Effects on wastewater due to new active pharmaceutical ingredients and products

by

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Picture on front page: Beaker with water. Photo by Marina Vik

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Preface

I want to give a special thanks to Ann, who has been my supervisor at McNeil. Especially for her straightforward approach, for allowing me to take initiative, for allowing me to use my own judgement, honest critique and for overall support during this entire project. I also want to thank Kristoffer, Sebastian, Ulf, Kujtim and the entire hardworking staff at the R project. Your help made it possible to collect the wastewater in a safe, correct and efficient manner. I also want to thank the patient and helpful staff at the M project, Håkan, Mårten, Bengt-Göran Adin and Jasmin, thank you for taking time out of your schedule to assist me in collecting the wastewater that I needed. I also want to thank Per who has been my supervisor at LTH, for his eagerness to share his experience with wastewater treatment technologies. Finally, I want to thank Christian for his constructive criticism and for being my examiner.

Abstract

Wastewater from pharmaceutical industries can sometimes contain substances that could cause complications in the receiving wastewater treatment plant. This master thesis is about a pharmaceutical company and the wastewater from it. The company (McNeil) will introduce new products, and this will result in new wastewater streams with unknown properties. It is crucial that the new streams do not cause complications in the receiving wastewater treatment plant and for this reason the new streams needed to be examined.

Samples of the new streams were sent to an external laboratory that examined the properties of the water. The properties were: pH, BOD, COD, BOD/COD, phosphorus, nitrogen, toxicity and nitrification inhibition. The new streams were assessed based on different criteria. One was if the streams were within the permits and the other one was if the streams differed from previous wastewater and municipal wastewater.

McNeil also needed to investigate the previous characteristics of their wastewater, so a compilation of previous measurements was carried out. The measured properties in the compilation were: pH, BOD, COD, BOD/COD, suspended materials, phosphorus and nitrogen.

The historic streams from the company had levels that were in line with municipal wastewater for all parameters except for BOD and COD. Like the historic values, the new wastewater streams were in line with all parameters except for BOD and COD. However, the levels of BOD and COD were lower compared to previous streams from the company.

The examined streams were from different parts of the production and a total of 10 samples were collected. Some samples were assumed to have the same properties, these samples came from a process with parallel tanks. Streams that came from steps that corresponded with each other in the parallel tanks were assumed to have the same properties since the steps were identical but loaded in different tanks.

It seemed that the streams that contained low amounts of detergent showed less toxic and inhibitory properties. In contrast, streams that contained high amounts of detergent showed high toxicity and high inhibitory properties. Consequently, it seemed that traces of pharmaceutical products in the wastewater were not the issue, but rather the detergents.

All streams that do not contain significant amounts of detergent could be sent to the receiving wastewater treatment plant, but the detergent streams must be handled. The problematic streams can be dealt with an end-of-pipe solution or a proactive solution.

Sammanfattning

Avloppsvatten från läkemedelsindustrin innehåller ibland ämnen som kan orsaka komplikationer i den mottagande avloppsreningsverket. Denna uppsats handlar om ett läkemedelsföretag och dess avloppsvatten. Företaget (McNeil) kommer att introducera nya produkter, vilket resulterar i nya avloppsvatten med okända egenskaper. Det är av största vikt att de nya strömmarna inte orsakar komplikationer i det mottagande avloppsreningsverket och därför behövde de nya strömmarna undersökas.

Prover av de nya strömmarna skickades till ett externt laboratorium som undersökte egenskaperna hos vattnet. Egenskaperna var: pH, BOD, COD, BOD/COD, fosfor, kväve, toxicitet och nitrifikationsinhibering. De nya strömmarna bedömdes utifrån olika kriterier. En var om strömmarna var inom tillstånden och den andra var om strömmarna skilde sig från tidigare avloppsvatten och kommunalt avloppsvatten.

McNeil behövde också undersöka de tidigare egenskaperna hos deras avloppsvatten, därför genomfördes en sammanställning av tidigare mätningar. De uppmätta egenskaperna var: pH, BOD, COD, BOD/COD, suspensioner, fosfor och kväve.

De historiska strömmarna från företaget har varit i linje med kommunalt avloppsvatten för alla parametrar förutom BOD och COD. Liksom de historiska värdena var de nya avloppsvattnen i linje med alla parametrar förutom BOD och COD. Nivåerna av BOD och COD var emellertid lägre i de nya strömmarna jämfört med tidigare strömmar från företaget.

De undersökta strömmarna var från olika delar av produktionen och totalt samlades 10 prover. Vissa strömmar antogs ha samma egenskaper, dessa strömmar kom från processen med parallella tankar. Strömmar som kom från motsvarade steg i de parallella tankarna antogs ha samma egenskaper eftersom stegen var identiska men körda i olika tankar.

Det verkade som om de nya strömmarna med lågt detergent innehåll visade låg toxicitet och låga hämmande egenskaper. Däremot visade strömmar med högt detergent innehåll hög toxicitet och höga hämmande egenskaper. Det verkade alltså som att produktspår i avloppsvattnet inte var problemet, utan snarare detergent innehåll.

Alla strömmar som inte innehåller betydande mängder detergent kan skickas till mottagande avloppsreningsverk, men strömmar med högt detergent innehåll måste hanteras. De problematiska strömmarna kan hanteras med en end of pipe-lösning eller en förebyggande lösning.

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Abbreviations

API	Active pharmaceutical ingredient
BOD	Biological oxygen demand
COD	Chemical oxygen demand
GMP	Good manufacturing practice
NF	Nanofiltration
MF	Microfiltration
SS	Suspended substances
WWTP	Wastewater treatment plant
UV	Ultra violet
Tot-N	Total of nitrogenous compounds
Tot-P	Total of phosphorous compounds
EC50	Effective concentration 50 %
EC20	Effective concentration 20 %
AP	Aqua Purificata

1 Introduction

McNeil is a global company and is a part of Johnson & Johnson. Johnson & Johnson is the world's largest healthcare company, with 250 affiliated companies in 60 countries and 129 000 employees. McNeil is a manufacturer of over-the-counter drugs and their most renown product is Nicorette –smoking cessation aid. The entire site is under strict GMP regulations (Good Manufacturing Practices). GMP are a set of international regulations for production of pharmaceuticals meant to guarantee that products do not harm the patient. Keywords in GMP are: strength (the product has the right potency), purity (the product has not been contaminated), efficacy (the product has the properties claimed) and identity (the right product is being manufactured) [1, 2].

Pharmaceutical traces in wastewater are an emerging environmental problem. One of the contributors to this issue is wastewater from pharmaceutical production facilities. Companies of this nature have restrictions and permits for wastewater handling. McNeil is an example of a pharmaceutical company with strict regulations and permits that must be followed. The current wastewater from McNeil is treated at the wastewater treatment plant (Öresundsverket) without complications.

Three new products will be introduced in McNeil's production line within the next 2-3 years. The active pharmaceutical ingredients (APIs) in the new products are: budesonide, benzocaine and nicotine. The third product containing nicotine was not examined for two reasons. The first reason was that there was no wastewater to collect within the time frame and the other reason was that the process is well known, and the appropriate handling is already established. When referring to the active ingredients in this paper the abbreviation APIs will be used. The scope of this master thesis is to assess the new process water and the effects of the new products.

1.1 Goal

The goal of this thesis is to answer the following questions: what properties has the wastewater shown in past measurements, does the introduction of new products change the properties and lastly what actions/methods are appropriate when handling the new process water? Long term effects were not examined due to time restrictions.

2 Literature Review

2.1 Relevant permits and regulations

Miljöbalken is a collection of Swedish laws with the purpose of securing the local environment for present and future generations. It should be applied in such a manner that human health and environment is protected against damage and pollutions, ecosystems and cultural heritage is protected, biodiversity is preserved, and recycling is promoted [3]. According to the environmental legislation miljöbalken chapter 9, McNeil is categorized as a facility that can cause harm to the environment. Companies are put in this category if they meet at least one of the definitions below.

I. The company discharges wastewater, solids or gas from land, from its buildings or facilities [3].

II. The company's usage of land, buildings or facilities could cause inconvenience to human health or the surrounding environment through emissions other than those referred to in I [3].

III. The company's usage of land, buildings or facilities could cause environmental inconvenience by noise, shaking, light, ionizing or non-ionizing radiation or the like [3].

McNeil has received their permits from Miljöprövningsdelegationen in Skåne county according to the ninth chapter in Miljöbalken. The relevant part of the permit is regarding the wastewater and is summarized in the list below. The complete permit can be found in Appen-dix A.

Permit regarding wastewater:

- McNeil is not allowed to release more BOD7 than 300 tons per year [4].
- The BOD/COD ratio is recommended to be above 0.4 [4].
- McNeil is not allowed to release wastewater with pH levels outside the interval 6.5-10 [4].

There are also other guidelines and recommendations that are relevant for the wastewater from McNeil. The guidelines and recommendations are from Öresundsverket and they are summarized in the list below. The list also includes a table for overring fees.

Other guidelines and other recommendations:

- Nitrification inhibition is only seen as acceptable if the inhibition is 10% after 20% dilution in municipal water [5].

- The wastewater entering the plant cannot have properties that can harm Öresundsverket's process, sludge, recipient, piping or personnel [4].

- Wastewater should have sufficient levels of either BOD, nitrous compounds or phosphorus compounds. This recommendation is to ensure that the water is treatable. A treatable water has either a BOD level exceeding 10 mg/l, Tot-N exceeding 10 mg/l or a Tot-P higher than 0.3 mg/l [4].

- Water from industries can result in overriding fees if levels of a parameter are higher than normal municipal wastewater. The values that are traditionally found in municipal wastewater is referred to as normal values. The content that can result in penalties are: BOD7, Tot-P, Tot-N and suspended substances. More detailed information about fees and normal values are presented in Table 2.1. [5].

Table 2.1. Overring fees for the parameters BOD, Tot-P, Tot-N and SS.

Parameter	**Normal values [mg/l]**	**Overriding fee [kr/kg]**
BOD7	260	2.53
Phosphorus compounds (Tot-P)	10.5	3.03
Nitrogenous compounds (Tot-N)	52	55.57
Suspended substances	260	30.31

2.2 McNeil and Öresundsverket

2.2.1 Monthly audits of McNeil's wastewater and the executing laboratory

Every month McNeil must submit a report with certain measurements. If the measurements exceed levels that are usually found in municipal wastewater McNeil must pay an overriding fee. According to the regulations the water is tested monthly for flow, pH, BOD, COD, BOD/COD and suspended substances. Phosphorus and nitrogenous compounds are also tested but every third month [1].

The abbreviation BOD stands for biological oxygen demand, whilst COD for chemical oxygen demand. Information about BOD and COD have been gathered from [6]. COD is per definition the oxygen equivalent of the organic matter when it is exposed to a powerful chemical oxidant. When determining the COD the oxidizing agent used is usually dichromate. COD measures both easily degradable organic chemicals and very persistent chemicals. BOD describes the amount of oxygen that is required to degrade the organic matter in the water over a given period. The period is given as an index, the usual BOD measurement is BOD7 (where the period is seven days). BOD cannot determine the level of persistent organic chemicals. If BOD and COD are the same (a BOD/COD ratio of 1) all organic compounds are easily biodegradable. If COD is higher than the BOD it means that the mixture contains persistent organic compounds.

All samples are sent to an external accredited laboratory. The information about accredited laboratories have been retrieved from [7]. Accredited laboratories that are located in Sweden are first inspected and then certified by European and international standards. A laboratory can only be accredited when competence, routines and methods meet the quality demands set by the standards. The purpose of accreditation is to ensure that the laboratory performs with consistency at a high quality. Once a laboratory has been accredited regular internal and external audits will be made. The supervision ensures that the standards are met and if not, the laboratory will lose their certificate.

McNeil uses an external accredited laboratory for all monthly audits since this ensures a trustworthy result. The executing accredited laboratory is Synlab. Synlab also performed the laboratory analyses in this master thesis.

2.2.2 An overview of the receiving plant

Öresundsverket is the receiver of McNeil's wastewater. It is essential that the water from McNeil does not impair the receiving wastewater treatment plant (WWTP). To assess the water and how product traces or other unusual constituents in wastewater can result in complications some basic knowledge about the WWTP is needed. The current process in Öresundsverket includes a coarse mechanical treatment, a second mechanical treatment in parallel supply basins, biological removal of phosphorus and nitrogen in activated sludge and sludge sediments with two-media filters [8]. The information about Öresundsverket that is presented below have been collected from [8, 9].

The first step in Öresundsverket is a grid chamber for removal of solid contaminants and the water is pumped further on in the process via parallel screw pumps. The solid particles are collected as residual waste. Smaller particles are separated by sedimentation. After the mechanical separation steps, subsequent biological treatments take place. The biological treatments remove and/or reduce the levels of BOD, Tot-P and Tot-N. Biological treatments can be affected by toxic or inhibitory properties since it is reliant upon living organisms. The water finally goes through a filter to remove the remainder of the suspended substances before being released into Öresund.

Öresundsverket is the receiving wastewater treatment plant to other organizations as well. To put McNeil's discharges in relation to the total influx to Öresundsverket the fraction was calculated for the BOD and the flow. The actual BOD is not available for the current year, so the used BOD value for the calculation will be the maximal permitted amount (300 ton per year). Öresundsverket yearly receives 5 150 tons/year and McNeil's contribution to the BOD is 5.8 % [10]. The mean volume that Öresundsverket receives in total from various sources is 54 200 m^3/day and 1 626 000 m^3/monthly [10]. Corresponding values for McNeil are 53 m^3/day and 1 600 m^3/monthly. McNeil's' contribution to Öreundsverket is around 0.098 % of the total.

2.2.3 Undesired properties of the wastewater from McNeil

The streams from McNeil that enters Öresundsverket cannot be corrosive, a corrosive stream would cause complications in the mechanical steps, the piping, the biological process and the local environment in Öresund. This means that the pH level should not be too high or too low. McNeil's permit allows them to have a pH within 6.5-10 if the pH is outside this interval the pH must be adjusted on site [3].

Furthermore, the streams cannot be toxic or have inhibitory properties. A toxic/inhibitory water can affect the biological treatments. Biological removal of Tot-N is particularly critical due to its low rate of growth and sensitive microbes [8]. The biological removal of Tot-N is usually by nitrification followed by denitrification.

If the water has low to moderate toxic/inhibitory properties, the result in the WWTP is usually loss of capacity and increased running costs. In the worst case these types of wastewater can knock out the biological treatments. Inhibition can stem from various sources depending on the microbe and some of them are: toxicity, competition, oxygen levels, nutrient levels and pH [8]. If the water contains substances that harm the microbes the inhibition is caused by toxicity [8].

A very high BOD level is also undesired since it can lower the efficiency in the plant and result in increased running costs. McNeil is permitted to release 300 ton BOD per year and is recommended to have a BOD/COD ratio above 0.4. A low BOD/COD ratio is undesirable, a low ratio means a high content of persistent substances [3].

2.3 Issues that need to be examined

2.3.1 Standard monthly test

To assess the new water the fundamental properties had to be known. The fundamental properties were the parameters in the monthly audit. Properties that are very deviant from the municipal wastewater and/or past wastewater must be identified and examined.

2.3.2 Nitrification inhibition

Nitrification is a vital part of the removal of nitrogen in the receiving WWTP. Consequently, the new wastewater's inhibitory properties were examined. This was to ensure that the new water would not impair the nitrification process at Öresundsverket.

Nitrification involves a series of aerobic biochemical reactions. In the first part of the nitrification process, ammonium is converted to nitrite by a series of chemical reactions [8]. The product, nitrite is transformed into nitrate in a subsequent step. Some of the reaction routes are unknown but the overall conversion can be seen in equation number 2.1. and 2.2 [8]. The microbes that are involved in nitrification processes are referred to as ammonium oxidizers (responsible for the first part of the process) and nitrite oxidizers (responsible for the second part of the process) [8].

$$NH_4^+ \rightarrow NH_2OH \rightarrow unknown \rightarrow NO_2^- \qquad \text{(Eq 2.1)}$$

$$NO_2^- \rightarrow NO_3^- \qquad \text{(Eq 2.2)}$$

Other than the traditional inhibitory sources (toxicity, competition, oxygen level, pH level) the microorganisms in the nitrification process can also be inhibited by the substrates (ammonium and nitrite) [8].

2.3.3 Toxicity

The nitrification test is limited to the specific microbes used in the test and cannot be used to evaluate toxicity towards other microorganisms. There are other microbes in the biological processes of the WWTP and a more general toxicity test was needed, for this reason a toxicity test was conducted as well.

2.3.4 Summary of the purpose of laboratory tests

A summary of the purpose of the laboratory tests is presented in the list below. The list includes the purpose of the toxicity test, standard monthly test and nitrification test.

Summary of the purpose of the laboratory tests:

- Toxicity test
  -Determines the toxicity of the new water. This test is linked to Öresundsverket's rule: "*The wastewater cannot have properties that can harm Öresundsverket's process, sludge, recipient, piping or personnel"* and it can be found in chapter 2.1 "Relevant Permits and regulations".

- Standard monthly test: pH, BOD, COD, BOD/COD, Tot-P and Tot-N
  - Determines the fundamental properties of the new water. This test is linked to the permits found in chapter 2.1 "Relevant Permits and regulations".

- Nitrification inhibition test
  -Determines the nitrification inhibition of the new water. This test is linked to the same rule as the toxicity test and "*Nitrification inhibition is only seen as acceptable if the inhibition is 10% after 20% dilution in municipal water"*. Both recommendations can be found in chapter 2.1 "Relevant Permits and regulations".

2.4 Chemical and ecological information about the APIs

2.4.1 Nicotine

Chemical properties
Nicotine is also known as 3-(1-methyl-2-pyrrolidinyl)-pyridine, a nicotine molecule consists of a pyridine and a pyrrolidine ring [12]. The substance is a toxic alkaloid found in tobacco [11]. The substance is a medium strong organic base (pKa=8.5) and is yellow, viscous and oily [12]. Nicotine has the molecular formula $C_{10}H_{14}N_2$ and a molecular weight of 162.236 g/mol and is completely soluble in water [12]. The substance is stable under normal conditions, adverse mixtures with other substances is not known [11]. Nicotine is produced from dried leaves of the tobacco plant *Nicotiana tabacum* and related species and has a very characteristic scent [12,13]. Nicotine has two stereoisomers and S (-) is the dominant from in tobacco and is also the most pharmacologically active [12].

Therapeutic uses and possible side effects
Nicotine causes addiction in humans, effects the nervous system and increases the risk of cancer and is readily absorbed by the skin, lungs and membranes [12]. Since nicotine effects the nervous system long term use of nicotine can cause psychological and physical dependence [12]. Regular consumption of nicotine causes cardiovascular effects such as: peripheral vasoconstriction, tachycardia and elevated blood pressure. Nicotine can also be used as a quit-smoking aid additive in gums and patches [12].

Environment
Nicotine is biodegradable but degrades slowly and is unlikely to bioaccumulate in aquatic organisms [12]. Nicotine is highly toxic to microorganisms and aquatic organisms [12]. The toxicity for nicotine has been tested on a water living organism, the organism used in the test was *Oncorhynchus mykiss* (trout) and the results are presented in Table 2.2 [12].

Table 2.2. Toxicity levels of nicotine for the organisms Oncorhynchus mykiss.

Organism	Concentration	Exposure time	Result
Oncorhynchus mykiss	4 mg/l	96 hours	50% of the population die at exposure

The results from the toxicity test shows that the substance will exhibit toxic properties when the concentration is in the order of magnitude mg/l.

2.4.2 Budesonide

Chemical properties
The molecular formula of budesonide is $C_{25}H_{34}O_6$ and it has molecular weight of 430.541 g/mol [17]. Budesonide is a scentless crystalline powder with the color white to off-white and is stable under normal conditions [14]. There are no known hazardous reaction routes, conditions that should be avoided and no hazardous decomposition products are known [17]. Release of budesonide into municipal water, streams and wells should be avoided [15]. Budesonide has a LogP (partition coefficient) of 3.2 which means that it is practically water insoluble (1 mg/l) [16, 17]. It does not have a pKa since this compound does not dissociate at any pH level [17].

Therapeutic uses and possible side effects
This glucocorticoid steroid is anti-inflammatory and is used to treat asthma, allergic rhinitis and obstructive pulmonary disease [15]. Budesonide has a low acute toxicity but exposure to skin can cause rashes and allergenic responses [15, 17, 19]. Exposure to eyes may cause cataracts and viral infection [17]. If the respiratory tract is exposed to budesonide a sore throat and hoarseness can occur [14, 15]. No signs of cancerogenic effects or genotoxicity have been found for budesonide. It is however, suspected to inflict fetus injuries. Long term exposure above 0.01mg/m^3 can cause: edema, negative kidney effects, elevated blood pressure and fatigue [16].

Environment
Budesonide effects water living organisms in certain concentrations and can also have long lasting effects on the environment. The risk for bioaccumulation in aquatic organisms is moderate and the substance is not readily biodegradable [17]. Budesonides toxicity has been tested on water living organisms, *Oncorhynchus mykiss* (trout) and *Pseudokirchinella subcapitata* (algae) [19]. The acute toxicity of the substance was determined with the trout and the growth inhibition properties were determined with the algae, the result is presented Table 2.3.

Table 2.3. Toxicity levels of budesonide for Oncorhynchus mykiss and Pseudokirchinella subcapitata.

Organism	Concentration	Exposure time	Result
Oncorhynchus mykiss	>13 mg/l	96 hours	50% of the population die at exposure
Pseudokirchinella subcapitata	>8.6 mg/l	72 hours	50% of the algae show growth inhibition

The results from the toxicity test shows that the substance will exhibit toxic properties when the concentration is in the order of magnitude mg/l.

2.4.3 Benzocaine

Chemical properties

The information about the chemical properties of benzocaine has been retrieved from [20, 21]. Benzocaine (ethyl 4-aminobenzoate) has the molecular formula $C_9H_{11}NO_2$ and has a molecular weight of 165.192 g/mol. It is a scentless white crystalline powder. Benzocaine should not be exposed to light, heat and is incompatible with strong oxidizing agents. Hazardous decomposition products are formed during fires, e.g. NO_X and CO_X. Release of benzocaine into municipal water, streams and wells should be avoided. The substance can be degraded by chemical and biological agents. Benzocaine is slightly soluble in water. The pK_a of benzocaine is 2,51 which means that it is a medium strong acid.

Therapeutic uses and possible side effects

The information about the therapeutic uses and possible side effects of benzocaine was gathered from [21]. Benzocaine is an ester and is used as a pharmaceutical ingredient for topical anesthetic purposes (to relieve pain and itching from various sources). Benzocaine relieves pain due to its ability to temporally block conductivity of the nerve receptors. It can also be used as a lubricant and to suppress the gag reflex.

Environment

Benzocaine is toxic to aquatic organisms and may have long-lasting effects on the water environment [20]. It is readily biodegradable and bioaccumulation in aquatic organisms is unlikely [21]. The results from a toxicity test for benzocaine was found, the organism was O. Mykiss and the outcome is presented Table 2.4. [21].

Table 2.4. Toxicity levels of benzocaine for Oncorhynchus mykiss.

Organism	Concentration	Exposure time	Result
Oncorhynchus mykiss	>5.92 mg/l	96 hours	50% of the population die at exposure

The results from the toxicity test shows that the substance will exhibit toxic properties when the concentration is in the order of magnitude mg/l.

2.5 Upgrading methods

2.5.1 Available methods for lowering BOD and/or COD levels

There are several methods for lowering overall BOD levels. The methods can be divided into three main groups: phase separation, biological treatments and advanced oxidation processes [22]. In a phase separation process the contaminants is not destroyed but moved to another phase [23]. Biological treatments utilize microbes that degrade and take up the organic contaminants [22]. Chemical oxidation techniques also degrade the contaminants but with strong oxidizing agents instead of organisms [22]. A selection of available upgrading techniques is presented below.

Adsorption

One of the phase-changing methods is adsorption. Adsorption is a process where a material within a fluid sticks to another media [23]. The once dissolved material will now from a film on the introduced media, and a separation of unwanted substances is made possible. There are some preconditions for a successful adsorption. The most important one is that the material must from stable bonds with the adsorbing agent. In more scientific words, the material must have weaker intermolecular forces between the solution than the material and the adsorbant [23].

The adsorbing agent is usually activated carbon. Activated carbon is an efficient adsorbing agent due to its high porosity and specific surface area [22]. It can also be customized by chemical preparation to be more selective towards a specific contaminant [23]. The arrangement of the adsorption process depends on the particle size of the activated carbon. Powdered activated carbon is used in batch processes, where it is mixed with the wastewater during constant mixing [22]. The tank is then emptied and the carbon with the adsorbed substance goes through a filter and is then sent to disposal. If the activated carbon is granular, the wastewater is pumped through a carbon packed filter [22]. The filter can be open or closed but is always under pressure. The lifetime of the filters is shortened by high levels of suspended materials and/or high levels of dissolved organic material [23]. Irrespective of the adsorption design, the sites on which the adsorption takes place will become occupied after some time. When this has happened, the carbon must be regenerated or replaced [23]. The reactivation demands high temperature and the adsorbed organic compounds are destroyed [23]. The column efficiency is harmed by suspended materials and high levels of organic material [22].

Membrane filtration

In membrane filtration the contaminated water is sent through a filter and the water will pass through whilst targeted contaminants will be retained. Traditionally membranes allow water and low molecular weight solutes to pass and retain suspended solids and high molecular weight solutes [23]. Membranes are divided into five subclasses depending on their pore-size. Membranes with the smallest pore size is referred to as an reverse osmosis membrane (0.0001 µm) and the largest is called microfiltration membrane (1 µm) [23, 24]. Depending on the pore size, hydrophobicity and charge of the membrane and other filtering features different chemicals will be retained [24].

Separation principles are conditions that determine the efficiency of the separation. Separation principles in membrane filtration are the following: the sieve effect (pore size in relation to molecular size), electrostatic effects (charge repulsion) and diffusion of solvent [24].

Cutoff values are used as a characterization of the membrane and its linked to the sieve effect [24]. The cutoff value represents the lowest molecular weight that a substance can have and still be separated by 90% [24]. For example, Nanofiltration membranes traditionally have cutoff values between 150-500 Dalton (g/mole) [23, 24].

Suspended materials shorten the lifespan of the membranes. Prefilters are usually installed to spare the membrane filter when a water with a high content of suspended materials is treated [23, 25]. After the separation at least two streams are formed, one diluted and one concentrated stream. The concentrated stream must be handled by a second step or sent to destruction. It is not uncommon that membrane technology is combined with biological or chemical oxidation [25].

Advanced and chemical oxidation techniques

In advanced oxidation methods strong oxidizing agents are used. The most common ones are ozone (O_3) and hydrogen peroxide (H_2O_2) [23]. If a substance is not oxidized by ozone or hydrogen peroxide, it might be oxidized by a stronger agent, the hydroxyl radical (OH*) [23]. Radicals have one unpaired electron and is therefore a group of very strong oxidizing agents. The hydroxyl radical is produced by exposing hydrogen peroxide to UV-light, titanium dioxide (TiO_2) or iron (Fenton reaction) [23].

In most oxidation techniques the wastewater is sent through a tank where it is exposed to the oxidizing agents [23]. Advanced oxidation technologies have the capability to degrade a wide range of substances and at a high removal efficiency [25]. Titanium dioxide photocatalysis for example, removed 90% of a selection of 15 pharmaceutical substances [26]. Similar results were attained for solar photocatalysis, solar-Fenton and ozonation [26]. UV assisted oxidation can be crippled by a complex matrix for a few reasons. One of the issues are non-target consumption of the oxidant, meaning that substances in the matrix are being oxidized instead of the targeted substance [27]. The matrix could also contain chemicals that are disruptive by absorbing photons from the irradiation [27]. The phenomenon is called inner filter effect, no reaction will take place if the effect is very strong [27]. Oxidation offers a very high removal rates, 90-100% are not uncommon numbers [27] [23].

Biological treatments

Biological treatments utilize microorganisms that degrade the organic components in the water. A biological degradation process has a very wide range of efficiency, the interval is 0-99% removal. The efficiency of the biological treatment is usually very high for easily degradable substances and nonexistent for persistent substances [23]. Biological methods are often based on activated sludge or biofilms and these methods can either be aerobic or anaerobic [23, 25].

A site-specific pilot study was conducted in 2015 at McNeil [25]. The aim of the study was to identify possible methods for reducing BOD levels of the wastewater at McNeil if a future need arose. The wastewater that was examined in the study was from a process at the site and the streams contained sugar alcohols. The pilot study deemed biofilms as a possible treatment option for the examined streams [25].

In a biofilm process, the wastewater is usually sent to a reactor tank filled with a carrier material [25]. A biofilm grows on the carrier material and the suspended carrier is kept within the reactor by a coarse grid in the tank outlet [25].

A biofilm consists of a group of bacterial populations living on a surface. The microbial community must be compatible with the organic contaminants in the wastewater and with each other [28]. Conventional biofilms are less sensitive to toxic substances compared to activated sludge processes but are like any other biological process vulnerable due to the living organisms [25]. Biofilms can however be fortified with bioaugmentation [28]. Bioaugmentation involves adding microorganisms into the microbial community [28, 29]. Bioaugmentation has shown both promising and failed results. Failure is often reported during scale up and is often due to loss of organisms [29].

2.5.2 Available methods for lowering API levels

In general, APIs are expensive raw materials and several efforts are made to minimize losses and maximize the yield. This in turn, will probably result in low content of APIs in the water [1]. The available methods for lowering a specific API level are the same as for lowering BOD levels. It is possible to lower API levels by a general approach or to target a API specifically [25].

General treatments are nonspecific and so, removal of a substance is proportional to its compatibility with the method. This phenomenon is of course a drawback since high removal of a specific substance could be disturbed by other organic compounds. If a specific API is to be removed, a process that lowers disruptive BOD (other organic compounds) should be applied first [25]. The pretreatment should be followed by a secondary treatment customized to lower the targeted API. Another option is to intercept the stream before it reaches the gathering point and treat it, since the water will have a less complex matrix.

It has been reported that some of the methods described in chapter 2.5.1 “Available methods for lowering BOD and/or COD levels” can be customized for targeting the APIs of this thesis. Biological treatments can be customized to target a specific API by bioaugmentation [28]. Nicotine can for example be degraded by microbials that utilizes nicotine in its metabolism [28]. The group is referred to as Nicotine-degrading microorganisms (NDMs).

One of the NDMs is *Arthrobacter nicotinovorans*, a gram-positive soil bacterium that use nicotine as its sole carbon source [29]. Other kinds of soil bacteria that can decompose nicotine is A*grobacterium sp. strain S33* and *pseudomonas* (both gram negative) [28]. Nicotine can also be degraded by *Aspergillus oryzae,* a fungus that can be found on tobacco leaves [28, 29].

Removal of nicotine in wastewater has been reported to reach removal efficiencies of 98% [28]. The case was on lab scale with a biofilm process fortified with *Pseudomonas sp*. and *Acinetobacter sp* [28]. Information about this procedure on a larger scale is scarce. One of the known successful big scale bioaugmentation processes are removal of chlorinated compounds by *Dehalococcoides* bacteria from groundwater [29]. Bioaugmentation is also possible for Budesonide and Benzocaine if microbes are found that degrade them. Budesonide can for example be degraded to completion (100%) by the colonic bacteria found in the human body [30].

Like biological treatments, activated carbon can be customized to be more selective towards one substance. The activated carbon is customized by chemical preparation to be more selective towards a specific contaminant. In one study activated carbon was modified to increase the nicotine adsorption [31].

No cases where membranes or oxidation was customized to target the APIs were found. Chemical oxidation cannot be customized since the degradation is based on very reactive substances that will react with most species. Like oxidation, membranes cannot be customized to target a specific substance.

2.5.3 Other treatments

Other methods that are relevant are presented in this section. Other treatments that McNeil might need to implement are treatments that adjust the parameters: pH, suspended materials, Tot-P and Tot-N.

pH adjustment

pH adjustments are needed if the wastewater is outside the permitted interval. Correction of the pH is achieved by monitoring the pH and adding acid or bases until an acceptable pH is reached. Acids used for pH adjustment are usually: sulfuric acid, hydrochloric acid, nitric ac-id, phosphoric acid and carbon dioxide [32]. Bases used for pH adjustments are: sodium hydroxide, ammonium hydroxide, magnesium hydroxide, and calcium hydroxide (lime) [32].

The simplest systems for pH adjustment has one neutralizing agent. To only have one neutralizing agent can lead to complications, since the adjustment of the pH is in one direction. If pH passes the neutral point by overloading of the neutralizing agent, the pH cannot be altered again. Overloading is not uncommon, and the reason is that pH response is delayed and nonlinear [33]. To have two neutralizing agents (one base and one acid) means that overloading can be dealt with since it can be adjusted by the other neutralizing agent.

Lowering of SS

Suspended materials can be reduced by filtration, coagulation-flocculation and flotation. Filters are made of a mechanical support, a coarse filtration that separates SS from the mixture by using a thin sheet. Microfiltration is often accomplished by microdisc filters or similar. After some time, the captured material causes fouling in the filter. Fouling increases with a high filtration velocity and high content of SS [34]. Coagulation-flocculation and floatation can be used if the SS have another density than the liquid that is to be upgraded [34].

Lowering of Tot-N and Tot-P

Phosphorus and nitrogenous compounds are also a parameter that should be lowered if it exceeds the levels of municipal wastewater . The levels of Tot-N can be lowered with a biological nitrification and denitrification process [8]. Phosphorus levels can be lowered by chemical precipitation, usually with ions from aluminum [35].

2.6 Summary of the R and the M process

The new products are a pill against a sore throat, a nasal spray to ease allergic reactions and an electric cigarette [1]. The pill is referred to as the M product and the API used is benzocaine, the process that produce the product is referred to as the M process. The nasal spray is referred to as the R product and the API used is budesonide, the process that produce the product is referred to as the R process. The third product was the E product and the API used was nicotine. The water that has been examined during this project are from the M process and the R process.

The M process is a dry process, meaning that no wastewater is created during a batch. Between each batch, tanks and other equipment is cleaned [36, 37]. It is cleaned in several steps and the last step includes a wash with aqua purificata water (AP water) at 80 ℃. Aqua purificata is a purified, deionized and demineralized water of pharmaceutical quality in accordance with the European pharmacopoeia [1]. The duration of the washing step is 1.5 hours [36]. The total volume of washing water in the M process is 1.8 m^3.

The R process is a wet process, meaning that water is used throughout the process. The R-process is a continuous process with two parallel tanks (big tank and small tank). When the product is finished the tank and piping is cleaned with an automatic washing procedure [38]. The first wastewater is sent to destruction, this water was not sampled since it was not within the scope of this thesis. In the automatic washing procedure there is a sequence of steps with predetermined discrete volumes [38]. The steps in the parallel tanks are identical but more AP water is used in the steps of the big tank.

The first step is referred to as the first wash and in this step the tank and pipes are washed solely with AP water [39]. After the first wash the tank and equipment are washed with detergent and AP water, this step is called the neutralization [39]. The neutralization step is repeated once and followed by the last wash. In the last wash AP water is used and no additional substances are loaded [39]. It is very likely that the streams from the last wash contain detergents even if it is not being loaded in the step, since the tank and pipes can contain detergents from the previous steps [39]. After each step the water from the pipes and tank is sent to an automatic neutralization tank and is not released from the outlet until it is deemed neutral [38, 39].

It was assumed that the streams from corresponding steps would have the same properties regardless if they came from the big tank or the small tank. The neutralization steps were also assumed to have the same properties regardless if it was the first or second round.

Since the washing for the M process is continuous there are no discrete streams. The volume and possible content of the streams from the M and R process is summarized in Table 2.5.

Table 2.5. Volume and possible content of the streams in the R process and M process.

Stream	Possible content	Volume [m^3]	Percentage of the daily total flow from McNeil [%]
M process **Equipment water**	AP water+ traces of product	Not applicable	3.4% (not individual stream, total volume from the process)
M process **Equipment and well water**	AP water + traces of product	Not applicable	3.4% (not individual stream, total volume from the process)
R process **First wash, small tank (internal number 28)**	AP water + traces of product	0.09	0.17
R process **Neutralization, small tank (internal number 52)**	AP water + traces of product + detergent	0.08	0.15
R process **Neutralization, small tank (internal number 132)**	AP water + traces of product + detergent	0.09	0.17
R process **Last wash, small tank (internal number 397)**	AP water + traces of product +traces of detergent	0.09	0.17
R process **First wash, big tank (internal number 456)**	AP water + traces of product	0.12	0.23
R process **Neutralization, big tank (internal number 515)**	AP water + traces of product + detergent	0.12	0.23
R process **Neutralization, big tank (internal number 540)**	AP water + traces of product + detergent	0.12	0.23
R process **Last wash, big tank (internal number 568)**	AP water + traces of product +traces of detergent	0.12	0.23

3 Materials and Methods

3.1 Sample collection

The water from the M process was collected in two ways. The first collecting method was to place the sample container underneath the equipment during the washing. The containers where placed in different positions beneath the equipment. This means the distribution of product traces and flow was random and this resulted in that some of the AP water came straight into the container without going through the equipment. The distribution of the flow was random and so, it is not possible to guarantee that the samples will have an even distribution of the content. There is also a risk that some of the samples do not contain any residues. However, the water from the first method is more representative since the sample only contains residues from the M process.

In the second method the water was collected from a well where all the water is collected before it is sent to Öresundsverket. The water from the well was collected every third minute during the entire washing period. There is a risk that residues from other products might be in the well, which is a weakness of this method. An advantage with this method compared to the first method is that the content in the well probably will be closer to the mean content. The reason for this is that all water from the wash will be collected in the well before it is sent towards the receiving WWTP.

The water from the R process was collected by filling the sample containers from the outlet.

3.2 Identification of suitable laboratory tests

All collected samples were sent to an external lab, Synlab in Linköping. By sending the samples to an accredited laboratory the content and properties of the water were determined with minimal sources of error. The current wastewater does not contribute to major disturbances in the receiving wastewater treatment plant. The first method for characterizing the water was therefore the regular monthly test. If the new wastewater is like the previous wastewater, it is unlikely to cause issues in Öresundsverket. The standard monthly test included: pH, BOD, COD, BOD/COD, Tot-P, Tot-N and suspended substances. Suspended substances were not tested since McNeil's activities does not give rise to this type of issue.

Two additional tests were deemed suitable: the toxicity test and the nitrification inhibition test. The reason behind this choice was that the receiving wastewater treatment plant (Öresundsverket) have biological steps in its process. It is essential that the new wastewater does not impair the microbes or the nitrification process. Toxicity can impair the nitrification process and the other biological steps. The nitrification test was also deemed necessary since inhibition can be caused from various reasons and it does not have to be toxicity.

3.2.1 Standard monthly analyses

The overall steps of the analyses that Synlab conducted will be accounted for in a concise list and the information was retrieved from [40].

Standard monthly analyses:

- Determining of the samples pH, with the analysis method SS-EN ISO 10523:2012.
- Determining of the samples BOD7, with the analysis method SS-EN ISO SS-EN 1899-1.
- Determining of the samples COD, with the analysis method ISO 15705:2002.
- Determining of the samples Tot-P, with the analysis method ISO SS-EN ISO 15681-2:2005.
- Determining of the samples Tot-N, with the analysis method ISO SS-EN ISO SS-EN 12260:2004.

3.2.2 Nitrification inhibition analysis

The nitrification inhibition test examines how the nitrification bacteria found in activated sludge are affected when it is exposed to the examined sample [1]. The nitrification inhibition is measured by comparing the production of oxidized nitrogen in two beakers. One beaker is a blank and only contains activated sludge and sewage water, the other beaker has the same content as the blank and also contain the sample. The concentration of the sample is 20% [1]. If the beaker with the sample has a lower production than the blank, the sample is categorized as inhibitory. The loss of production (inhibition) when the activated sludge is exposed to the sample is accounted for in percent [1]. Synlab performs the nitrification inhibition by a collection of standard methods that are gathered in one ISO method and is accounted for below.

- Determination of the nitrification inhibition with the sample concentration 200ml/l, with the analysis method EN ISO 9509:2006. [40].

3.2.3 Toxicity analysis

The toxicity test is an acute toxicity test. The used test organism is the marine bacterium *Vibrio fischeri* that produce light. The acute toxicity is measured in loss of bioluminescence. Toxicity of the sample is determined by the values of EC20 and EC50. EC50 corresponds to the concentration of the sample where 50% of the population show loss of bioluminescence. EC20 corresponds to the concentration of the sample where 20% of the population show loss of bioluminescence. Samples are divided into three groups depending on the EC50 after 15 min.

In this test The EC50 and EC20 is given in volume percent of the sample. Samples with and EC50 below 20% are highly toxic, a moderate toxic sample has a EC50 within 20-70% and a low toxic sample has a EC50 over 70% [41]. The overall steps of the toxicity test will be accounted for in a concise list and the information was retrieved from [41].

Toxicity test methodology:

1. Determining of the samples pH, with the analysis method SS-EN ISO 10523:2012.

2. Amendment of the pH if it is needed, with the analysis method SS-EN ISO 10523:2012.

3. Filtering of the sample, with the analysis method “Filt 0.45 um membranfilt”.

4. Screening for EC50 (the concentration where half of the population shows inhibition) for the exposure time 5, 10 and 30 minutes, with the analysis method SS-EN ISO 11348-3 mod.

5. Screening for EC20 (the concentration where half of the population shows inhibition) for the exposure time 5, 10 and 30 minutes, with the analysis method SS-EN ISO 11348-3 mod.

6. Calculation of the TU (toxic unit), the calculation is based on the correlation in equation 3.1 The results from step 4 and 5 are used individually to calculate a TU and the mean value of these are the TU of the sample.

$$TU = \frac{100}{EC} \qquad \text{(Eq 3.1)}$$

4 Results and Discussion

4.1 Historical review of the process water

The data of the historical flows have been collected from McNeil's monthly internal environment reports and put in an excel file. There are two points where the water is collected and sampled, S1 and S5. The new wastewater will be sent towards S5 and for that reason S1 is not of interest in this thesis.

4.1.1 Historical flows and measurements – pH S5

In 2015 the highest pH was obtained in February and the lowest in December. The next year (2016) March was the month with the lowest pH and November and December had the highest pH levels of that year. In 2017 the highest pH was reached in December and the lowest in November. In the current year (2018) March had the highest pH level and February the lowest. The values are summarized in Table 4.1.

Table 4.1. Data for the pH measured in S5, the index shows the month from which the measurement was taken.

Year	Highest pH	Lowest pH	Mean pH	Municipal wastewater
2015	8.4_{Feb}	$7.6_{\text{Mar \& Dec}}$	7.98	7-8 [42]
2016	$8.4_{\text{Nov \& Dec}}$	7.6_{Mar}	8.10	
2017	8.5_{Dec}	7.4_{Nov}	8.19	
2018	8.6_{Mar}	8.0_{Feb}	8.30	

Identified trends

- There is a tendency for the water to be alkaline, with a pH above 7. The values are in line with the values for municipal wastewater.

- pH is a logarithmic scale and it complicates the assessment of fluctuations. An increase of 1 on the pH scale means that the solution has become ten times stronger. The level fluctuance significantly when considering what pH represent. It does not fluctuate significantly if the numbers and/or the levels that have been found acceptable by McNeil (pH 6.5-10) are considered.

- The levels are evenly distributed throughout the year. It is a result of the pH adjustments that is taken as a step to ensure that the water is within 6.5-10.

4.1.2 Historical flows and measurements – Flow S5

Flow is measured as volume per time unit, however due to the discrete flows the flow is first measured then used to calculate the produced volume for the month. The flow in this section should be called total volume, but it is referred to as "flow" since it gives a uniformity to the terminology used at McNeil.

The highest flow was in August and it was measured to 2 149 m^3, the lowest was 1 071 m^3 and was measured in January. The total flow for 2015 was 18 076 m^3 and the mean flow each month was 1 506 m^3. The following year (2016) the flows were lower, and no evident trend was found. In April the lowest flow was 708 m^3, the highest was recorded in September and was 1262 m^3. In 2016 the mean flow was 924 m^3 and the total flow for that year was 11 095 m^3. In 2017 the flows were higher than the previous year and the mean was 1 325 m^3. June had the highest recorded flow which was 1 574 m^3, whilst the lowest was 923 m^3. Measurements collected from the current year (2018) are from January to July. The values are summarized in Table 4.2.

Table 4.2 Data for the flow measured in S5, the index shows the month from which the measurement was taken

Year	Highest flow [m^3]	Lowest flow [m^3]	Mean flow [m^3]	Annual flow [m^3]	Municipal wastewater
2015	2 149 $_{Aug}$	1 071 $_{Jan}$	1 506	18 076	Not applicable
2016	1 262 $_{Sep}$	708 $_{Apr}$	924	11 095	
2017	1 574 $_{Jun}$	923 $_{Jan}$	1 325	15 136	
2018	1 831 $_{Jun}$	1 314 $_{Jan}$	1 562	9 370	

Identified trends

- The monthly flows for each year ranged from 1000 to 2000.
- Fluctuations in this parameter are evident. Some months have a flow that is twice as high as the previous month.
- Higher levels are attained in the summer and early autumn while the lowest are attained in the beginning of the year. The flows for 2015 had a clear profile with a peak in the summer but after 2015 the flows where evenly distributed through the year.

4.1.3 Historical flows and measurements – BOD S5

In 2015 the highest concentration of BOD substances was obtained in May and December. The lowest levels were recorded in July. In the following year (2016) the lowest levels of BOD were recorded in December and the highest in April. In 2017 the highest BOD was recorded in November and the lowest in August. For the current year (2018) January and April had the highest BOD level and February the lowest.

Table 4.3. Data for the BOD measured in S5, the index shows the month from which the measurement was taken

Year	Highest BOD [mg/l]	Lowest BOD [mg/l]	Mean BOD [mg/l]	Municipal wastewater
2015	11 000 $_{\text{May \& Dec}}$	6 000 $_{\text{Jul}}$	8 791	115-400 [42]
2016	12 000 $_{\text{Apr}}$	3 400 $_{\text{Dec}}$	6 958	
2017	14 000 $_{\text{Nov}}$	2 800 $_{\text{Aug}}$	6 733	
2018	14 000 $_{\text{Jan \& Apr}}$	6 200 $_{\text{Feb}}$	10 566	

Identified trends

- The BOD concentration ranged from 3 000 to 14 000 mg/l. The values are significantly higher than municipal wastewater.
- Fluctuations are significant.
- The BOD content of the current year seems to be random and show great fluctuations between each month.
- It was not possible to distinguish a certain month or a period that showed similar behavior throughout the years.

4.1.4 Historical flows and measurements – COD S5

In 2015 the highest concentration of COD substances was obtained in May. The lowest levels were recorded in July. In the following year (2016) the lowest levels of COD were recorded in January and the highest in April. In 2017 the highest COD was recorded in December and the lowest in august. For the current year (2018) July had the highest BOD level and February the lowest. The values are summarized in Table 4.4.

Table 4.4. Data for the COD measured in S5, the index shows the month from which the measurement was taken

Year	Highest COD [mg/l]	Lowest COD [mg/l]	Mean COD [mg/l]	Municipal wastewater
2015	21 000 $_{May}$	9 800 $_{July}$	14 650	210-740 [42]
2016	19 000 $_{Apr}$	6 000 $_{Jan}$	11 550	
2017	24 000 $_{Dec}$	6 000 $_{Aug}$	11 400	
2018	44 000 $_{Jul}$	8 500 $_{Feb}$	21 055	

Identified trends

- The COD concentration ranged from 6 000 mg/l to 44 000 mg/l. COD values are high, the values are significantly higher than municipal wastewater.
- Fluctuations are significant.
- COD values decreased after 2015 but increased again in the end of 2017. It was not possible to distinguish a certain month or a period that showed similar behavior throughout the years.

4.1.5 Historical flows and measurements – Suspended substances S5

In 2015 the highest concentration of SS substances was obtained in December and the lowest in August. In the following year (2016) the lowest levels of SS were recorded in November and the highest in February. In 2017 the highest SS level was recorded in November and the lowest in August. For the current year (2018) May had the lowest levels and the highest levels were found in June. The values are summarized in Table 4.5.

Table 4.5. Data for the SS measured in S5, the index shows the month from which the measurement was taken.

Year	Highest SS [mg/l]	Lowest SS [mg/l]	Mean SS [mg/l]	Municipal wastewater
2015	880 $_{Dec}$	130 $_{Aug}$	327	120-450 [42]
2016	71 $_{Nov}$	1 000 $_{Feb}$	355	
2017	440 $_{Nov}$	23 $_{Aug}$	182	
2018	320 $_{June}$	110 $_{May}$	208	

Identified trends

- The SS concentration ranged from 20 mg/l to 1000 mg/l. The values are lower than municipal wastewater (excluding the outlier in February 2016 and December 2015).
- There are significant fluctuations in 2015 and 2016. The years 2017 and 2018 have a smooth profile and low to moderate concentration.
- It is not possible to distinguish a trend that applies to every year. The only month that shows consistency throughout the period (2015-2018) is March. The levels in March have been around 200 mg/l every year.

4.1.6 Historical flows and measurements – BOD/COD ratio

In 2015 the highest ratio was recorded in December and November and the lowest in May. In the following year (2016) the lowest ratio was found in October and the highest in February. In 2017 the highest ratio was recorded in august and the highest in March. The highest ratio for 2018 was recorded in February and the lowest in June. The values are summarized in Table 4.6.

Table 4.6. Data for the BOD/COD ratio measured in S5, the index shows the month from which the measurement was taken.

Year	Highest ratio	Lowest ratio	Mean ratio	Municipal wastewater
2015	$0.69_{\text{Nov \& Dec}}$	0.52_{May}	0.61	Not applicable
2016	0.69_{Feb}	0.46_{Oct}	0.60	
2017	0.68_{Mar}	0.47_{Aug}	0.59	
2018	0.87_{Apr}	0.52_{Feb}	0.53	

Identified trends

- The BOD/COD ratio is within the interval 0.47-0.87.
- The fluctuations are moderate in 2015, 2016 and 2017 whilst they are significant for the current year. The ratio is in general higher for 2018 compared to previous years.
- It is not possible to distinguish a trend that applies to every year.

4.1.7 Historical flows and measurements –Nitrogenous compounds

Nitrogenous compounds are measured every third month. In 2015 the highest concentration of nitrogenous compounds (Tot-N) substances was obtained in September and the lowest in March. In the following year (2016) the lowest levels of Tot-N were recorded in September and December and the highest in March. In 2017 the highest Tot-N was recorded in December and the lowest in June. For the current year (2018) March had the highest levels and June had the lowest. The values are summarized in Table 4.6.

Table 4.6. Data for Tot-N measured in S5 index show the month from which the measurement was taken.

Year	Highest Tot-N [mg/l]	Lowest Tot-N [mg/l]	Mean Tot-N [mg/l]	Municipal wastewater
2015	14 Sep	3.9 Mar	8.75	20-80 [42]
2016	17 Mar	12.0 Sep & Dec	13.75	
2017	50 Dec	8.9 Jun	20.48	
2018	46 Jun	43.0 Mar	44.50	

Identified trends

- All concentrations are within the interval 3.9-50 mg/l. The values are lower than the values for municipal wastewater.
- In 2015-2016 the levels were low to moderate (3.9-17). 2017 and 2018 show an increase of the concentrations with levels closer to 50 mg/l.

4.1.8 Historical flows and measurements – Phosphorus compounds

In 2015 the highest concentration of phosphorus compounds (Tot-P) substances was in September and the lowest in March. In the following year (2016) the lowest levels of Tot-P was recorded in September and the highest in March. In 2017 the highest Tot-P was recorded in December and the lowest in June. The highest levels for 2018 were recorded in June and the lowest in March. The values are summarized in Table 4.7.

Table 4.7. Data for Tot-P measured in S5, the index shows the month from which the measurement was taken.

Year	Highest Tot-P [mg/l]	Lowest Tot-P [mg/l]	Mean Tot-P [mg/l]	Municipal wastewater
2015	2 $_{Sep}$	1.3 $_{Dec}$	1.6	4-14 [42]
2016	2.4 $_{Jun}$	0.85 $_{Sep}$	1.6	
2017	2.7 $_{Dec}$	0.64 $_{Mar}$	1.3	
2018	3.8 $_{Jun}$	2.5 $_{Mar}$	3.1	

Identified trends

- All concentrations are within the interval 1.3-3.8 mg/l. Compared with municipal wastewater the levels are slightly lower than municipal wastewater.
- The entire period 2015-2018 show stable and low values.
- No trends could be distinguished.

4.2 Results from the external laboratory

4.2.1 Results from the external laboratory concerning the standard package

The results from the laboratory tests are shown below. The new wastewater was tested with the standard package (pH, BOD7, COD, BOD/COD, nitrogenous and phosphorous). The abbreviations used in the Table are:

M_e M process, Water from equipment

M_w+e M process, Water from equipment and well

R_456 R process, First wash, big tank, internal number 456

R_28 R process, First wash, small tank, internal number 28

R_397 R process, Last wash, small tank, internal number 397

R_132 R process, Neutralization, small tank, internal number 132

R_540 R process, Neutralization, big tank, internal number 540

The results regarding the standard package are summarized in Table 4.8 since the wash step of M is a continuous process the volume of the different samples is not applicable.

Table 4.8. Results from the external laboratory with water from the R and M process concerning the parameters: pH, BOD7, COD, BOD/COD ratio, Tot-N and Tot-P.

Sample	pH	BOD7 [mg/l]	COD [mg/l]	BOD/COD	Tot-N [mg/l]	Tot-P [mg/l]	Volume [m³]
Historical values	7.4-8.6	2800-14 000	6 000- 44 000	0.46-0.87	3.9-50	0.64-3.8	-
M_e	8.1	160	250	0.64	1.3	<0.1	not applicable
M_w+e	6.1	200	360	0.55	1.8	<0.1	not applicable
R_456	5.7	<3	<30	0.1	<1	<0.1	0.12
R_28	5.9	5.8	<30	0.19	<1	<0.1	0.09
R_397	4.8	210	560	0.38	3.8	1.2	0.09
R_132	6.3	900	2 500	0.36	19	5.2	0.09
R_540	6.6	520	1 300	0.4	11	3.2	0.12

BOD and COD levels are dramatically lower compared to the historical values for the gathering point. pH levels of the wastewater are not in line with the historic values, they are lower and some are below the permit limit. Nitrogenous levels are in line with the traditional values for all process flows. Phosphorus levels had similar results but wastewater with internal number 132 had a slightly higher phosphorus level.

4.2.2 Results from the external laboratory concerning toxicity

EC is an abbreviation often used in toxicity tests, EC stands for effective concentration and usually a percentage is also given as a number after the EC. The external laboratory used EC50 and EC20 for assessment of the toxicity. EC50 and EC20 were decided for three different exposure times (5 min, 15 min and 30 min). EC50 corresponds to the concentration of the sample where 50% of the population show loss of bioluminescence. EC20 corresponds to the concentration of the sample where 20% of the population show loss of bioluminescence. The EC50 and EC20 is given in volume percent (vol%) of the sample. A high TU indicates a greater toxicity [43]. The results are presented in Table 4.9. The abbreviations used in Table 4.9 are:

M_e M process, Water from equipment

M_w+e M process, Water from equipment and well

R_456 R process, First wash, big tank, internal number 456

R_568 R process, Last wash, big tank, internal number 568

R_515 R process, Neutralization, small tank, internal number 515 (contains detergents)

Table 4.9. Results from the external laboratory with water from the R and M process concerning toxicity.

Sample	EC50 5 min [vol%]	EC50 15 min [vol%]	EC50 30 min [vol%]	EC20 5 min [vol%]	EC20 15 min [vol%]	EC20 30 min [vol%]	TU (toxic unit) [%]
M_e	>82	>82	>82	37	48	54	<1.22
M_w+e	>82	>82	>82	>82	>82	>82	<1.22
R_456	>82	>82	>82	>82	>82	>82	<1.22
R_568	48	46	44	9	8	8	2.17
R_515	2	1	1	0.3	0.3	0.3	100

The EC50 of sample R_456 was >82 vol%. This sample was of low toxicity, since the EC50 was higher than 70 vol% (the lower bound for low toxicity samples). Wastewater number 568 showed moderate toxicity since the EC50 for this water was 46 vol% (which is within the interval for moderate toxicity samples). Whilst the 515 stream was highly toxic, since the EC50 of this sample was below 20%.

The water from the M process had the same toxic unit because the streams had the same EC50 (15 min) but M_e was a bit more toxic since the EC20 was lower.

The M process streams did not contain any detergents. Stream R_456 was the first wash and no detergents were added and no residue of detergent could be in the tank or pipes from previous steps. R_456 and the M streams has the same toxicity and did not contain detergents. The steps with high and moderate toxicity contained detergents and nothing else content-wise differed them from the other stream from the R process. It seemed like product traces were not the cause of toxicity but rather detergent content.

4.2.3 Results from the external laboratory concerning nitrification inhibition

The results from the nitrification inhibition test are presented in Table 4.10. The abbreviations used in Table 4.10 are:

M_e M process, Water from equipment

M_w+e M process, Water from equipment and well

R_456 R process, First wash, big tank, internal number 456

R_568 R process, Last wash, big tank, internal number 568

R_515 R process, Neutralization, small tank, internal number 515 (contains detergents)

Table 4.10. Results from the external laboratory with water from the R and M process concerning the nitrification inhibition.

Sample	Nitrification inhibition %
M_e	<10
M_w+e	<10
R_456	<10
R_568	14
R_515	55

The nitrification inhibition was moderate to low for all streams except for R_515, where the inhibition was significant. Water from the M process only contained traces of the product and

AP water and so does the stream R_456 (first wash) and they had the same inhibition. Water that only contained traces of product showed low inhibition regardless of the product since the M water and R_456 (first wash) showed the same inhibition.

R_515 (neutralization) had very high inhibitory properties, the only difference in content between this stream and the other streams of the process was the detergent content. Detergent content seems to increase the inhibitory properties, since there was no other difference between the content of the streams.

The first wash and last wash should have the same inhibitory properties since the steps were only loaded with AP water. However, stream R_568 (last wash) had heightened inhibitory properties compared to the first wash, probably because of detergent traces from previous steps. Without the detergent traces, the last wash would probably have lower inhibitory properties compared to the first wash since it should contain less product traces.

4.3 Assessment of the new wastewater

For assessing the water and needed actions an assessing matrix was used. The water was assed based on different criteria that are based on the permits and recommendations. The examined water received different signs depending on its properties, (+) was used if the method meets the criteria, (-) if it did not and (0) if it was not applicable or possible to determine. The abbreviations used in the matrix are:

M_e M process, Water from equipment

M_w+e M process, Water from equipment and well

R_456 R process, First wash, big tank, internal number 456

R_28 R process, First wash, small tank, internal number 28

R_397 R process, Last wash, small tank, internal number 397

R_132 R process, Neutralization, small tank, internal number 132

R_540 R process, Neutralization, big tank, internal number 540

The streams were assessed based on their BOD content and the result can be seen in Table 4.11.

Table 4.11. Assessment matrix for the criterium BOD for the wastewater from the M and R process.

Criterion: Is BOD levels in line with municipal wastewater (below 260 mg/l)			
Water	**BOD [mg/l]**	**Sign**	**Actions/comments**
M_e	160	+	No actions needed
M_w+e	200	+	No actions needed
R_456	<3	+	No actions needed
R_28	5.8	+	No actions needed
R_397	210	+	No actions needed
R_132	900	-	Lowering of the BOD levels might be needed
R_540	520	-	Lowering of the BOD levels might be needed

The BOD levels were very low for R_28 and R_456 (parallel steps in the R process). These streams were the first wash in the big tank and the small tank, the values are very similar <3 resp. 5.8. To some extent, the result validated the assumption that parallel steps have the same properties. The remaining streams in the R process (R_397, R_132 and R_540) had higher BOD levels which was probably due to loading of detergents or traces of detergents.

Both M streams showed quite high levels of BOD compared to R_28 and R_456. However, the values were still in line with municipal wastewater. The only streams that exceeded the levels of normal municipal wastewater were R_132 and R_540.

The streams were also assessed based on nitrification inhibition and the result can be seen in Table 4.12. The abbreviations used in the matrix are:

M_e M process, Water from equipment

M_w+e M process, Water from equipment and well

R_456 R process, First wash, big tank, internal number 456

R_568 R process, Neutralization, small tank, internal number 132

R_515 R process, Neutralization, big tank, internal number 540

Table 4.12. Assessment matrix for the criterium inhibition for the wastewater from the M and R process.

Criterion: Is the nitrification inhibition acceptable (Inhibition of 10% after 20% dilution in municipal water)			
Water	**Inhibition %**	**Sign**	**Actions/comments**
M_e	<10	+	No actions needed
M_w+e	<10	+	No actions needed
R_456	<10	+	No actions needed
R_568	14	0	This stream will probably show acceptable inhibition after the dilution in the gathering point
R_515	55	**-**	This stream must be handled

The water from the M process showed acceptable inhibition and R_568 will probably also attain an acceptable level after the dilution in the gathering point.
The effects of the dilution needs to be confirmed. R_515 showed inhibitory properties and will not reach an acceptable level after the dilution. For this reason, this stream must be dealt with.

The streams were also evaluated based on the toxicity. Toxicity is usually measured with the 15-minute EC50 concentration [43]. This concentration is shown in the Table 4.13 for the different streams. The abbreviations used in the matrix are:

M_e M process, Water from equipment

M_w+e M process, Water from equipment and well

R_456 R process, First wash, big tank, internal number 456

R_568 R process, Neutralization, small tank, internal number 132

R_515 R process, Neutralization, big tank, internal number 540

Table 4.13. Assessment matrix for the criterium toxicity for the wastewater from the M and R process.

Criterion: Does the water has acceptable toxicity levels (The water cannot have properties that can harm Öresundsverket's process, sludge, recipient, piping or personnel)			
Water	**Toxicity, EC50(%) 15 min**	**Sign**	**Actions/comments**
M_e	>82	+	No actions needed, low toxicity
M_w+e	>82	+	No actions needed, low toxicity
R_456	>82	+	No actions needed, low toxicity
R_568	46	0	Moderate toxicity
R_515	1	-	This stream must be handled

All streams except R_515 showed low to moderate toxicity and were not in need of treatments. Stream R_568 showed moderate toxicity, however the dilution in the gathering point will probably make this stream show low toxicity levels. The effects of the dilution should be confirmed.

R_515 showed high toxicity properties and will not reach an acceptable level after the dilution. For this reason, this stream must be dealt with.

In Table 4.14 the water is being assessed based on the Tot-P content. The abbreviations used in the matrix are:

M_e M process, Water from equipment

M_w+e M process, Water from equipment and well

R_456 R process, First wash, big tank, internal number 456

R_568 R process, Neutralization, small tank, internal number 132

R_515 R process, Neutralization, big tank, internal number 540

Table 4.14. Assessment matrix for the criterium Tot-P for the wastewater from the M and R process.

Criteria: Is Tot-P levels in line with municipal wastewater (below 10.5 mg/l)			
Water	**Tot-P [mg/l]**	**Sign**	**Actions/comments**
M_e	<0.1	+	No actions needed
M_w+e	<0.1	+	No actions needed
R_456	<0.1	+	No actions needed
R_28	<0.1	+	No actions needed
R_397	1.2	+	No actions needed
R_132	5.2	+	No actions needed
R_540	3.2	+	No actions needed

The phosphorus levels were low, which was expected. None of the streams needs treatment regarding this parameter.

In Table 4.15 the water is being assed based on its Tot-N content. The abbreviations used in the matrix are:

M_e M process, Water from equipment

M_w+e M process, Water from equipment and well

R_456 R process First wash, big tank, internal number 456

R_568 R process Neutralization, small tank, internal number 132

R_515 R process Neutralization, big tank, internal number 540

Table 4.15. Assessment matrix for the criterium Tot-N for the wastewater from the M and R process.

Criteria: Is Tot-N levels in line with municipal wastewater (below 52 mg/l)			
Water	**Tot-N [mg/l]**	**Sign**	**Actions/comments**
M_e	1.3	+	No actions needed
M_w+e	1.8	+	No actions needed
R_456	<1	+	No actions needed
R_28	<1	+	No actions needed
R_397	3.8	+	No actions needed
R_132	19	+	No actions needed
R_540	11	+	No actions needed

The nitrogenous levels were low, which was expected. None of the streams needs treatment regarding this parameter.

In Table 4.16 the water is being assessed based on its pH levels. The abbreviations used in the matrix are:

M_e M process, Water from equipment

M_w+e M process, Water from equipment and well

R_456 R process First wash, big tank, internal number 456

R_568 R process Neutralization, small tank, internal number 132

R_515 R process Neutralization, big tank, internal number 540

Table 4.16. Assessment matrix for the criterium pH for the wastewater from the M and R process.

Criteria: Is the pH level within the permit 6.5-10			
Water	**pH**	**Sign**	**Actions/comments**
M_e	8.1	+	No actions needed
M_w+e	6.1	-	The water needs to be treated with an alkaline neutralizing agent.
R_456	5.7	-	Investigation and trouble-shooting of the neutralizing process is needed
R_28	5.9	-	Investigation and trouble-shooting of the neutralizing process is needed
R_397	4.8	-	Investigation and trouble-shooting of the neutralizing process is needed
R_132	6.3	-	Investigation and trouble-shooting of the neutralizing process is needed
R_540	6.6	0	Even if the level is above the permit, water comes from a process that needs adjustment.

The water from the R process were too acidic and are below the permit. The overall alkaline pH at the gathering point would probably neutralize the acidic streams. However, no stream should be sent towards the gathering point with a pH below the permit and the streams must be handled. The reason behind the pH issue could be: overloading of a neutralizing agent, or an issue with the pH meter.

The M process does not have several steps and so the pH levels should agree. The water from the equipment was alkaline and the water from the well was acidic and below the permit. The water from the well could contain other substances from previous batches and it could be the reason behind the discrepancy. The reason could also be traced back to product content.

The M_w+e water might contain more of the product and therefore has a lower pH, since the product is acidic.

BOD levels and COD levels can be used to assess which water that probably contains the highest amount of organic compounds. BOD levels measure the easily degradable organic substances, this parameter can therefore be misleading. Persistent organic chemicals will not be detected by BOD measurements. Intuitively a low BOD level should correspond to low levels of organic compounds, but this is not always the case. A water with low BOD levels can still have a high content of organic substances if they are persistent. COD is therefore a better parameter when comparing organic compound levels. COD levels for the M_w+e water was 360 mg/l and the levels for M_e was 250 mg/l. The M_w+e water probably has the highest content of products (possibly a mixture between other products and the M product) since it has the highest COD concentration.

4.4 Overall results and discussion

The overall results from chapter 4.2.1, 4.2.2, 4.2.3 and 4.3 are summarized in the following sections.

4.4.1 Overall results and discussion - Historical review

The past wastewater has been in line with municipal wastewater or slightly above (excluding outliers). parameters Tot-P, pH, SS and Tot-N have been in line with BOD and COD values are significantly higher than municipal wastewater.

The production is batch based which in turn means that the process flows will not be continuous. Every parameter will be dependent on the product that is being produced and the levels of the measured parameters will most likely fluctuate during the day. For this reason, the content will not only vary during the year but also the day. Batch based sampling is a challenge since there could be an issue of misrepresentation. A sample could be collected at a time of the process where the wastewater has a significantly different content compared to the mean content of the entire process. As a result, the samples may not reflect the true content accurately.

4.4.2 Overall results and discussion - Properties of the new water

The new wastewater had a low content of Tot-P and Tot-N and none of the treatments for lowering these parameters were needed. The water from the R process were too acidic and below the permit. The overall alkaline pH at the gathering point would probably neutralize the acidic streams. However, no stream should be sent towards the gathering point with a pH below the permit. This is to ensure that all streams that leave the site are within the permit. The R-process has a neutralizing automated process installed. Since it was not performing satisfactorily, the reasons were investigated by the process engineers at the site and the issue was solved. The water from the M process should be examined further and the reason for the pH discrepancy should be investigated. It might be more pragmatic to find the reason for the discrepancy before adjusting the pH.

The daily total flow is approximately 53 m^3. Wastewater from the M process is approximately 1.8 m^3 which is approx. 3.4 % of the daily flow. Wastewater from the R process is 0.83 m^3 in total which is approx. 1.6 % of the daily flow. The new wastewater will not contribute to a significant increase of the water flow.

BOD and COD levels of the new wastewater were lower than the historical values. Despite the lower content in the new water some streams were above the levels that are traditionally found in municipal waste water. The streams R_132 and R_540 had a BOD content of 900 and 500 mg/l respectively. BOD content of the new streams were much lower than the historical mean value (10 566 mg/l). This indicates that the new wastewater will not be a significant contributor to increasing the levels of BOD.

Lowering the BOD of the new wastewater will not accomplish a significant decrease of the overall BOD and COD, since the new water is a small fraction of the total volume with a relatively low content. If McNeil wants to lower their BOD and COD levels, it would be pragmatic to first identify the biggest contributor.

4.4.3 Overall results and discussion - Toxicity of the new water

All streams excluding number 515 showed toxic properties when the concentration of the wastewater was 37-82%, which means that almost all streams showed low to moderate toxicity. The concentration of the streams will never reach this high concentration or even come close. The concentration of the total mantle stream in the gathering point would be 1.6 % and the remaining individual R streams would have a concentration around 0.23 %. The streams were deemed acceptable due to their low toxicity in combination with that they will not come close to the critical concentration. Other streams from McNeil could cause additional effects in the gathering point. This is however unlikely considering the other processes at McNeil, since the wastewater from those predominately contains sugars and sugar alcohols [1].

Toxicity can be caused by various substances, one of them is detergents. It is very likely that the high toxicity found in stream number 515 is due to the high content of detergent and not traces of product. The total volume of the streams with high detergent content is 1.94 m^3 which is 3.7 % of the total volume in the gathering point. The toxic properties of the streams with high detergent content will be assumed to be the same as 515. Toxic properties of the stream 515 are present at the concentration 0.3 %. The streams will however be diluted and may not even reach the critical concentration. The first dilution is in the gathering point, and here the concentration is above the critical point. If the dilution in Öresundsverket is considered, the concentration will be much lower. Öresundsverket receives 54 200 m^3/day, the volume of the original streams is 1.94 m^3 the concentration will be 0.0036 % and it is unlikely that the water will show toxic properties at this concentration. And so, the water will probably have little to no effect on the biological processes considering the high dilution. However, the stream 515 is highly toxic (see definition in chapter 3.2.3) and this should be dealt with. The detergent should therefore be examined. The other streams that contain significant amounts of detergents (540, 515, 132 and 52) should also be dealt with. Possibilities to remove, replace and/or lessen the impact should also be examined. There are at least three alternatives to solve the issue and they are accounted for below. Additional information about the detergent can be found in appendix B.

Alternative 1 - Remove or Detoxify the detergent

The problematic streams could be treated with a removal or separation technique before being sent to the WWTP. There are several separation techniques available for handling detergents some of them are: flocculation, flotation, adsorption with activated carbon, ion exchange and filtration [45].

Another solution could be to detoxify the detergent. Activated sludge have been proven to decrease the toxic effects of detergents, complete detoxification has also been reported [44]. Complete detoxification means that no toxicity could be measured, it was attained after 15 days with biodegradation with activated sludge [44]. The streams that need treatment are discrete and it is possible to intercept them and transfer it to a treatment tank. Considering the volume that needs to be treated, a tank volume of 2.5 m^3 would be sufficient. The treatment tank should be a continuous stirred-tank reactor and under aeration. The tank should also contain activated sludge. The residence time in the tank would be 15 days and afterwards the water could be sent towards the gathering point.

Alternative 2- Replace the detergent

The detergent could be replaced with a less toxic one. There is a close relationship between the level of surfactant content and the level of toxicity of a detergent [44]. Surfactants increase toxicity and gives a slower rate of detoxification [44]. If it is possible the detergent could be replaced by a detergent with a lower surfactant content.

Alternative 3- Lessen the amount of detergent or do not include it in the process

The third alternative is to not use the detergent, but this might not be possible due to high quality and hygiene demands. Loading volumes of the detergent could also be lowered.

4.4.4 Overall results and discussion – Nitrification inhibition of the new water

Nitrification inhibition was at an acceptable level for all streams except R_568 and R_515. The toxicity of the detergent was also affirmed in the nitrification inhibition test. It was known that the M process streams did not contain any detergents and these waters showed low inhibition. Stream R_456 also showed low inhibition and was the first wash, and like the water from the M process it did not contain any detergents (streams from the first wash cannot contain detergents since no detergents are added in this step and no residue of detergent is in the tank from previous steps). R_456 and the M streams had the same inhibition and did not contain detergents. Whilst the streams that contained significant amounts of detergent showed heighted inhibition.

The result in this test affirms the suspicions in the section "Overall results and discussion – Toxicity of the new water", the detergents were the problem and not the traces of product.

5 Conclusions

- The new wastewater will not contribute to a significant increase of the water flow. Wastewater from the M process is approximately 1.8 m^3 which is approx. 3.4 % of the daily flow. Wastewater from the R process is in total 0.83 m^3 which is approx. 1.6 % of the daily flow.

- The new water will not need of treatments regarding Tot-N and Tot-P, the pH levels must and have been addressed. Treatments for BOD and COD lowering should be put on hold.

- The new wastewater was in line with normal municipal water levels regarding all parameters except BOD and COD. Some streams were slightly above the municipal wastewater levels regarding the parameters BOD and COD.

- The new APIs were not the cause of toxic properties. A high detergent contentment resulted in heightened toxic properties.

- All streams (excluding the streams that contains significant amounts of detergents) could be sent to the receiving wastewater treatment plant, it is very unlikely that they would impair the process at the WWTP in any way. Stream 515 and the other streams that contain significant amounts of detergents should be handled and should not be sent directly to the receiving WWTP.

6 Future Work

It seems that issues regarding toxicity and inhibition do not stem from product traces, but rather the detergents used in the washing step. The detergents should be examined further as well as possible removal/ separation techniques. There are several separation techniques available for handling detergents some of them are: flocculation, flotation, adsorption with activated carbon, ion exchange and filtration [45].

The COD and BOD levels of the new water are very low compared to usual levels found in the gathering points. If McNeil wishes to lower the total release of BOD and COD, the examined streams should not be prioritized. Instead a mapping of the biggest BOD/COD contributor should be carried out. When this process/stream is identified the streams should be intercepted before the gathering point and treated. The treatment should upgrade the water to a level that complies with the levels of municipal water. The trade-off between penalty fees and running costs for the upgrading process should be examined. Due to the current situation at the site, any suggested process must be integrated with the current flows. Meaning that a process that requires a lot of additional space is not a possible process. This is of course a challenge since the tertiary treatments whether it is adsorption, biological and/or chemical oxidation, filtration etc. traditionally requires spacious areas.

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8 Appendices

Appendix A

2018-12-06/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 nikotin-tuggummi, 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

Verksam-hetsdrift	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)
Kväveox-ider	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)
Renings-grad 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)

Appendix B

General information about the detergent used in the R process

- The detergent is only used in the R process and is specifically tailored for the process it is used in.

- The detergent is a mixture of several chemicals. The levels of the different components are in accordance with the standards set by the European Parliament (reference number EG 648/2004). Allowed composition is: nonionic surfactants within the interval 15-30%, soap within the interval 5-15% and phosphonates below 5%.

- The surfactants in the detergent are biodegradable according to the standards and laws set by the European Parliament (reference number EG 648/2004).

- The surfactants in the detergents are classified as harmful to the environment.

- The detergent is not deemed to be persistent, bioaccumulative, toxic or highly bioaccumulative at levels of 0.1% or higher.

- The detergent has a pH above 7 and is alkaline.