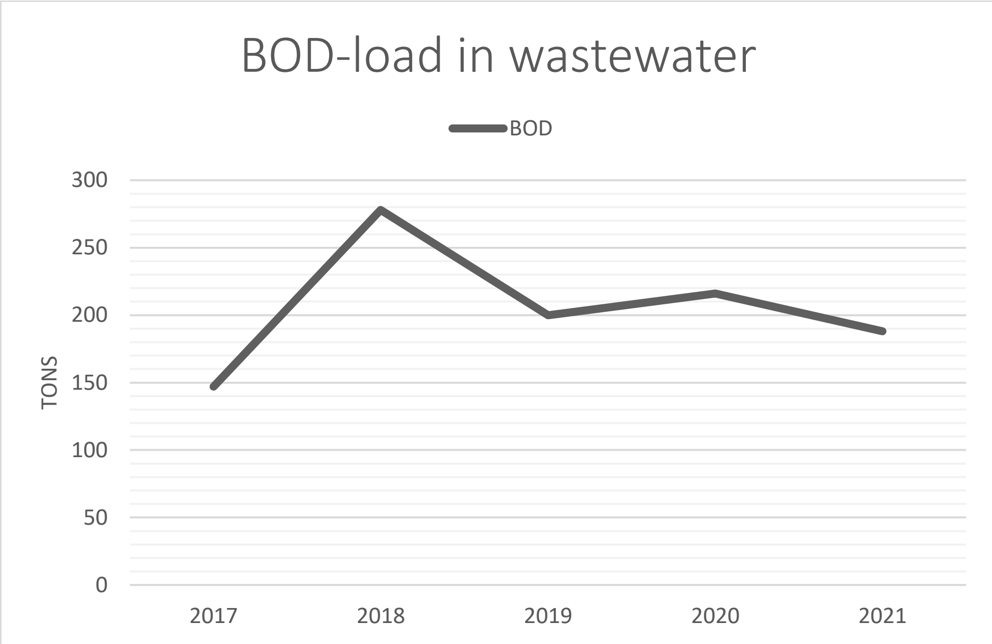

Figure 4: The yearly BOD-load in the wastewater. The release of other solutions in the production of other products is also considered in the calculation of the total BOD-load.

4.3 Handling today

The production on site is batchwise and thus some of the solutions are prepared in excess to ensure that the production capacity is fulfilled.[15] As the GMP manufacturer, it is not allowed to reuse the solutions of the batchwise production to avoid contamination and mix up. After the batch is finished, the residues of different solutions are either released to the municipal sewer system or collected, and the equipment is then cleaned. The collection is performed after the batch is finished and the residues of the solution are drained to a collection container further called CIPAX. Not only are the residues of the solutions collected, but also some of the water used for cleaning of the equipment as it can still be high in BOD-concentration.[15] The filled CIPAX containers are then collected by an approved recycling and waste management contractor Ragn-Sells and transported to the incineration plant SYSAV located in Malmö, Sweden. Prior to and after emptying the containers, the truck is weighed, and the total incinerated amount is calculated. This weight is then used to charge McNeil for the waste handling. The costs and the collected amounts for the past three years can be seen in the table 9 below.[34]

Table 9: The amount of water sent for incineration and the costs associated for the past 3 years[34]

	2019	2020	2021
Amount (tons)	244	283	368
Transportation (SEK)	126 750	196 170	250 744
Container rent (SEK)	27 461	28 871	29 209
Handling cost (SEK)	436 967	502 683	673 879
Total cost (SEK)	**591 179**	**727 724**	**953 832**

The amounts in the table 9 account for all water solutions that are sent to Ragn-Sells. These include the coating waters and the waters from the production of nasal and mouth sprays. The waters from the coating process account for over 90 % of the total amount.

The increase for each year can be explained differently. Before 2020, when the problem with the BOD-load has been identified, only the film solutions were collected into CIPAX containers as they contain flavour oils that are hazardous to the environment.[5] The collection of the sugar suspension started in the end of 2020, but the production volume has greatly increased during 2020 (figure 1) explaining the increase in the amount. By 2021, an increase of 30 % in the amount of waters can be seen. With only a slight increase in the production of lozenges, this increase can be mainly associated with the collection of sugar suspension.

The main cost is the handling or, more precisely, the incineration cost that makes up for around 70 % of the total cost. Considering that this is the total cost for incineration of water, the price for incineration of each ton is 1831 SEK.

4.4 Cost today

Today's handling costs do not only consist of the costs for the incineration of these waters but also include the costs for override fees. Furthermore, as there are production residues that are collected, the costs for unutilized raw materials should also be considered. In the table 10 below, the average prices for the raw materials that are present in the highest concentrations in the solutions are presented.[35]

Table 10: The costs for the raw materials present in highest concentration in the production of different solutions[35]

Raw material	Cost (SEK/kg)
Xylitol	37.70
Titanium dioxide	90.53
Hypromellose	251
Flavouring oils	608

The table 11 below summarizes the major costs associated with wastewater that are calculated and reported every year. The override fees in the table below are only for the connection point S5 as this is the point where the water used for the coating equipment is released. As the solutions from coating are the major contributors to the incineration amounts, this combination of override fees for S5 and incineration costs should give a good representation of the coating wastewater economy.

Table 11: The total cost of today, consisting of override fees and incineration

Type of cost	Cost 2019 (SEK)	Cost 2020 (SEK)	Cost 2021 (SEK)
Override fees	573 689	712 338	734 569
Incineration	591 179	727 724	953 832
Total cost	**1 164 868**	**1 440 062**	**1 688 401**

From the table above, the contribution of both costs to the total cost during 2019 and 2020 are nearly the same with approximately 51 % accounting for incineration costs. During 2021 the incineration cost accounts for approximately 56 % of the total cost.

5 Methodology

As the first step of the work, the analysis of the cleaning process is performed to evaluate what is going into the CIPAX containers. In order to understand that, the information regarding the cleaning is collected. As the recipes differ depending on the product being produced, only major and important steps of the cleaning are summarized for each of the equipment. When an understanding of the cleaning process and a better understanding of the contents of each CIPAX are achieved, the analysis of the contents is performed to understand how each container contributes to the environmental parameters.

5.1 Cleaning of equipment

The cleaning of the equipment is performed in place, Cleaning-In-Place (CIP). There are different requirements on when the equipment must be cleaned, often based on what type of solution is produced. The most important one is cleaning after each batch.[15]

The CIP-cleaning includes automated steps according to the required CIP-recipe and manual steps performed by the operators. There are seven CIP-stations that clean different equipment. Two of the stations have a different cleaning and handling method and are out of scope for this project. The visual summary of the CIP-stations and the equipment that is cleaned on these stations is shown in figure 5 below.[15,36]

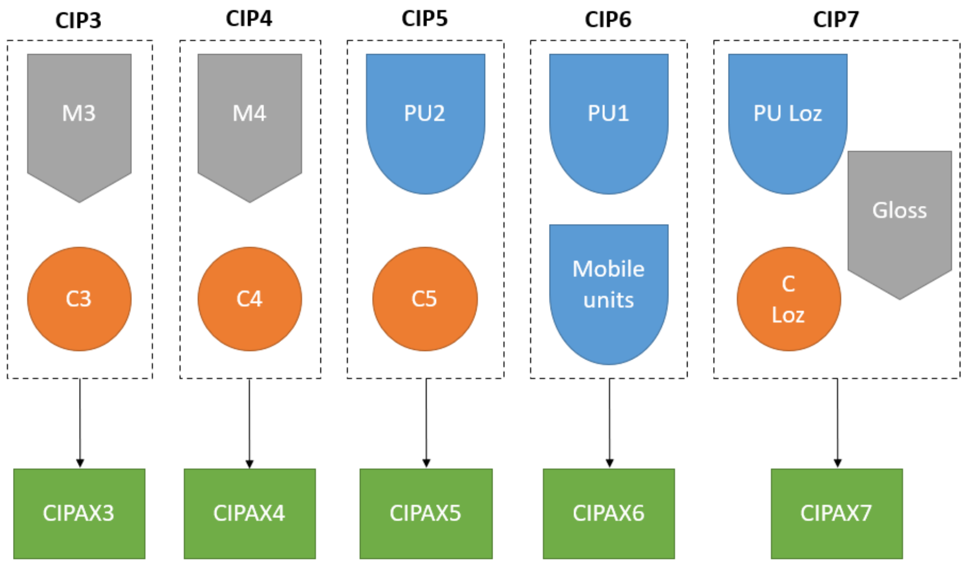

Figure 5: The visual summary of CIP-stations and the equipment that is cleaned on these stations. M – mixer, C – coater, PU – preparation unit.

To get a better understanding of the situation and how each solution contributes to the total amount of collected water, the number of changes of each CIPAX during a year are also calculated. This way, an approximate, percentual contribution of each solution can be obtained. This also gives an indication of where the problem is of highest priority.[15,36]

5.1.1 CIP-station 3

The CIP-station 3 serves the cleaning of mixer 3 and coater 3. First, the remainder of the suspension in the mixer and the holding tank is drained to CIPAX. When this is done, the CIP can be started and involves the cleaning steps of rinsing of the unit with cold and warm water, washing with a detergent and rinsing with AP-water for disinfection. During each of these cleaning steps, the valve to the CIPAX is opened for a few seconds to clean the pipes that lead to the CIPAX. This is done to ensure that the pipes are not clogged, since xylitol can crystallise upon cooling. The cleaning process is finished by draining the remaining liquid with air purge.[15,36]

5.1.2 CIP-station 4

The CIP-station 4 serves the cleaning of mixer 4 and coater 4. As in the CIP-station 3, the remainder of the suspension from the mixer and the holding tank is drained to CIPAX. The CIP-cleaning steps are the same as for CIP-station 3.[15,36]

5.1.3 CIP-station 5

Unlike CIP-stations 3 and 4, this station serves preparation unit 2 and coater 5. The coater is cleaned in the same manner as coater 3 and 4. The remainder of the suspension in the holding tank is drained to the CIPAX and the cleaning is started. As in stations 3 and 4, the valve leading to the CIPAX is rinsed during the cleaning steps.[15,36]

The cleaning of the preparation unit is slightly different. In the first step, the remainder of the film is drained to the CIPAX using compressed air. The tanks are then rinsed with cold water that is also sent to the CIPAX as this water still contains flavouring oils. The subsequent cleaning steps are the same as above with the unit being rinsed with cold and hot water, washed with detergent and disinfected with AP-water.[15,36]

5.1.4 CIP-station 6

This station serves the cleaning of preparation unit 1 and the mobile units that are used for film transportation. The remainder in the preparation unit and the mobile units is first blown out into the CIPAX with compressed air. The units are then cleaned in the same manner as the preparation unit 2 and the remainder of the film, as well as first rinse with cold water, are collected in the CIPAX.[15,36]

5.1.5 CIP-station 7

The last station serves the cleaning of the lozenge coating equipment – preparation unit, coater and gloss tank. The cleaning recipe for preparation unit and coater differs from the recipes above. As with the other CIP-stations, the remainder is first drained to the CIPAX container, but in the next step the equipment is rinsed in cycles using a weak detergent solution to improve cleaning. This first rinse is also drained to the CIPAX container. In the following step, the equipment is washed again with a slightly higher concentrated detergent solution which is then sent to the neutralisation tank where pH is adjusted to enable release to the drains. The equipment is then washed in the similar manner as above, with cold water that is also sent to the neutralisation tank followed by rinse with AP-water that is in turn sent to the drains. The cleaning is finished by blowing out the residues to the drains. The coater is also dried with air. The gloss tank is cleaned in the similar manner as gum preparation units.[15,36]

5.2 Search for relevant solutions

Based on the composition of each solution (see section 3.1 Coating substances) and the equipment cleaned on each CIP-station, it is evident what components can be expected in each CIPAX. The search for relevant solutions is conducted based on the components but also by contacting different authorities and companies. As high BOD-loads are still present in the wastewater, different methods for wastewater treatment are also analysed.

5.2.1 Waste handling

The waste handling in Sweden follows the European Union directives. The European Waste Framework Directive characterizes the concepts and definitions related to waste and its handling. The EU members are to improve their waste handling, taking the directive as a guidance. The two main objectives of the framework are to improve the efficiency of resource utilization and to prevent and reduce the negative impacts associated with waste handling. By applying the concepts defined in Waste Hierarchy, which is used as a foundation for waste management, the members of EU can improve the waste handling.[37,38]

The Waste Hierarchy has five levels of disposal, recovery, recycling, preparation for re-use and prevention (figure 6).[37,38,39] Disposal, where the waste is landfilled, is the lowest level in the hierarchy and is undesirable. If the waste cannot be recycled, the preferred handling method is the energy recovery. By incinerating the waste, the extracted energy can be used for electricity and power generation. If the waste cannot be re-used, the materials present in waste can be recycled and the material itself can be used for production of other products. The re-use of waste implies the extension of its use. Something that is seen as waste can be seen as a valuable source for someone else. At the top of the waste hierarchy is the prevention of waste generation. This is where the production of products has an efficient use of the raw materials, and the consumption is at minimum.[39]

Figure 6: The visual representation of the waste hierarchy.

One of the relevant authorities to contact is the Swedish Waste Management and Recycling Association, Avfall Sverige. The members of Avfall Sverige make sure that their vision of "Zero Waste" is fulfilled by making sure that waste is collected and recycled. By founding the association in 1947 the goal was to enable the people to exchange experience and drive the waste management towards development. The activities have not changed since and the association still provides a place for exchange, development and education.[40]

Avfall Sverige identifies four different waste treatment methods with each method being suitable for different types of wastes:[40]

- Material recycling: what is seen as waste may be seen as the source if handled correctly. By recycling materials, the development is pushed towards a more sustainable society, the consumption of virgin material is reduced, and the energy is saved.

- Biological treatment: the waste is anaerobically digested or composted with the main purpose being the circulation of nutrients. Although the material is not reused, the nutrients are, and the eco-cycle is closed.

- Energy recovery: this alternative is suitable for waste that cannot or should not be treated differently. It provides a hygienic and environmentally friendly method. If the waste incineration has efficient energy recovery, this method can be seen as recycling according to the EU Framework Directive on Waste.

- Landfill: this method is implemented only when it is not possible to recover energy. Materials that are landfilled can for example be contaminated.

The goal of contacting the association is to get their insight on the situation and see if they can identify any possible solutions, as the members have great experience in waste management and are driven to educate and provide information.

5.2.2 Biogas production

As the solutions used in coating are considered to have a high BOD-load and thus a high organic content, one of the possible solutions considered is the production of biogas. Biogas is produced by naturally degrading the organic matter found in agricultural and industry residues, sewage sludge, municipal waste, etc. by means of anaerobic digestion. Under the anaerobic conditions, the microorganisms convert the organic material to biogas which is in turn used for electricity and heat production, but also as fuel. The gas produced is rich in methane and can thus also be used as a feedstock in chemical and material production.[41]

During the anaerobic digestion, several reactions take place carried out by different microorganisms. The figure 7 below summarizes the general reactions taking place. The polymers are divided into smaller mono- and oligomers which are in turn converted to fatty acids, acetate, and hydrogen and carbon dioxide. These are in turn converted to methane by two different methanogenic bacteria giving the desired biogas.[42]

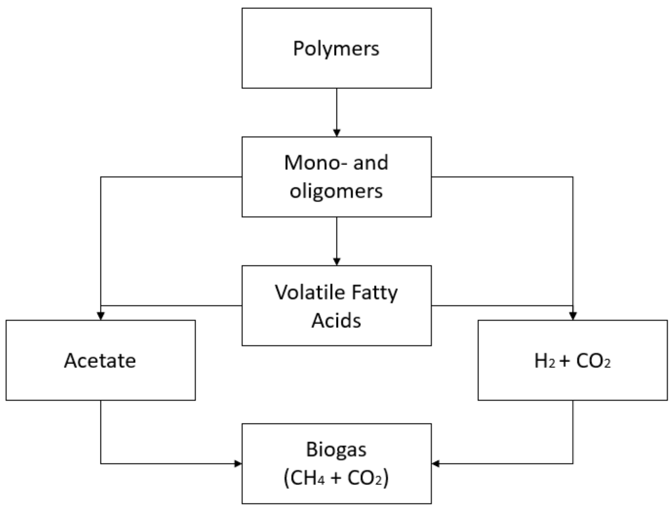

Figure 7: Visual summary of the steps during biogas production.

In order to evaluate the possibility of biogas production using the waters generated in the coating process, two companies related to the biogas production are contacted. To avoid the unnecessary transportation costs, the search of the relevant companies is restricted to Scania County.

Two companies have been identified – Biond located in Helsingborg and SYSAV located in Malmö. While Biond is a biogas producer[43], SYSAV treats and manages the household waste. SYSAV was primarily contacted because of the existing cooperation, but also because of the SYSAV's pre-treatment plant that can receive liquid food waste, which is the case for the coating waters. The waste is converted into slurry which is then used to produce biogas and biofertilizer.[44] Biond was contacted because of its closeness to McNeil that enables easy transportation but also to support a circular economy, as the biogas produced is used in Helsingborg. As one of Sweden's largest biogas producers, with a yearly production of 100 GWh biogas and 200 000 tons biofertilizer, the company operates two refineries where the collected organic waste is digested to biogas.[43]

As a voluntary commitment, the biogas and biofertilizer producers can certify the fertilizer according to SPCR 120. The obtained certification shows that the fertilizer has been produced from separated, clean and biodegradable substrates with food or feed chain origin. It also shows that the requirements for contaminants and metal content are met. The certification rules of SPCR 120 state the terms of certification and technical and control requirements for the producers of biofertilizer. The approved substrates are presented in the appendix to the certification rules and include for instance leaves and plants from parks and gardens, food waste from restaurants and households, residues from food industry etc. The complete list of the approved substrates can be found in the Appendix.[45]

If the substrate is not present on the list, the biogas producer must apply to the certifier and get the new substrate on the approved list. Prior to that, the producer performs a risk analysis to assess if the new substrate will affect the regulated parameters of biofertilizer. The regulated parameters for the produced biofertilizer include the following:[45]

- Biofertilizer contains at least 20 % organic matter, measured as loss on ignition expressed in weight percentage of dry matter
- Solid fertilizer contains the maximum of 30 cm^2/kg of visible contaminants
- Liquid fertilizer contains the maximum of 10 cm^2/kg of visible contaminants
- Metal content in the finished fertilizer should not exceed the limits presented in table 12 below

Table 12: The limits for metal content in produced biofertilizer regulated by SPCR 120 certification of biofertilizer[45]

Metal	Maximum content (mg/kg dry matter)
Lead, Pb	100
Cadmium, Cd	1
Copper, Cu	600
Chromium, Cr	100
Mercury, Hg	1
Nickel, Ni	50
Zinc, Zn	800

5.2.3 Wastewater treatment

As the BOD in the effluent is still high and considering that increase in the production volumes will increase the BOD in the effluent wastewater, there is a need to evaluate the techniques that can be implemented on site to reduce the discharge. If no further action is taken, the discharge will eventually reach the limit of the permit. In this section different techniques for BOD reduction are presented.

Generally, the wastewater treatment methods are classified into two separate groups – biological and physiochemical treatment methods. As the names indicate, the biological treatment uses microorganisms to reduce the levels of pollutants in water, while the physiochemical treatment uses physical and/or chemical techniques to alter the properties of the wastewater.[46] Although there are many techniques available, there are often only a few techniques that are commonly used. These techniques provide often a cheaper and more technologically feasible treatment.[47] Looking back, it can be seen the problem at McNeil is mainly associated with BOD. The treatment methods that enhance the removal of it are therefore in focus here.

Of all available techniques, there is no direct answer to which one is the best. All techniques have their advantages and disadvantages, and the choice should be based on the characteristics of the water that is to be treated. In general, a combination of different methods is used to achieve the desired quality. In the case of the industrial wastewater, the wastewater can be categorized as cooling, washing and process wastewater. In most cases, the process wastewater contributes the most to the quality and poses the greatest problems.[47]

By using the review for treatment of palm oil mill effluents (POME), different techniques for treatment of McNeil's wastewater are also considered. The brown semi-liquid mixture of POME consists of lipids and carbohydrates, but also other nitrogen and organic compounds that can be found in plants. POME has also a large amount of oil and grease.[46] Although the composition of the two wastewaters differs, considering that the BOD in the POME is high, the treatment methods and their effect on the BOD can be used as a basis for evaluation of possible solutions. The table 13 below summarizes the properties of the two wastewaters and their discharge limits. Based on the values in table 13, the POME treatment requires the reduction of 99.9 % in BOD to reach the discharge limit while McNeil requires the reduction of 96 %.

Table 13: The properties of the POME and McNeil's wastewater[46,33]

Parameter	POME	Limit POME	McNeil	Limit McNeil
BOD	23 492 mg/L	20 mg/L	7 060 mg/L	260 mg/L
COD	46 940 mg/L	-	11 767 mg/L	-
SS	26 019 mg/L	200 mg/L	163 mg/L	260 mg/L
pH	4.2	5.0 – 9.0	8.4	6.5 – 10.0

Biological treatment

The principal of biological treatment is the reduction of organic pollution in water with help of microorganisms that use the organic matter for growth and building of new cells. The general reactions taking place in the biological treatment are shown below.[48]

Oxidation: $Organic\ matter + O_2 + nutrients \rightarrow CO_2 + NH_3 + new\ cells + other$

Nitrification: $NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$

Denitrification: $NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

Examples of biological treatment methods include anaerobic and aerobic treatment, as well as facultative ponds. Here, the microorganisms consume the organic matter found in wastewater producing methane and carbon dioxide. For the levels of 300 mg/L and below, aerobic treatment is used. For levels above 300 mg/L, anaerobic treatment is preferred. The anaerobic ponds can be constructed on the limited space and therefore this technique is widely utilized. Although the technique is preferred for limited space, the ponds themselves require extensive space and a long retention time. Here, the 98 %

reduction of BOD in POME has been observed. One important factor to consider is the production of greenhouse gases during the wastewater treatment that influences the overall environmental performance. This issue can be resolved by integrating the biogas capture system in the wastewater treatment plant. The captured biogas can then be used to produce heat, electrical power or fertilizers.[46]

For the aerobic treatment process, the requirements are different. The aerobic microorganisms require optimal conditions to treat wastewater – presence of oxygen and nutrients. If the organic load to the treatment plant is too high, the microorganisms will not survive and will suffocate if not enough oxygen is present for growth. Furthermore, the most optimal nutrient ratio of BOD:N:P is 100:5:1, and if the influent to the treatment plant lacks the nutrients, the addition of these is required. The BOD removal efficiency for aerobic treatment of POME has been observed to 90 %.[46]

Of all the available biological treatment methods, the best BOD removal in POME is seen with rotating biological contractor (RBC), aerobic oxidation on anaerobically treated POME and sequencing batch reactor (SBR) where the removal efficiencies exceed 90 %. For more advanced treatment methods, the ultrasonic-membrane anaerobic system (UMAS), up flow anaerobic filter (UAF) and integrated anaerobic-aerobic bioreactor (IAAB) show the BOD removal efficiencies of over 96 %.[46]

The techniques above have their advantages and disadvantages. While RBC has no sludge return, it requires frequent maintenance. SBR on the other hand, has high stability rate but the overall performance is dependent on the design. As with all membranes and filters, the UMAS and UAF techniques are prone to fouling and clogging requiring regular maintenance. Overall, the biological treatment techniques have a relatively long start-up phase as it is necessary to create an optimal environment and they also require management and maintenance. Furthermore, the sludge that is generated during treatment requires separate handling.[46,47]

Physiochemical treatment

These treatment processes are called polishing techniques, since in many cases they are used after the biological treatment, as the effluent from biological treatment may still not have the required results. The colloidal particles found in wastewater are separated by the means of physiochemical treatment. These processes are however associated with high costs, including investment, operational and maintenance costs. Examples of such techniques are coagulation or flocculation, adsorption, oxidation and filtration.[46,47]

For the POME treatment, the best BOD removal efficiencies are seen for electrocoagulation, adsorption, advanced oxidation process (AOP) and membrane separation, where the BOD removal efficiency of the last three techniques exceeds 96 %. These techniques are often simple, rapid and efficient and do not require extensive space. The main disadvantage of these techniques is however their high operational and investment costs. In order to have an optimum process, the pilot studies using these techniques should be conducted. Furthermore, in most cases, the pre- or post-treatment of water is required.[46]

Electrocoagulation has recently proved to be one of the techniques that is successful in treatment of different wastewaters. The treatment is performed in a shorter time without addition of any chemicals but is dependent on the design and material choice. In the case of adsorption, different adsorbents can be used affecting the BOD removal efficiency. AOP techniques have also different design combinations of ultraviolet radiation, hydrogen peroxide and ozone. In some cases, the addition of different catalysts improved the performance. As with biological treatment using membranes, the membranes in the physiochemical treatment are prone to fouling and require maintenance.[46,47] For the treatment of POME, the combination of ultrafiltration and reverse osmosis showed the BOD removal efficiency of 99.8 %.[47]

Evaporation is also one of the techniques that can be used to treat wastewater. This technique involves the concentration of the solution by driving away water and separating a soluble solid. There are usually high costs involved for treatment of high volumes of wastewater, where the main contribution to the cost is the energy use. Furthermore, the concentrate has to be disposed and there is a risk of damaging the equipment as solids may crystallize.[47]

NCH Europe and BioAmp

One of the companies that may provide a suitable solution is NCH Europe. By providing water and maintenance solutions and focusing on its customers in hospitality, industrial and infrastructure businesses, NCH Europe is now present in 25 countries. One of the service areas of NCH is wastewater treatment.[49] BioAmp is a patented engineering and microbiological system that focuses on biological treatment of drain and wastewater. By delivering a large amount of active, naturally occurring bacteria, the quality of the wastewater can be greatly improved.[50]

BioAmp is a microbial fermentation unit that is installed directly on site. The bacteria blend of aerobe and facultative anaerobe bacteria, called FreeFlow bacteria, is delivered directly into the stream, speeding up the natural degradation of organic waste. The waste is converted to water and carbon dioxide creating new bacteria at the same time. The direct result of such conversion is a reduction of BOD and SS values. As NCH is responsible for installation, monitoring and service of the system, charging the client on a monthly fee basis, no additional attention from customer is required. The BioAmp system is in compliance with European Directives and local regulations, cleaning the polluted wastewater to levels that are acceptable by the environmental agencies and wastewater treatment plants.[51]

5.2.4 Release to municipal sewer system

Although the collection containers were installed due to high BOD in the wastewater, an analysis of the contribution of the release of these waters has not been conducted and it therefore performed in this work. Furthermore, considering that the containers collect waters used for cleaning of the equipment, analyses of these waters and their contribution to the overall quality shall also be conducted. Should the analyses show low BOD-contribution and low overall effect on the quality of wastewater, an evaluation of possible release is to be performed.

One important factor to consider evaluating the possible release of the contents is the toxicity of solutions. As these waters are to be sent to the wastewater treatment plant, they should not contain any components that can cause harm to the wastewater treatment process and the personnel working there, the produced sludge, the piping and the recipient.[30] As flavouring oils are toxic to the aquatic life in the concentrated form, their toxicity in the solution should be analysed.

5.2.5 Studies conducted earlier

The similar issue has been studied before by the consulting company ÅF in 2015 hired by McNeil. They have mainly analysed the issues with high BOD-load in the wastewater and presented possible purification methods. The study compares biological treatment, chemical precipitation, absorption, membrane filtration, chemical oxidation and evaporation. The choice of the purification methods was based on the properties of wastewater as it contains easily biodegradable organic matter.[52]

Taking into consideration the installation and operational costs, as well as the design parameters with concern of limited available space, safety and easiness of operation, ÅF has identified biological treatment with biofilm, oxidation and evaporation as suitable purification methods. In order to give an estimation of the costs for installation and operation of the identified methods, ÅF has used the following dimensioning data presented in table 14. The data was based on the overall performance of McNeil for 2013 and the assumption that the production reaches the maximum allowed production volumes given by the permit.[52]

Table 14: The dimensioning parameters used by ÅF to calculate the installation and operational costs for the identified purification methods[52]

Parameter	Dimensioning
Lozenges (tons/year)	500
Chewing gum (tons/year)	4600
Flow through S5 (m^3/day)	90
BOD through S5 (tons/day)	1.3

ÅF has also identified the need for installation of an equalization tank to balance the variations in BOD and flow due to batchwise production. The volume of the tank is based on a residence time of 12 hours. Using the dimensioning value for the flow through S5, the volume of the tank is approximately 50 m^3. To avoid creation of anaerobic conditions in the tank that will result in smell, the aeration of the tank is required, and the gases should be taken care of by scrubber or coal filter. Furthermore, to enable the handling of the wastewater, it must be pumped to the purification equipment. One of the suggested solutions is the installation of a pump station near S5 where water is led to the municipal sewer network. The complication with this solution is the power cables in the ground that make the installation of the pump station complicated. To avoid it, the pump stations can also be installed in the production facilities.[52]

The biological treatment using biofilm is dimensioned based on the amount of organic material with a typical value of 6 kg COD/m^3, day. With the BOD/COD ratio of 0.55 and the dimensioning value for BOD through S5 the tank volume of 400 m^3 is required. To avoid risk of oxygen deficiency, it is also recommended to recirculate the flow to dilute the stream.[52]

For the chemical oxidation, the volume of the tank is based on the residence time of 5 hours resulting in the tank volume of 20 m^3. The residence time varies and is based on the type and quality of water. ÅF has chosen ozone as oxidation agent. Ozone is generated on site with a generator supplied with air or oxygen. The generator produces heat that is cooled by cooling water with supply of approximately 1000 m^3/day.[52]

For all purification methods, a facility where all equipment is placed is required. The area of the facility is approximated to 100 m^2. ÅF then estimates the costs for purification methods based on standard values and internal data. The costs and the BOD in the outflow are presented in the table 15 below.[52]

Table 15: The costs associated with installation of the wastewater treatment equipment identified by ÅF in 2015

Purification method	BOD out (tons/year)	Investment cost (MSEK)	Operating costs (MSEK/year)	Yearly costs (MSEK/year)
Biofilm	60	17 – 22	~ 2	4 – 5
Chemical oxidation	240	20 – 25	~ 3	5 – 6
Evaporation	70	25 – 30	~ 5	9 – 10

5.3 Identified analyses of CIPAX waters

Next step of the work consists of the analysis of the contents of each of the containers. As the composition of each container is given by both the solution and cleaning recipe and considering that the composition may vary as the production is batchwise, no analysis to give an exact composition of each CIPAX is performed. It should however be noted that the composition varies depending on the product and CIP-recipe. The highest variation is expected in the CIPAX from preparation and mobile units where different flavours are used. All analyses are performed by the accredited lab with standardised methods. The lab also performs the regular monthly tests. The identification of other suitable analyses is performed by contacting the lab.

Effect on wastewater

As the collection containers were installed due to high BOD-levels in the wastewater, the analysis of the BOD-concentration in each CIPAX is performed. Together with the BOD-analysis the analysis of the COD is also performed to evaluate the BOD/COD ratio that is regulated by the authorities. Furthermore, as CIPAX contain the water used for the cleaning of the equipment, the water content and pH of each CIPAX is also analysed. The water content is obtained by performing analysis of dry content and using it to calculate the water content. Below follows the summary of methods used for determination of the parameters.

- BOD analysis with a standardised method ISO 5815-1:2019
- COD analysis with a standardised method ISO 15705:2002
- Analysis of dry matter content, DM, with a standardised method SS 028113-1
- Analysis of pH with a standardised method ISO 10523:2012

Biogas production

With biogas production being identified as a possible solution there are some analyses that must be performed to evaluate its possibility. As Biond has SPCR 120 certification, the risk assessment of introduction of new substrate must be performed by conducting the analyses of the regulated parameters. The analyses include the loss on ignition, ash, total nitrogen and phosphorus, and presence of heavy metals and other substances such as potassium, magnesium, sulphur, and calcium. The list below summarizes the performed analyses.

- Dry matter content, loss on ignition and residue on ignition with a standardised method SS 028113-1
- Nitrogen content with a standardised method SS 028101-1
- Ammonium nitrogen content with a standardised method ISO 15923-1:2013 B
- Total phosphorus content with a standardised method ISO 15681-2:2018

- Content of Pb, Cd, Cu, Cr, Ni, Zn, Co, Ag with a standardised method ISO 17294
- Content of Hg with a standardised method ISO 15587-2
- Content of K and S with a standardised method ISO 11885

Toxicity analyses

If the release of the wastewater shows to be a possible solution, the released waters should not have a negative impact on the wastewater treatment plant and the recipient. As the flavouring oils are toxic to the aquatic life in the concentrated form, the toxicity of the solution is analysed to ensure that neither the microorganisms used in treatment nor the aquatic life in the recipient are affected. Furthermore, to ensure that the waters have no negative impact on the wastewater treatment plant, the nitrification inhibition analysis is performed. As one of the major wastewater treatment steps in Öresundsverket involves the nitrification step, this must not be affected by the released waters. The list below summarizes the performed analyses

- Nitrification inhibition with a standardised method ISO 9509:2006
- Toxicity with the analysis package
    - Determination and adjustment of pH with a standardised method ISO 10523:2012
    - Filtration of the sample through a 0.45 m membrane filter
    - Screening for EC50 and EC20 with different exposure times with a standardised method ISO 11348-3
    - Calculation of the toxicity unit, TU=100/EC

The nitrification inhibition test is performed by placing the sample in the beaker with activated sludge and sewage water. The nitrification bacteria present in the activated sludge are thus exposed to the sample and the effect of the exposure is measured by measuring the production of oxidised nitrogen. The beaker with the sample is compared to the blank. If the beaker with the sample has lower production of oxidised nitrogen compared to the blank, the sample is inhibitory. The laboratory reports the results in percentage of the loss of production.[53]

The toxicity test measures the acute toxicity of the sample by exposing *Vibrio fischeri* to it. As the microorganisms produce light, the toxicity is measured as loss of bioluminescence. The laboratory reports the effective concentration (EC), EC50 and EC20, that correspond to the concentrations where 50 and 20 % of the population show loss of bioluminescence. If the EC50 value is below 20 %, the sample is highly toxic. The value over 70 % shows low toxicity. The same relation is used for EC20 values. The TU is then calculated individually for EC50 and EC20, and the mean value of these is reported.[53]

6 Results

In order to understand the contribution of each CIPAX to the total amount of collected waters, information regarding the number of changes for each container was collected. The information was collected by taking advantage of the automated system which alerts when the water level in each container is high. By collecting the number of alerts for each container during the specific period and assuming that each container is filled with around 930 L, an approximate amount during a year can be calculated. As the containers mainly contain water and the density of water is approximately 1000 kg/m^3 the mass of the contents of each container is approximately 930 kg.

Table 16: The number of container changes on each station

	Changes/month	Changes/year	Collected waters/year
CIPAX 3	3	36	33 480 kg
CIPAX 4	5	60	55 800 kg
CIPAX 5	2	24	22 320 kg
CIPAX 6	10	120	111 600 kg
CIPAX 7	12	144	133 920 kg
Total	32	384	**357 120 kg = 357 tons**

Looking at the table 16 above it can be seen that the major contribution to the total amount comes from CIPAX 7, collecting the remainder and rinsing water from the preparation and mobile units where the film is prepared. Next major contribution comes from CIPAX 6 that collects the remainder and rinsing water from the equipment to produce the lozenge film. Both CIPAX 3 and 4 collect the remainder of the suspension, but it can be seen that more is collected with CIPAX 4. CIPAX 5 contributes the least to the total amount.

The contents of each CIPAX were then analysed to see how the different CIPAX contribute to the overall BOD-load. The contents were also analysed for the water content. The results of these analyses are presented in the table 17 below.

Table 17: The results of the analyses of the CIPAX containers

CIPAX	pH	BOD_7 (mg/l)	COD (mg/l)	BOD_7/COD	DMf (%)	Water content (%)
CIPAX 3	8.4	290 000	420 000	0.69	32	68
CIPAX 4	8	240 000	370 000	0.65	29	71
CIPAX 5	6.5	110 000	240 000	0.46	11	89
CIPAX 6	11.9	5 200	42 000	0.12	1	99
CIPAX 7	12.7	1 900	10 000	0.19	1	99

From the table above it can be seen that BOD and COD are highest in the CIPAX 3 and 4 used for the collection of sugar suspension. These containers have also the lowest water content. CIPAX 6 and 7 on the other hand have lowest BOD and COD values and highest water content. These containers are used for the collection of film residues. CIPAX 5, that is used for the collection of sugar suspension from the coater 5 and the preparation unit 2, has the characteristics of both identified groups. The BOD and COD are high, but the water content is also high.

For the CIPAX 7 used for lozenge equipment and CIPAX 6 used for gum film equipment, the water content showed to be 99%. Since the water content is so high, a possible release of some of the water was considered. Since the CIPAX containers collect both the residues of the film solutions and the rinsing water, the same analysis of the rinsing water was performed. The samples were taken during the CIP of the respective equipment by pausing the recipe to only collect the rinsing waters. Table 18 below shows the results of these analyses. The approximate volumes used for cleaning of the equipment are also shown.

Table 18: The results of the analyses of the rinsing water used for cleaning of the equipment

Sample	Total volume (L)	BOD_7 (mg/l)	COD (mg/l)	BOD_7/COD	Water content (%)
PU gum	50 – 60	8 450	24 000	0.46	99
Mobile unit	50 – 60	14 950	24 000	0.33	99
PU lozenge	300	230	2 800	0.08	99
Lozenge coater	500	220	1 700	0.13	99

It can be seen from the tables 17 and 18 above that both BOD and COD are greatly reduced for the lozenge equipment comparing it with results for CIPAX 7 in table 17. It is also seen that a much water is used for rinsing of equipment. Looking at the results for gum equipment where rinsing water is taken for both preparation and mobile units the BOD content is higher compared to the BOD content of the whole CIPAX 6. The COD on the other hand is lower.

6.1 Release of the contents

One of the solutions considers the release of the contents of the containers to the municipal sewer system. In order to evaluate this alternative, the contribution of such release to the flow and BOD-load is calculated. The average flow during 2021 has been calculated to be 1969 m^3/month and the average BOD to 7060 g/m^3. Firstly, the contribution of the release of all contents in each CIPAX to the municipal sewer system is calculated using the number of container changes, the BOD in each container and assuming that each container is filled with 930 L.

The average monthly BOD-load is calculated using the flow and BOD averages:

Monthly average BOD-load$= 1969 \frac{m^3}{month} * 7060 \frac{g}{m^3} \approx 13\ 901 \frac{kg}{month}$

Below is the contribution of the release of contents of CIPAX 3 calculated as an example. The calculations for the rest of the containers are performed in the similar manner and the results are summarized in the table 19 below.

<u>CIPAX 3</u>

Monthly flow $= 3 \frac{containers}{month} * 0.93\ m^3 = 2.79\ m^3$

Increase in the average monthly flow $= \frac{2.79}{1969} * 100\ \% = \approx 0.14\ \%$

BOD-contribution $= 2.79\ m^3 * 290\ 000 \frac{g}{m^3} \approx 809 \frac{kg}{month}$

Increase in the monthly BOD-load $= \frac{809}{13901} * 100\ \% \approx 6\ \%$

Table 19: The results of calculations for contribution of each container to the total BOD-load

	Monthly flow (m^3)	**Increase in average flow (%)**	**BOD-contribution (kg/month)**	**Increase in monthly BOD-load (%)**
CIPAX 3	2.79	0.14	809	5.82
CIPAX 4	4.65	0.24	1116	8.03
CIPAX 5	1.86	0.09	205	1.47
CIPAX 6	9.30	0.47	48	0.35
CIPAX 7	11.16	0.57	21	0.15
Total	29.76	**1.51**	2199	**15.82**

The highest contribution to the total BOD-load comes from CIPAX 3 and 4 in which the sugar suspension is collected. The highest contribution to the monthly flow comes from CIPAX 6 and 7, but their contribution to the BOD-load is low. Should all contents be released, an increase of approximately 16 % in the monthly BOD is expected.

As the release of the rinsing water to the municipal sewers is considered as a possible solution for the reduction of water content in some of the containers, and thus the amounts sent for incineration, a contribution of such release to the overall BOD is calculated in the similar manner as above.

Both preparation unit and mobile units are rinsed to the same CIPAX. By evaluating the production statistics, the number of rinses to fill one CIPAX was obtained to 10. In general, 8 rinses of mobile units and 2 rinses of preparation unit take place. By using this information and the information regarding the BOD in the rinsing water (presented in table 18), the contribution of the release of these rinsing waters can be calculated.

Rinse of gum preparation unit

BOD in one rinse $= 55\ L * 8450 \frac{mg}{L} \approx 465\ g$

BOD in one CIPAX $= 465 \frac{g}{rinse} * 2 \frac{rinses}{CIPAX} * 10 \frac{CIPAX}{month} = 9.3 \frac{kg}{month}$

Increase in monthly BOD-load $= \frac{9.3}{13901} * 100\ \% \approx 0.067\ \%$

Rinse of mobile units

BOD in one rinse $= 55\ L * 14\,950 \frac{mg}{L} \approx 822\ g$

BOD in one CIPAX $= 822 \frac{g}{rinse} * 8 \frac{rinses}{CIPAX} * 10 \frac{CIPAX}{month} \approx 65.8 \frac{kg}{month}$

Increase in monthly BOD-load $= \frac{65.8}{13901} * 100\ \% \approx 0.473\ \%$

In the case of CIPAX 7, which collects the residues and rinsing water from the lozenge equipment, the water content is also high. In the similar manner as above, the contribution of the release of these rinsing waters is also calculated. Here, the CIPAX is filled when both the preparation unit and the holding tank of lozenge coater are rinsed. As both the preparation unit and the coater are used regularly directly after each other, the number of CIPAX changes is equivalent to the number of rinses for both coater and preparation unit.

Rinse of lozenge preparation unit

BOD in one rinse $= 300\ L * 230 \frac{mg}{L} = 69\ g$

BOD in one CIPAX $= 69 \frac{g}{rinse} * 12 \frac{rinses}{month} \approx 0.8 \frac{kg}{month}$

$$\textbf{Increase in monthly BOD-load} = \frac{0.8}{13901} * 100\ \% \approx 0.006\ \%$$

Rinse of holding tank of lozenge coater

$$\textbf{BOD in one rinse} = 500\ L * 220 \frac{mg}{L} = 110\ g$$

$$\textbf{BOD in one CIPAX} = 110 \frac{g}{rinse} * 12 \frac{rinses}{month} \approx 1.3 \frac{kg}{month}$$

$$\textbf{Increase in monthly BOD} = \frac{1.3}{13901} * 100\ \% \approx 0.009\ \%$$

In the table 20 below the results of the calculations are summarized. In general, the rinsing waters have no significant effect on the average monthly BOD-load. The highest contribution is expected from rinsing of the equipment used for preparation of gum film. The contribution from rinsing of lozenge equipment is insignificant.

Table 20: The results of calculations for contribution of rinsing to the total BOD-load

	BOD contribution (kg/month)	**Increase in monthly BOD (%)**
PU gum rinse	9.3	0.067
Mobile unit rinse	65.8	0.473
PU lozenge rinse	0.8	0.006
Holding tank lozenge rinse	1.3	0.009
Total	77.2	**0.555**

As mentioned before, the toxicity of the solutions must be evaluated. The containers of interest here are the containers used for the collection of film, as flavouring oils are used for its production. These containers are CIPAX 5, 6 and 7. The analyses are however only performed on CIPAX 6 and 7. CIPAX 5 uses the same film as CIPAX 6 and the analysis of it should provide the required information.

The table 21 below summarizes the results of the toxicity and nitrification inhibition analyses. Both EC50 and EC20 are measured for exposure times of 5, 15 and 30 minutes. The results of the analyses are expressed as volume percentages of the sample that results in 50 and 20 % loss of bioluminescence. The results for nitrification inhibition are expressed in percentage of the loss of production of oxidised nitrogen. Toxicity unit is calculated from the value for EC50 (15 minutes). The higher the value, the more toxic the sample is.

Table 21: The results of toxicity and nitrification inhibition analyses

	CIPAX 6	**CIPAX 7**
EC50, 5 min (%)	< 3	4
EC50, 15 min (%)	< 3	4
EC50, 30 min (%)	< 3	4
EC20, 5 min (%)	< 3	< 3
EC20, 15 min (%)	< 3	< 3
EC20, 30 min (%)	< 3	< 3
TU	> 33.3	25
Nitrification inhibition (%)	86	18

Both samples show high toxicity with the EC50 and EC20 values under 20 %. The TU also indicate a high toxicity of the samples. The nitrification inhibition is high for sample taken from CIPAX 6 and low for sample taken from CIPAX 7.

6.1.1 Economy

Three different alternatives can be evaluated here – the release of contents of all containers, the release of contents for containers with highest water content and the release of the rinsing water. By releasing the contents, the amount sent for incineration is reduced and thus the cost associated with the handling of these waters is also reduced. Most probably, in the case of partial release, the transportation costs are also affected since fewer rides are required to collect the containers. This factor is however not considered as the incineration cost is highest for the handling today.

If no containers are required and the contents of all the containers are released to the municipal sewer system, the savings associated with this solution are the total costs for sending the contents to incineration, which were calculated to 953 832 SEK for 2021. If the wastewater is not treated, the release will influence the override fees as the BOD will increase. Using the calculated BOD-contribution for all containers (table 19), and assuming that all this contribution will result in the override fees, the cost for the released BOD is calculated below.

$$\textbf{Override fees} = 2199\,\frac{kg\ BOD}{month} * 5.01\,\frac{SEK}{kg\ BOD} * 12\,\frac{month}{year} \approx 132\ 204\,\frac{SEK}{year}$$

$$\textbf{Overall savings} = 953\ 832 - 132\ 204 = 821\ 628\,\frac{SEK}{year}$$

The containers with highest water content are CIPAX 6 and 7, and they are also the ones with highest number of container changes. To calculate the savings, the amount that is generally sent for incineration and the cost associated with it are used. Using the number of container changes per year (table 16) and the weight of 930 kg per container, the total amount is calculated. Using the handling cost of 1831 SEK/ton, presented in the section 4.3 Handling Today, the incineration savings are calculated. The release of the contents from these containers will result in override fees and the costs that are associated with release are calculated as above.

$$\textbf{Water from CIPAX 6} = 120\,\frac{CIPAX}{year} * 930\,\frac{kg}{CIPAX} \approx 112\,\frac{tons}{year}$$

$$\textbf{Water from CIPAX 7} = 144\,\frac{CIPAX}{year} * 930\,\frac{kg}{CIPAX} \approx 134\,\frac{tons}{year}$$

$$\textbf{Total wastewater} = 112 + 134 = 246\,\frac{tons}{year}$$

$$\textbf{Incineration savings} = 246\,\frac{tons}{year} * 1831\,\frac{SEK}{ton} = 450\ 426\,\frac{SEK}{year}$$

$$\textbf{Monthly BOD contribution} = 48\,\frac{kg\ BOD}{month} + 21\,\frac{kg\ BOD}{month} = 69\,\frac{kg\ BOD}{month}$$

$$\textbf{Override} = 69\,\frac{kg\ BOD}{month} * 5.01\,\frac{SEK}{kg\ BOD} * 12\,\frac{month}{year} \approx 4148\,\frac{SEK}{year}$$

$$\textbf{Overall savings} = 450\ 426 - 4148 = 446\ 278\,\frac{SEK}{year}$$

In the case of the release of the rinsing water, the savings are calculated in the similar manner. Here, the total rinsing volume (table 18) and the yearly container changes (table 16) are used to calculate the total amount sent for incineration. Considering that this is water, the volume and weight are used interchangeably since the density of water is 1000 kg/m^3. As above, the override fees associated with this solution are calculated. The BOD-contribution of the release of these waters is taken from table 20.

$$\textbf{Rinsing CIPAX 6, PU} = 55\,\frac{kg}{rinse} * 2\,\frac{rinses}{CIPAX} * 120\,\frac{CIPAX}{year} \approx 13\,\frac{tons}{year}$$

$$\textbf{Rinsing CIPAX 6, MU} = 55\frac{kg}{rinse} * 8\frac{rinses}{CIPAX} * 120\frac{CIPAX}{year} \approx 53\frac{tons}{year}$$

$$\textbf{Rinsing CIPAX 7, PU} = 300\frac{kg}{rinse} * 144\frac{rinses}{year} \approx 43\frac{tons}{year}$$

$$\textbf{Rinsing CIPAX 7, CT} = 500\frac{kg}{rinse} * 144\frac{rinses}{year} = 72\frac{tons}{year}$$

$$\textbf{Total wastewater} = 13 + 53 + 43 + 72 = 181\frac{tons}{year}$$

$$\textbf{Incineration savings} = 181\frac{tons}{year} * 1831\frac{SEK}{ton} = 331\,411\frac{SEK}{year}$$

$$\textbf{Override fees} = 77.2\frac{kg\ BOD}{month} * 5.01\frac{SEK}{kg} * 12\frac{month}{year} \approx 4641\frac{SEK}{year}$$

$$\textbf{Overall savings} = 331\,411 - 4641 = 326\,770\frac{SEK}{year}$$

6.2 Wastewater treatment

The requirements for wastewater treatment can be identified by looking at the conducted monthly measurements, where it can clearly be seen that the major issue is associated with the BOD. Furthermore, using the averages and the normal content that is accepted in the wastewater (table 6), the required BOD removal can be calculated.

$$\textbf{BOD removal} = 7060\frac{g}{m^3} - 260\frac{g}{m^3} = 6800\frac{g}{m^3}$$

$$\textbf{BOD removal} = 6800\frac{g}{m^3} * 1969\frac{m^3}{month} \approx 13\,389\frac{kg}{month} \approx 446\frac{kg}{day}$$

As the BOD-removal requires the presence of nitrogen and phosphorus in relation 100:5:1 for aerobic treatment, the required amounts on nutrients can thus be calculated.

$$\textbf{Nitrogen required} = \frac{446}{100} * 5 = 22.3\frac{kg}{day}$$

$$\textbf{Phosphorus required} = \frac{446}{100} * 1 = 4.46\frac{kg}{day}$$

One of the important aspects to consider is that the flow and BOD levels vary in the wastewater throughout the day, as the flows are generated from process waters. Most of the load is generated when the production takes place. Because of this, the installation of equalization tank is required to even out variations and provide a more uniform flow enabling a more precise treatment design.

The required tank volume is calculated using the same residence time of 12 hours as ÅF used. Using the average monthly flow, the average daily flow is calculated and then used to calculate the volume required for the equalization tank.

$$\textbf{Daily flow} = \frac{1969}{30} \approx 66\frac{m^3}{day}$$

$$\textbf{Volume of equalization tank} = \frac{66\frac{m^3}{day}}{24\frac{hours}{day}} * 12\ hours = 33\ m^3$$

Upon contact with NCH Europe, a discussion on an appropriate solution has taken place. There are two different equipment available that can reduce the required BOD – BioAmp 600 with a reduction of 35 kg BOD/day and BioAmp 5000 with reduction of 1200 kg BOD/day. The recommendation is to install a few units with lower capacity instead of installing one unit that can handle all BOD. The primary reason behind this solution is that the microorganisms require 24 hours of preparation in order to provide efficient handling. With a few smaller units, every unit can have a different release time set up. This enables a more regular wastewater treatment compared to the one unit with higher capacity that can release microorganisms once per day. By installing few smaller units, a more robust wastewater treatment equipment is used by ensuring that there is always some unit available in case of disturbances.

Since the capacity of BioAmp 600 is approximately 35 kg BOD/day, the required number of units can be calculated based on the required BOD removal calculated above.

$$\textbf{Number of units} = \frac{446\frac{kg\ BOD}{day}}{35\frac{kg\ BOD}{day,unit}} = 13\ units$$

The microorganisms need at least 3 hours of residence time to treat the water and as above, the required tank volume can be calculated.

$$\textbf{Tank volume} = \frac{66\frac{m^3}{day}}{24\frac{hours}{day}} * 3\ hours\ \approx 8\ m^3$$

6.2.1 Economy

The proposed cost for the operation of 13 smaller units is 54 600 SEK/month. The annual cost is therefore 655 200 SEK/year. With installation of BioAmp 5000 that has a higher capacity, the monthly cost is 32 000 SEK, giving the annual cost of 384 000 SEK.

The savings are calculated for two alternatives – the treatment of wastewater without the release of the contents in CIPAX and the treatment of wastewater with release of the contents. In the first case, the savings are the costs associated with override fees.

$$\textbf{Savings with BioAmp 600} = 734\ 569 - 655\ 200 = 79\ 369\ \frac{SEK}{year}$$

$$\textbf{Savings with BioAmp 5000} = 734\ 569 - 384\ 000 = 350\ 569\ \frac{SEK}{year}$$

In the second case, a few calculations are required as the BOD-load will increase and thus also the cost for the wastewater treatment. The BOD concentration in the wastewater is expected to increase with 16 %, while the monthly flow is expected to increase with 2 %. This is used to calculate the required BOD-removal and the required number of BioAmp 600 units.

$$\textbf{New BOD} = 7060 * 1.16 \approx 8190\ \frac{g}{m^3}$$

$$\textbf{BOD removal} = 8190 - 260 = 7930\ \frac{g}{m^3}$$

$$\textbf{New flow} = 1969 * 1.02\ \approx 2008\ \frac{m^3}{month}$$

$$\textbf{BOD removal} = 7930\ \frac{g\ BOD}{m^3} * 2008\ \frac{m^3}{month} \approx 15\ 923\ \frac{kg}{month} \approx 531\ \frac{kg}{day}$$

$$\textbf{Number of units} = \frac{531\frac{kg\ BOD}{day}}{35\frac{kg\ BOD}{day,unit}} = 15\ units$$

$$\textbf{Cost for 15 units} = 15 * 4200\ \frac{SEK}{month,} * 12\ months = 756\ 000\ \frac{SEK}{year}$$

Here, the savings are based on the total cost for both incineration and override fees today since wastewater treatment reduces and, in best case, eliminates override fees. The incineration is also no longer required and therefore the cost for incineration is considered as saving.

$$\textbf{Savings with BioAmp 600} = 1\ 688\ 401 - 756\ 000 = 932\ 401 \frac{SEK}{year}$$

$$\textbf{Savings with BioAmp 5000} = 1\ 688\ 401 - 384\ 000 = 1\ 304\ 401 \frac{SEK}{year}$$

6.3 Biogas production

Both Avfall Sverige and SYSAV have identified biogas production as a suitable alternative for collected waters. As there must be a biogas facility that is interested in this substrate for this alternative to work, Biond has been contacted. An evaluation of the possibility for production of biogas from these waters has been performed by Biond.

Since the first step of the evaluation requires the performance of risk assessment for the use of new substrate, the required analyses were performed and sent to Biond for further evaluation. Of outmost importance are the levels of heavy metals in the samples that indicate if the samples will affect the produced biofertilizer. There are guidelines on the levels of the heavy metals in the produced fertilizer given by SPCR 120.

Table 22: The results for of the performed analyses for biogas evaluation

Analysis	CIPAX 3	CIPAX 4	CIPAX 5	CIPAX 6	CIPAX 7
pH at 20 °C	8.4	8.0	6.5	11.9	12.7
Dry matter, TS (%)	37	22	9.9	1.4	0.8
Loss on ignition (%)	99.8	99.8	99.8	86	62
Rest on ignition (%)	0.2	0.2	0.2	14	38
Total nitrogen (mg/kg)	< 3.39	2.34	< 6.05	5.32	15.02
Total nitrogen (% TS)	0.001	0.001	0.006	0.040	0.200
Ammonium nitrogen (mg/kg)	4.80	< 1.80	< 2.02	< 0.50	0.15
Ammonium nitrogen (% TS)	0.001	0.001	0.002	0.004	0.002
Total phosphorus (mg/kg TS)	95.12	22.46	24.29	929	3157
Lead, Pb (mg/kg TS)	0.005	< 0.008	< 0.020	0.070	0.26
Cadmium, Cd (mg/kg TS)	< 0.001	< 0.001	< 0.003	< 0.002	< 0.004
Copper, Cu (mg/kg TS)	0.03	0.09	0.15	7.07	10.92
Chromium, Cr (mg/kg TS)	< 0.01	< 0.02	< 0.05	0.40	0.63
Mercury, Hg (mg/kg TS)	< 0.0002	< 0.0004	< 0.063	< 0.007	< 0.013
Nickel, Ni (mg/kg TS)	0.008	0.013	0.143	1.214	0.723
Zinc, Zn (mg/kg TS)	< 0.07	< 0.13	0.49	2.14	2.50
Potassium, K (mg/kg TS)	< 76	129	< 316	1286	5789
Sulphur, S (mg/kg TS)	22	104	42	1000	4605
Cobalt, Co (mg/kg TS)	< 0.001	< 0.002	< 0.005	0.007	< 0.007
Silver, Ag (mg/kg TS)	< 0.002	< 0.004	< 0.01	< 0.007	< 0.013

The table 23 below compares the limits for metal content regulated by SCPR 120 with the contents obtained through analysis. It should however be noted that the regulated limits are for the produced biofertilizer and not for the substrates used by the biogas facility.

Table 23: The comparison of the obtained analysis results of metal content to the limits regulated by SCPR 120

Metal	SCPR 120	CIPAX 3	CIPAX 4	CIPAX 5	CIPAX 6	CIPAX 7
Lead, Pb	100	0.005	< 0.008	< 0.020	0.070	0.26
Cadmium, Cd	1	< 0.001	< 0.001	< 0.003	< 0.002	< 0.004
Copper, Cu	600	0.03	0.09	0.15	7.07	10.92
Chromium, Cr	100	< 0.01	< 0.02	< 0.05	0.40	0.63
Mercury, Hg	1	< 0.0002	< 0.0004	< 0.063	< 0.007	< 0.013
Nickel, Ni	50	0.008	0.013	0.143	1.214	0.723
Zinc, Zn	800	< 0.07	< 0.13	0.49	2.14	2.50

According to the primary assessment of the analyses (table 22), Biond concluded that all samples can be used to produce biogas. The next step of the introduction of this alternative is to get the waters approved for the production of biogas according to the certification. The approval is performed by application.

6.3.1 Economy

By further discussion with Biond, an approximate cost associated with this handling alternative has been obtained. The application to get this waters approved for biogas production is performed by Biond and the application fee is 5000 SEK. The handling itself is approximated to 800-1200 SEK/ton. The cost is based on possible gas production, labour associated with handling of waste, the amount of rejected material that will have to be transferred to the waste handling, the incineration tax and emission rights. At this stage it is hard to conclude what effects the waters from CIPAX will have on the mentioned parameters. Therefore, the highest cost is taken here to calculate the economy of this solution. The costs are calculated for each CIPAX and presented in table 24 below. The yearly amounts are taken from table 16.

Table 24: The calculated costs for biogas production

	Wastewater/year	Cost/year (SEK)
CIPAX 3	33 480 kg	40 176
CIPAX 4	55 800 kg	66 960
CIPAX 5	22 320 kg	26 784
CIPAX 6	111 600 kg	133 920
CIPAX 7	133 920 kg	160 704
Total	**357 120 kg = 357 tons**	**428 544**

If this solution is implemented for all containers, the associated saving costs are calculated from the yearly incineration costs.

$$\textbf{Savings} = 953\,832 - 428\,544 = 525\,288\,\frac{SEK}{year}$$

6.4 Evaporation and centrifugation

There were also labs conducted to test separation of the samples. As some of the components used for production of solutions are not soluble in water, the centrifugation of the samples has been performed. To test if the evaporation could be a suitable solution for handling of the collected waters, evaporation of the samples has also been performed. The samples have been taken from each container and tested. To give an indication of the quality of the separated water, COD-analyses have been performed.

The centrifugation of the samples resulted in faster settlement of the insoluble compounds, but the water was still not obviously clean. With samples containing flavouring oils, the oils have floated to the surface of the sample. To see if the separation of flavour oils gives a cleaner water, the COD-analysis of the layer under the flavouring oils have been conducted. A reduction of approximately 63 % in the COD-value has been observed.

The evaporation of three samples from CIPAX 3, 6 and 7 have been conducted. The remaining containers have the similar composition to the tested samples and have not been tested. The parameters analysed with evaporation are weight reduction and reduction of COD by comparing the COD of the sample with COD in the condensed water. The table 25 below summarizes the obtained results.

Table 25: The results for measured lab parameters after evaporation of the samples

Sample	Weight reduction (%)	Reduction in COD (%)
CIPAX 3	62	94
CIPAX 6	90	93
CIPAX 7	90	68

7 Evaluation of results

In this section an evaluation of different solutions based on the results and observations is performed. An overall discussion of the project and observations made during its performance is followed by evaluation of different solutions and what effect they will have for McNeil. Evaluation is based on the waste hierarchy and where different solutions place on its levels if applicable.

7.1 General discussion

Looking at all collected data, the issue with BOD in wastewater can be seen, as the levels are reaching the limit regulated by the permit. The production volumes today indicate also that the site does not operate at full permitted capacity and the BOD-load will continue to be an issue if no action is taken. There are however some issues associated with the estimation of the yearly BOD-load. The BOD-load in the wastewater is calculated based on the monthly measurements and during the period of last three years there were some issues with flow meters as well as samples, mainly because of the water composition. This indicates that the BOD-load might be over- or underestimated.

The samples for estimation of the BOD in wastewater are also taken once a month, not always showing the actual fluctuations that are present in the wastewater, which also affects the estimation of the BOD-load. Figure 4 gives a good representation of BOD and flow variations that can be seen from performed measurements. The average values follow a trend while the maximum and minimum values vary affecting thus the estimated BOD-load. The sampling method is approved by both the authorities and McNeil.

To give more data for the estimation of the BOD-load, it is suggested to perform a more rapid COD-analysis on site on a more regular basis. Using the BOD/COD quote with an average value of 0.6, the BOD in wastewater can be calculated. The average BOD-concentrations obtained by this method can then be used to calculate the BOD-load during a specific period. This method may show the variation in BOD but will still not be fully representative as both the flows and concentrations are dependent on the production.

Another suggestion is to perform a more precise mapping of where the BOD-load comes from. In this case, it is suggested to perform analyses on the water going to the drains and keep track of what type of product has been produced and what CIP-recipe is used during sampling. It is also suggested to monitor other processes that release the water to S5.

Based on the monthly measurements, it is also hard to evaluate if the reason behind the decrease in the yearly BOD-load is due to installation of the collection containers, since both the average BOD-concentration and flow in S5 are in the same order of magnitude as before. The calculated BOD-loads from the two connection points show that the load in S1 has decreased while the load in S5 has increased, also indicating that there might be another reason behind the observed decrease in the BOD-load.

The analyses of BOD-concentrations in the containers, however, show that should the contents be released to the drains, the overall increase of 16 % in the BOD-load is expected, proving that the collection does indeed reduce the BOD-load. The highest contribution to the BOD-load is expected from CIPAX 3, 4 and 5 that collect the sugar suspensions. The containers used for collection of film have little contribution to the BOD-load but are the containers that generate most of the collected water.

The increase in the BOD-load may also come from other processes as S5 collects the process waters not only from the coating, but also from the manufacturing of other products. It is also important to consider that two of the CIP-stations have another handling and may have influence on the BOD-load. Should any of the solutions proposed here be implemented on the containers, a possible implementation of the same handling for these stations may be considered.

Important to consider with all analyses is that they are not fully representative. Since production is batchwise and there are different recipes for production of different solutions, the composition in the containers varies with production and CIP-recipe. The lowest variation is expected in the CIPAX 3 and 4 since they only collect the xylitol suspension. The containers that collect film have different flavours, depending on the product, and different concentrations of flavouring oils, depending on the CIP-recipe.

By looking at the results obtained for BOD in CIPAX 6, and BOD obtained for rinsing water that goes to the container, it can be seen that the rinsing water has higher BOD. This shows how the flavouring oils and CIP-recipe affect the obtained results. Another source of error in the sampling is that the mixing of the containers is not perfect, and this has a direct influence on the results of the analyses since there is a risk that not all fractions are collected in the sample.

Furthermore, the handling today is not sustainable and generates a high cost. Considering that the production today is below the permitted capacity, this handling may not be sustainable in the near future as increase in the production will generate an increase in the collected volumes. It will also generate a high BOD-load in wastewater thus increasing the cost for override fees which are also increased on the yearly basis. Another alternative to handle the increase in the BOD-load is through a permit change. This is however not desirable since the process is complicated and requires re-examination of the site.

The total handling cost of today does not only consist of override fees but also of the cost for unutilized chemicals with hypromellose and flavouring oils being the most expensive ones. No calculation for the exact cost associated with it has however been performed, mainly because of the difficulty of estimating the exact weights of the disposed solutions.

There are some levels in the Waste Hierarchy that are hard to reach. The prevention of generation of waste is almost impossible as the batchwise production requires a production of extra solutions to ensure that the capacity is fulfilled. It would instead be desirable to reuse the wastewater collected in containers for a repetitive cleaning of equipment. A possible recirculation of the water for cleaning of the equipment may therefore be considered. The implementation of such a solution requires however the water to be treated prior to recirculation as well as changes in the process to enable recirculation. It is also a question of how much the water can be reused before it is considered as wastewater again. In best case, with implementation of new solutions, the handling today can be moved one level higher to recycling where either the water is used in some other processes, or the collected film or suspension are used for production of other products.

7.2 Biogas production

The conducted analyses indicate high content of organic matter in all samples. CIPAX 6 and 7 also indicate a high water content. The concentrations of heavy metals in all samples are below 0.1 mg/kg dry matter. The only concentrations that show high values are the concentrations of potassium and sulphur. The high concentrations of these components are due to the nature of wastewater treatment. The water used for production of solutions as well as for cleaning of equipment is drinking water from the Örby field where the water has been filtrated through the natural gravel composed of many minerals, where potassium and sulphur are present in abundance. No analysis on the incoming water has however been performed to confirm this. The high concentrations of these should not have a negative effect on the biofertilizer and biogas production.

Looking at the conducted analyses and comparing them to the limits in a biofertilizer regulated by SPCR 120, the collected solutions impose no negative impact on biogas production. The production from the collected waters is evaluated as one of the suitable solutions. In the Waste Hierarchy this solution is considered as recovery, where instead of incineration for production of heat, the waters are used for production of biogas. The positive outcome of this solution is that the biogas is produced in Helsingborg, reducing the transportation costs. The produced biogas can also be used on site and this solution can thus partly be considered as recycling, moving over to the higher level in the Waste Hierarchy. Should this solution be implemented, there are also expected savings of approximately 500 000 SEK/year. Once the substrate is approved, this solution does not require any investment costs and can be implemented with the already existing setup, sending the collected solutions to Biond instead.

7.3 Wastewater treatment

The BOD-load is expected to increase with increased production and the wastewater treatment should therefore be considered. There are however a few constraints with implementation of wastewater treatment on site. The limited available space, due to closeness to city centre, puts constraints on the implementation of some of the techniques. Some wastewater treatment solutions also require a high investment cost and are expensive in operation and maintenance. These aspects should therefore be considered when choosing the most suitable method. In the study conducted in 2015, the annual cost for the identified wastewater treatment solutions has already surpassed the handling cost of today. Considering that the yearly costs have increased now compared to 2015, the implementation of these solutions based on cost is hard to motivate. However, the wastewater treatment on site gives a very positive sustainability image, since the environmental impacts are reduced in place.

Some other issues associated with implementation of wastewater treatment are the handling of the generated sludge and the carbon dioxide released during treatment. Considering that McNeil is certified as carbon dioxide neutral, an evaluation of the installation of the wastewater treatment facility on this status should be performed. The sludge that is generated during biological treatment requires handling which is associated with unattractive factors, such as smell and disposal.

The solution with installation of a BioAmp system has many advantages and eliminates some of the issues described above. It does not require extensive space and can also be installed at the source, dosing the microorganisms directly to the drains. The number of required units may therefore also be reduced by installing equipment directly at the source. BioAmp is cheaper compared to other alternatives generating savings of 80 000 SEK to 1.3 million SEK per year. As the operation and maintenance are included in the cost, no personnel are required. Should BioAmp after the installation show to be no longer suitable for treatment of wastewater, the equipment can be easily removed, which would not be possible with other techniques. To provide suitable for microorganisms conditions, addition of nutrients is required. This can be solved by dosing the salt to the solution.

There are however many emerging and innovative techniques for the wastewater treatment that have been attracting a lot of attention. Some of the techniques do not require extensive space and are rapid in treatment. The review used for evaluation of possible BOD-reduction techniques considers the treatment of POME that has slightly different properties compared to water from McNeil. To ensure that these techniques will give the desired results, a performance of pilot studies with water from McNeil may be required.

7.4 Release of water

For the solutions with high water content such as contents of CIPAX 6 and 7, the release of the whole or parts of the solution to the municipal sewer system seems like a natural solution. By releasing some of the water, the amount of water sent for incineration will be greatly reduced as these containers contribute the most to the total amount resulting in savings of around 450 000 SEK/year. The contents of these containers have also little influence on the BOD-load. These are however also the containers where variation in the content is expected to be the highest, especially in CIPAX 6 where different flavouring oils are used.

The performed toxicity analyses have, however, shown that the contents of these containers are toxic, and the release of the contents is therefore not possible. Although the flavouring oils are present in low concentrations in the solutions, they still contribute to the toxicity of the collected water.

The removal of oils from the waters may seem like an attractive solution, but the removed oils will still require disposal. Furthermore, the collected oils are now considered as concentrated and a more careful handling of these will be required. The toxicity of the separated waters will still have to be tested since some of the components present in the flavouring oils may migrate to water.

It is recommended to perform the toxicity analyses for the rinsing water to see if the results differ there. Since the oils contribute the most to the toxicity, it is also recommended to examine if the drainage of the equipment can be performed better, draining more of the residues to the CIPAX. If the rinsing waters show no toxicity, the release of these to the drains results in the savings of around 330 000 SEK/year.

Some of the components used in the production are classified as slowly biodegradable and are present in small concentrations in the collected waters. A discussion with the authorities regarding the effects of the release of these compounds to the wastewater treatment plant is recommended.

7.5 Evaporation and centrifugation

The evaporation of the tested samples showed a reduction of over 90 % in the COD-values. It is however hard to come to any conclusion on what effect it has on BOD since there is not guarantee that the same BOD/COD relation is valid for the condensed water. There are also sources of errors in the performance of the laboratory tests as the samples were left overnight to evaporate and the right time to stop the evaporation may have been missed, resulting in the presence of the unwanted components in the condensed water. The evaporation technique itself is also expensive since a lot of energy is used to evaporate water. Considering that the water content in some of the samples is over 90 %, this technique may not be suitable for them. Another aspect to consider is that the problem with waste handling does not disappear as the concentrate still has to be disposed.

8 Conclusion

The composition of the collection containers differs, and they all contribute differently to the overall performance. The containers with highest BOD are the containers used for the collection of sugar suspension. The containers used for the collection of film emulsion are the containers that contribute the most to the amount of the collected waters and therefore the cost. For all containers, the water content is over 60 % and some of the containers have water content over 90 %, where the rest is the components used for production of the solutions.

The wastewater from the coating process does not only generate waste that is sent for incineration but also contributes to the observed high BOD-loads in the wastewater leaving the site. The costs of handling today do not only include the cost for incineration of the waters, but also the costs for override fees. With increased production, the cost of this alternative will continue to increase as the amounts of the collected waters will increase.

The production runs below the permitted capacity and the BOD-load is currently also below the limit. The installation of the containers does influence the BOD-load since the release of the contents will increase the BOD-load in the wastewater with 16 % where the collected sugar suspensions give the highest contribution.

Since the collected solutions are mainly composed of water, the incineration of these is not a suitable alternative. After conducting the analyses on the collected waters, it is concluded that biogas production is a better alternative. This alternative may be considered as recycling since the produced biogas can be used on site. Furthermore, since the biogas facility Biond is located in Helsingborg, the transportation costs are reduced. This handling alternative is also cheaper compared to the incineration and can generate savings of approximately 500 000 SEK per year. The biogas facility has concluded that all collected solutions can be used for biogas production but in order to implement this solution an application to get this substrate approved for biogas production must be sent in.

In order to reduce the BOD-load in the wastewater, a wastewater treatment is an appropriate alternative. There are many available techniques but considering that McNeil has limited space for installation of such equipment, the wastewater treatment equipment provided by NCH Europe is considered to be the most suitable. This equipment does not require a lot of space and all of maintenance and operation is performed by NCH personnel, thus not requiring any additional attention from McNeil. If the equipment is installed to treat wastewater that is released today, this alternative can reduce or eliminate the override fees and generate savings of approximately 80 000 SEK per year.

In order to improve the environmental performance and reduce the costs of the handling today, it is recommended for McNeil to implement both solutions with biogas production and wastewater treatment. This way the BOD-load in the wastewater is reduced and the collected solutions are used for production of biogas that can be used on site. This combined solution is also expected to generate savings of approximately 600 000 SEK/year.

9 Future work

With the obtained results and performed analyses, it is still not clear what contributes to the high BOD-load in the wastewater. If possible, a mapping of where the BOD-load is generated can be performed by analysing what waters are released to S5 connection point and performing analyses on these waters.

Some of the containers have water content over 90 % and the collection of these generates the highest amounts. Unfortunately, the performed toxicity analyses of these waters showed that the contents cannot be released to the drains. It is recommended to evaluate if there are any available techniques that can detoxify the toxic compounds present in water, enabling its release, as it would reduce the collected amounts and simplify the processes.

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11 Appendices

11.1 Permit and conditions

2021-03-25/AOA

Tillstånd och villkor enligt Miljöbalken

Beslut enligt Miljöbalken

Miljöprövningsdelegationen vid Länsstyrelsen i Skåne län har lämnat tillstånd enligt 9 kap Miljöbalken att i befintlig anläggning på fastigheterna inom kvarteren Svalan 37 och Backsvalan 6-7 bedriva farmaceutisk tillverkning, packning av externa produkter samt forskningsverksamhet. Beslut 2002-06-27, Dnr: 551-23144-01, 1283-115

Under 2007 lämnade företaget in en ansökan om ändringstillstånd för utökad produktion av nikotintuggummi, från dagens 3300 ton/år till 4600 ton/år. Beslut i ärendet erhölls 2008-01-31. I samband med beslutet ändrades villkor 5 i tidigare beslut, samt två nya villkor tillkom för reningsanläggningen.

Produktionens omfattning

Inom anläggningarna i kvarteren Svalan 37 och Backsvalan 6-7 är maximalt tillståndsgiven volym följande

Mixturer, salvor, pulver, pasta etc	2 000 ton/år
Brustabletter, tabletter, kapslar	2 000 ton/år
Rökavvänjningspreparat (tuggummi)	4 600 ton/år
Rökavvänjningspreparat (övrigt)	750 miljoner enheter/år

Anläggningens villkor

Verksamhetsdrift	Om inte annat framgår av övriga villkor eller föreskrifter skall verksamheten i huvudsak bedrivas i enlighet med vad bolaget angivit i ansökan eller i övrigt uppgett eller åtagit sig i ärendet. (Lst. 2002-06-27)
Kväveoxider	Vid naturgaseldning får utsläppet av kväveoxider (NOx) beräknat som NO2, som riktvärde och dygnsmedelvärde uppgå till högst 60 mg/MJ tillfört bränsle. Värdet skall även gälla som gränsvärde för årsmedelvärdet. Oljeeldning får endast ske med lätt eldningsolja (Eo1) med en svavelhalt om högst 0,1 %, eller ett bränsle som har minst lika bra miljöegenskaper. (Lst. 2002-06-27)
Stoft	Stofthalten i utgående luft från farmaceutisk produktion får som riktvärde ej överstiga 5 mg/Nm3 normaltorr gas. (Lst. 2002-06-27)
VOC	Utsläppen av flyktiga organiska ämnen (VOC) till luft får som riktvärde inte överstiga 10 ton per år. (Lst. 2002-06-27)
Utsläpp till vatten	Utsläppen av organiskt material via processavloppsvattnet räknat som BOD7 får som riktvärde inte överstiga 300 ton per år. Avloppsvattnets sammansättning avseende kvoten BOD7/COD får som riktvärde inte understiga 0.4.Lst. (2008-01-31)
Spill och läckage	Lagring och hantering av farligt avfall och kemiska produkter

	skall ske på sådant sätt så att spill och läckage inte kan förorena omgivningen eller nå det kommunala avloppsnätet. Förvaringen skall ske på en yta som är ogenomsläpplig och invallad. (Lst. 2002-06-27)
Avfall	Avfall av olika slag skall samlas upp och förvaras var för sig för att underlätta den miljömässigt bästa vidarebehandlingen. Avfallet skall i största möjliga utsträckning upparbetas, återanvändas eller nyttiggöras på annat sätt. Inom fastigheten får samtidigt lagras högst 50 ton farligt avfall, exklusive fasta uppsamlingstankar kopplade till process. (Lst. 2005-10-27)
Buller	Från och med 2003 får verksamheten som riktvärde inte ge upphov till högre ekvivalent ljudnivå utomhus vid närmaste bostäder än 50 dB(A) dagtid (kl 7-18) vardagar, 40 dB(A) nattetid (kl 22-7) och 45 dB(A) övrig tid. Om hörbara tonkomponenter eller impulsartat ljud förekommer skall den tillåtna ljudnivån sänkas med 5 dB(A) enheter. Momentana ljud nattetid får som riktvärde uppgå till högst 50 dB(A). (Lst. 2002-06-27)
Reningsgrad VOC-anläggning	Processluft innehållande smakämnen från drageringsprocessen ska behandlas i en reningsanläggning innan avledning till omgivningen sker. Reningsgraden ska som riktvärde vara minst 97 procent. (Lst. 2008-01-31)
Haveri VOC-anläggning	Skulle reningsanläggningen haverera under pågående drageringsprocess tillåts pågående körning avslutas, så att processen kan stängas ner på ett kontrollerat sätt.(Lst. 2008-01-31)

11.2 Approved substrates for biofertilizer production

Avfall Sverige

BILAGA 1 – version 22

CERTIFIERAD ÅTERVINNING

Bilaga 1a
SPCR 120
december 2021

Substrat

Substrat till certifierad biogödsel skall vara rena, källsorterade och biologiskt lättnedbrytbara enligt Tabell 1.

Om en anläggning önskar ta emot ett substrat som inte finns med i listan nedan måste ett ansökningsformulär fyllas i och skickas in för godkännande. Information och ansökningsformuläret finns på Avfall Sveriges webbplats.

Tabell 1. Substrat för certifierad biogödsel

Substratursprung	Exempel
Parker, trädgårdar och andra grönytor	Löv, gräsklipp, frukt, blommor, växter och växtdelar. Gödsel från djurpark
Växthus, handelsträdgårdar och liknande	Blommor, växter och växtdelar (blast och rens).
Hushåll, storkök och restauranger[1, 2]	Frukt- och grönsaksrester, kaffe- och terester, rester av livsmedel, matavfall, insamlingspåsar utvärderade för kontakt med livsmedel. Fettavskiljarslam[3], med följande villkor: - Fettavskiljarslammet ska endast komma från kök - Det ska finnas rutiner för renhet i transport - Endast miljömärkta och/eller livsmedelsgodkända kemikalier får användas i köken

Livsmedelsindustri (inkl. slakteri), livsmedelsrelaterad detaljhandel[2] och grossistverksamhet[1]	Frukt, grönsaker, potatis, mejeriprodukter, torkpapper, bröd, kött (köttdelar, ben och puts), charkuterivaror, fisk, godis och andra livsmedel. Restprodukter från livsmedelsindustrin som innehåller tillsatser som är godkända för livsmedelproduktion. Animaliska biprodukter klassat som lägsta riskklass i ABP-lagstiftningen (kategori 3) är godkänt. Även naturgödsel, mag- och tarmsystemet samt dess innehåll, mjölk, mjölkbaserade produkter, råmjölk, ägg och äggprodukter samt fisk (vattenlevande djur) är godkänt som substrat, vilka återfinns i en annan riskklass (kategori 2). Fettavskiljarslam[3], med följande villkor: - Fettavskiljarslammet ska endast komma från beredning och/eller tillverkning av livsmedel - Det ska finnas rutiner för renhet i transport - Endast miljömärkta och/eller livsmedelsgodkända kemikalier får användas i verksamheten
Lantbruk[1]	Gödsel från svin, nöt, får, häst, fågel och andra husdjur. Halm, skörderester, ensilerade jordbruks-grödor, grönmassa, energigrödor, fånggrödor, spannmål och inkuranta skördeprodukter. (Observera att gödsel omfattas av ABP-lagstiftningen)
Biodieselproduktion	Glycerol från FAME- produktion (Fatty Acides Methyl Ester), under förutsättning att FAME-produkten endast sker från grödor, exempelvis från raps vid tillverkning av RME, som odlats på åkermark. Glycerolen ska uppstå som en naturlig restprodukt från processen.
Foderindustri[1]	Rester från fodertillverkning