CHALMERS

Survey into Smaller Wastewater Treatment Plants

Bachelor Thesis in Mechanical Engineering

William Bogeryd Andersson
Felix Jacobs

Department of Architecture and Civil Engineering
CHALMERS University of Technology

Gothenburg, Sweden 2022
www.chalmers.se

Survey into Smaller Wastewater Treatment Plants

Bachelor Thesis in Mechanical Engineering

William Bogeryd Andersson
Felix Jacobs

Department of Architecture and Civil Engineering
Division for Water Environment Technology
Chalmers University of Technology
Gothenburg, Sweden

CHALMERS

Survey into Smaller Wastewater Treatment Plants

Bachelor Thesis in Mechanical Engineering

William Bogeryd Andersson
Felix Jacobs

© William Bogeryd Andersson, 2022
© Felix Jacobs, 2022

Department of Architecture and Civil Engineering
Division for Water Environment Technology
SE-412 96 Gothenburg
Sweden
+46(0)31-772 1000

Cover approved by svenskavloppsrening.se
Department of Architecture and Civil Engineering
Chalmers University of Technology
Gothenburg 2022

Preface

The authors of the report are mechanical engineering students, performing a study concerning a subject belonging to civil engineering. This work is made out of a product development standpoint to give a different view of the subject. This means that the focus is towards the customers and the market as a whole and out of the actual functionality of the products. The authors of the report also would like to thank the people working for the manufacturers of the different products that were willing to talk to us and answer our questions through both email and telephone. This includes people working for Godkända avlopp, Premier tech, Topas vatten and Uponor. We also like to thank our supervisor Britt-Marie Wilen for helping us with the report and teaching us about the chemical processes in treatment plants.

Sammandrag

För hushåll som befinner sig utanför de kommunala avloppssystemen i Sverige gäller det att hitta lösningar för att kunna ha ett fungerande avlopp. De vanligaste lösningarna har tidigare varit att ha utedass eller en trekammarbrunn. På senare år så har dock lagar kommit som kräver att trekammarbrunnar även ska ha infiltrationsanläggningar då det “renade” trekammarbrunn-vattnet fortfarande orsakar problem för naturen, såsom algblomning och annat. Med en infiltrationsanläggning installerad uppnår man kraven för det renade vattnet men får då istället problem med rör och annat som sticker ut ur marken samt med all plats som utrustningen tar under eller ovan mark.

Som ett resultat av detta har därför det privata minireningsverket blivit en alltmer populär produkt. Detta är för att de tar mindre plats, luktar ej och inte syns lika tydligt när den är nedgrävd. Problemen med dessa reningsverk är att de för tillfället är relativt nya på marknaden och folk vet därför inte så mycket om dem. Målet med denna rapport är därför att göra en kartläggning av dessa och undersöka hur dessa fungerar och vad som är skillnaden mellan dem.

I denna undersökning används ett flertal metoder för att få fram den eftersträvade informationen. Dessa metoder inkluderar undersökning av teknisk data, företagens egna data, recensioner från kunder och mail/telefon konversationer med olika företag angående deras produkter. Teoretisk information har också tagits fram angående reningsverken för att få en överblick om hur dessa fungerar och vad som är då värt att tänka på som kund.

Nyckelord: Minireningsverk, Avloppsrening, Aerob, Anaerob, SBR, Fosforreduktion, Kvävereduktion, BOD, COD, Personekvivalent (p.e), Slam, Sverige

Abstract

For households that are outside the municipal sewer systems in Sweden, it is important to find solutions to be able to have a functioning sewer. The most common solutions have previously been to have an outdoor toilet or a three-chamber well. In recent years, however, new laws demand that three-chamber wells need to have seperate infiltration facilities as the "purified" water that is coming from three-chamber wells still causes problems for the nature, such as algal blooms and oxygen depletion. With an external infiltration system installed, you will be able meet the requirements for

the purified water. The problem with this is all the extra pipes and other things that protrude from the ground combined with all the space that the equipment takes under and/or above ground.

As a result of this, the private mini-treatment plant has become an increasingly popular product. This is because it takes up less space, does not smell (theoretically) and is not as clearly visible when it is buried in the ground. The problem with these treatment plants is that they are currently relatively new on the market and people therefore do not know much about them. The aim of this report is therefore to make a survey of these and examine how they work and what the differences are between them.

In this study, a number of methods are used to obtain the desired information. These methods include examination of technical data, companies' own data, reviews from customers and e-mail / telephone conversations with various companies regarding their products. Theoretical information regarding the treatment plants have also been produced to help to get an overview of how they work and to know what is then worth thinking about as a customer.

Keywords: Private treatment plant, Sewage treatment, Aerobic, Anaerobic, SBR, Phosphorus reduction, Nitrogen reduction, BOD, COD, Person equivalent (p.e), sludge, Sweden

Content

Preface 3
1. Introduction 1
1.1 aim 1
1.2 purpose 2
1.3 research questions 2
1.4 Delimitations 2
2. Theroy 3
2.1 background 3
2.2 function 3
2.3 law 5
2.4 Sequencing batch reactor (SBR) 6
3. Method 7
3.1 Selection 7
3.3 interview method 8
3.4.2 Biokube venus 9
3.4.3 Topas plus 5 9
3.4.6 Solido Smart 10
3.4.7 Baga Biotank 11
3.4.8 Mälaren 11
3.4.9 Uponor Clean 1 12
4. Result 13
4.1 Price 13
4.2 Quality 13
4.3 Size 16
4.4 Conclusion 16
4.4.1 Permanent House 17
4.4.2 Vacation House 17
4.4.3 Comments 18
5. Conclusion 19
6. Discussion 20

6.1 Compliance of Laws 20
6.2 Product Selection 21
6.3 Ranking Method 21
6.4 Research information 22
6.5 Cost Estimation 22
7. Future Development Aspects 23
References 24

1. Introduction

The modern treatment plants were invented by Robert Thom in the late 1700s and were made of wool, sponge and charcoal. It started to develop during the 1800's and is still developing today. Although the first wastewater treatment and cleaning started as early as 2000 BC, in ancient Greek and Sanskrit (India), not much was known about the chemical and mechanical processes back then, but it was widely known that for instance heating water could counteract bacteria. (Baker, 1981)

The smaller treatment plants for private use, that are discussed in this thesis, are mainly used by people living outside the central water system, which often include vacation houses and people living in the countryside. Today Sweden consists of 1200-1300 treatment plants that are controlled by the county. There is a total of 101 000 km of sewage drainage in Sweden. It takes between 10 and 24 hours for the water to be cleaned. Only the 20 biggest facilities clean more than 50% of the water used is Sweden. (svensktvatten.se, 2022)
When it comes to sewage systems that are not connected to the municipal wastewater system, there are a total of 700 000 households. Out of these, only 180 000 do have a sludge separator, which does not have any wastewater purification. A problem with all these private sewage systems is that there exist a lot of old ones that are not working properly and others that simply do not get any or very little maintenance work done on them. This sometimes leads to contaminations in the area around the outlet of the sewage system or around the system due to leaks. (Havochvatten, 2022)

Only 84 % of the Swedish towns have a good view over the amount of independent sewage systems that are not connected to their municipal treatment plants. This means that 16 % of the sewage systems are unknown and therefore uncontrolled by the government. This can lead to more environmental problems and destruction of the ecosystem. An example of this is overfertilization. The private/smaller treatment plant is therefore a good solution to fix the problems as that should result in better sewage management compared to other older sewage systems. This will also help the communal authorities (the 16%) to get a better view over the private sewage systems that exist in their respective counties. (Svenska Miljöemissionsdata, 2022)

The biggest problem with these smaller treatment plants is that the information about them is not widely known. This problem is what this thesis is aiming to solve by comparing aspects including function, price, maintenance cost, current and future research and the laws that need to be considered. The data that is brought forward in the report will consist of information found through research in both technical and legal documentation and from the data brought forward by salesmen. Reviews made by customers will also be taken into consideration. A variety of technical terms will also be used to describe different products and data in the report. The meaning of these will be described in the text.

1.1 aim

The main goal with the thesis is to find out how the different treatment plants differ from each other, this includes cost, size, function, quality, and maintenance. The laws differ from

different municipalities. This report aims to find out which treatment plants to use, depending on what area the product is going to be installed in. The last aim is to present part of the systems that could be further developed and how it could be done.

1.2 purpose

The main purpose of the thesis is to gain knowledge for us, customers and developers when it comes to treatment plants for private use. The report could be used as a guide for people that are in a position to choose a system suited for their own specific situation.

1.3 research questions

The questions to be answered in this thesis work is:

- What is important to keep in mind when looking for your own private treatment plant?
- What are the differences in price?
- What are the laws that need to be followed?
- What solutions are currently available on the market?
- Are there any solutions that can only be found in patents or in other reports both nationally and internationally?
- Which/what smaller treatment plants are the best suited for private households, both vacation houses and permanent houses?

1.4 Delimitations

This thesis will not cover treatment plants that are made to treat more than 1 or 2 households at a time or have a capacity over 10 pe (person equivalent, one pe is the amount of BOD/day). This is because the limit is set to private use, which does not involve more centralized treatment plants as their solutions can be very different from the solutions that describe smaller treatment plants. The treatment plants and different solutions will also follow the Swedish national law as this is where the project group is based. Consideration will also be taken to communal laws since those can vary.

2. Theory

The theory is the thorough introduction that sets the base for the report. Explanations of common concepts such as SBR, the laws and an explanation of how the main principles (mechanical, biological and chemical cleaning) of the treatment plant works out.

2.1 background

For people without access to communal sewage drainage, the Swedish state laws say that sewage water nowadays can not only be stored in a three-chamber well but also needs to be infiltrated. As a result of this combined with technological development, private treatment plants have started to appear on the market. These treatment plants are made for between 1-2 households and produce cleaner wastewater and do not require much space. This market is currently somewhat new which means that consumers at the moment could be unaware of what treatment plant they should buy depending on factors like communal laws, amount of sewage and other environmental factors.

The project group has therefore been tasked by the head of the division Water Environment Technology at the department of Architecture and Civil Engineering at Chalmers University of Technology to do a detailed survey on this market and find out valuable information that they can use in their future research at the institution. The project group studies mechanical engineering at Chalmers University of Technology and will therefore do the research from a more mechanical and product-oriented standpoint and not do any deep dives into the chemical attributes of the products.

2.2 function

The function of a treatment plant consists of 3 main parts, which is mechanical-, chemical- and biological purification. The levels of BOD/COD (Biochemical/chemical oxygen demand), phosphorus and nitrogen are the most difficult and important substances to regulate. These substances need to be minimized as all of them have negative consequences on nature and are dangerous to be let out in water courses, lakes and seas. (Avloppsguiden, 2022)

The first step in the purification process is the mechanical part, this consists of a bar screen that separates the debris. Thereafter the water is transported to a chamber where the sand sinks to the bottom and can be separated from the water. Then the water will be transported to a new chamber where the water is separated from fat particles. (Miva, 2022) The next step in the purification is the chemical one. In the chemical part the water is mixed with chemicals. This chemical attracts phosphorous in the water. The chemicals creates lumps with phosphorus and are then sinking to the bottom of the chamber. The chemicals that are used are usually aluminum sulfate, sodium aluminate, polymer, sodium hydroxide, ferric chloride, polyaluminium chloride, ferrous chloride, hydrochloric acid, sulfur dioxide, magnesium oxide, calcium oxide and carbon dioxide. (Miva, 2022) (Azchemistry, 2018)

The third and last step in the process is biological purification. The water is transported to a biological chamber where the water is separated from nitrogen and other organic substances. The nitrogen needs to be separated to create nitrogen gas that is harmless and is already a part of our air and benefits our vegetation. (Miva, 2022)

High levels of phosphorus and nitrogen could lead to overfertilization which could affect the health for both humans as well as wildlife. The biggest problem with over fertilization is that it increases the number of algae and phytoplankton. This is leading to unwanted change such as acid deficiency, which in the long term can remove all wildlife from the affected area. This is mainly an issue in deeper water, where much of the “food fishes” live. The sewage systems are together with agriculture the main factors to over fertilization, although today's treatment plants can reduce 95-99% of all phosphorus. (Sveriges vattenmiljö, 2021)

The ratio of BOD/COD can give an idea of the substance's individual ability to be degraded. A low BOD/COD value means that the substance is difficult to degrade, which means that a higher value is desirable. When there is a mix of substance the value can be more difficult to draw any conclusions from. For instance, a low content of environmental toxin will not give any rash if the rest of the mixture consists of organic material which is light degradable. A value above 0.43 is considered easily degradable, and in normal cases the value is in between 0.35 and 0.60 for regular households. (Svenskt vatten, 2012)

In the treatment plants, there are also certain amounts of suspended solids (SS). These are solids in water that can be trapped by filters and can be everything from bacteria, sand, decaying plants, animal matter etc. Solids like this can cause a lot of problems in lakes, rivers and oceans since it can cause a lack of oxygen through less photosynthesis. It also blocks out sunlight and reduces water clarity which makes it harder for fish to find food and catch prey. Bigger amounts of suspended solids usually carry with it a high number of bacteria and nutrients which for a biological treatment plant is a good thing, but a bad thing for regular water streams as they can add on to the disruption of sea life. There is currently no Swedish legislation that clearly states how much of these suspended solids needs to be cleared out. They only state that it needs to be done in a way that does not harm the ecosystem. (WWD, 2021)

In the biological part of a treatment plant, there exists a high number of microbes. These microbes are what treats the waste in the biological part or the treatment plant. The way it works is that they essentially eat the wastewater, which keeps the microbes alive until there is no sewage left. These microbes grow in the treatment plant when the sewage enters the plant and provides all the essential nutrition for the microbes to grow. Some bacteria also need air which is also provided. If the plant is used regularly, the plant will work the best as it means that older microbes are still living in the plant as new sewage enters and then creates a thriving biosphere within the treatment plant. If the treatment plant is left without sewage for a longer period, it can decrease the number of microbes, which makes it harder for the treatment plant to work once in use again. This is usually different from plant to plant and if a person is looking to find a treatment plant for a facility that will be unused for a longer period, it is recommended to find a treatment plant that can stay unused for that same amount of time. (Nisha Rani, 2019)

There are also different types of bacteria in treatment plants. There are aerobic bacteria and anaerobic bacteria. Aerobic bacteria survive and grow in an oxygenated environment. Therefore, a lot of the treatment plants have an air duct since most of them use aerobic bacteria when breaking down the waste. Anaerobic bacteria are bacteria that doesn’t need oxygen to survive or even die if oxygen is present. Aerobic bacteria are known to be very

resilient and can survive for a very long time. In treatment plants this means that if air is present, the aerobic bacteria could theoretically survive for several months without any new substrate, or “bacterial growth” being added to the plant. They also grow fast in the treatment plant compared to anaerobic bacteria. Anaerobic bacteria are known to be good at turning sludge into gas. The process of using anaerobic digestion in treatment plants is popular because it can stabilize the water with little biomass production. The key microorganisms are methane formers and acid formers. These microorganisms form the sludge into either methane or acid. The aerobic and anaerobic processes are very different from each other and do different things. In normal treatment plants, both processes are used to achieve a good wastewater treatment. In smaller treatment plants, anaerobic are sometimes left out since they take a longer time to start working if the plant has been on standby for a longer period.

2.3 law

For a household to install a private treatment plant, several laws need to be fulfilled. In general, there are two security levels, “normal security level” and “high security level”. The higher one is usually applied around seas, lakes, and other water courses. The high level is expected to reach a 90% reduction of phosphorus and 50% reduction of nitrogen. The nitrogen and phosphorus levels are the main difference between requirements of the “normal security level” and “higher security level”. The laws and requirements follow bellow:

Basic requirements:

A. Day- and drainage -water is not led to the wastewater device
B. The sewage system is, with exception of the infiltrating part, sealed to prevent leakage, in- and out, of water.
C. The function of the sewage treatment plants must be easy to control.
D. The sewage device is constructed so that maintenance and service is facilitated.
E. The sewage system is installed so that the function will be keeping its quality during the expected lifetime.
F. The sewage device should come with a guide of operation- and maintenance instructions from the supplier that consist of all the tasks that are needed to secure the device's function.
G. The sewage system is provided, if possible, with alarm if problems with drift or other functional disorders. An alarm should always send signals before a closed container with sewage water has been filled.
H. It is possible to test the quality of the sewage water which is coming from the system besides when it is in its container.

Health:

A. Emission of sewage water should not lead to a significantly increased risk for infection or other inconveniences like smell where people can get exposed to it, for instance by pollution of the drinking water, ground water or bath water.
B. The handling of byproducts from the system shall be able to be maintained under hygienic circumstances.

Higher protection requirements:

C. Higher protective measures are provided, beyond the main cleansing in the system. For instance, there could be a need to forbid some emissions. This is to make the point of discharge more difficult to access and to provide the system robustness or add more cleaning steps, which further reduces the pollution content. This is also to increase the residence time and neutralize the variations of streams or receive any overflowed water.

Environmental:

A. Technique that limits the usage of water, for instance water efficient armature.
B. Phosphate free detergent and phosphate free chemicals are used.
C. The sewage system should be expected to reach a 90% reduction of organic substances, (BOD7/BOD5)
D. The sewage system is expected to reach a 70% reduction of phosphorus. (tot-P)
E. The sewage system enables recycling of material and substances from the byproduct or sewage fractions.
F. Actions to prevent and minimize risk of infection or other irregularity for animals should be taken.

Higher protection requirements

G. The sewage system is expected to reach a 90% reduction of phosphorus. (tot-P) (Havs- och vattenmyndigheten, 2016)

2.4 Sequencing batch reactor (SBR)

SBR is a water treatment technology, which works bacteria wise. The technique uses one water tank as a bioreactor. Which means that the wastewater is pumped in and there aerated for a certain period. The process starts when oxygen is pumped into the tank. The oxygen makes the aerobic bacteria convert ammonium to nitrite and then titrate to nitrate. Then when the air pump is stopped, the nitrate is converted to nitrogen, this means that the gas is moved away from the water and out to the air. To make this possible, it requires that sewage is in the first tank from the beginning when the process starts. This is the reason why much of the sewage is pumped back to the first tank after every cleaning step in a treatment plant.

The method is well suited for smaller treatment plants as it does not need to have a constant flow. The less water that is added into the tank, the more effective the process. This method is used for the vast majority of the smaller treatment plants, especially the ones available on the European market. (Waterworld.com, 2000)

3. Method

The method chapter will present the different companies and models, as well as the information and statistics about performance of treatment. A comparison of price, quality (phouspore, BOD/COD and nitrogen treatment levels) and size will be presented.

3.1 Selection

These following 7 companies and 7 models are the ones that will be investigated during report. The selection has been made from some of the most popular and well documented on the market. Images of the plants can be find in appendix.

- Biovac, FD 5 N PEH
- Biokube, venus 1850 standard
- Topas, plus 5
- Solido, minireningsverk
- Baga, bioTank
- Godkända avlopp i sverige, mälaren 12
- Uponor, clean 1

3.2 comparison (price, quality, size)

Comparison between the models is made out of the price that is set by the resellers in the cases where it is not possible to buy direct from the companies websites. Some of the models have higher p.e. This is for bigger households that cannot use smaller variants.

Model	Price (SEK)	person equivalent (p.e)	Comments
Biovac FD 5 N PEH (Biovac, 2022)	60 000	5	
Biokube venus 1850 (avloppscenter.se, 2022)	59 495	5 - 10	
Topas plus 5 (Avloppscenter, 2022)	60 375	5	One of several models, this being the smallest
Solido minireningsverk (Markgrossen, 2022)	95 000	5	There are models for up to 50 people. The project group is only gonna look at the smallest one.
Baga Biotank (Baga, 2022)	95 000	5	There are 6 models. The project group is only gonna look at the smallest one.
Mälaren 12 (svensktavlopp, 2022) (Godkändaavlopp, 2022)	90 000	5	There are different models of the same sizes.

Uponor 1 (svensktavlopp, 2022)	96 125	5	

Also a list of the companies reduction of phosphorus, nitrogen, BOD/COD and SS (suspended solids) according to their own websites. Some of the companies do not have information in all of these categories and therefore a "-" is put in the table.

Model	Phosphor	Nitrogen	COD	BOD	SS
Biovac, FD 5 N PEH (Länsstyrelsen Västra Götaland, 2009)	https://www.topasvatten.se/upl/files/123089.pdf 93%	54%	-	98%	-
biokube venus	>90%	>50%	-	>90%	-
Topas plus 5	95%	70%	-	99%	-
Premier Tech, solido	90%	74,5%	95,5%	98,7%	95,5%
Baga biotank	97%	53%	-	97%	99%
godkända avlopp, Mälaren	96%	68%	94%	96%	96%
Uponor clean 1	96%	50%	95%	98%	98%

3.3 interview method

Questions have been asked to the companies to receive more information about their models. The following questions have been asked:

- Purification principle?
- Operating cost, service, additives?
- How easy to use?
- Does it smell?
- How to handle residues/sludge?
- Can it stay inactive for a longer period of time?
- How many separate installations and modifications are there and what does it cost?
- Is it possible to take samples, are there datasheets with analyzes available?
- How well does the system handle intermittent load?
- How well does phosphorus and nitrogen removal work?
- How does your product differentiate from your competitors' products?

3.4 further investigation

A short summary of the advantages and disadvantages of every model will be presented. This includes prices, sizes, maintenance, operating cost and installation.

3.4.1 Biovac FD 5 N PEH

This model has a price of 60 000 SEK, which does not include installation cost. The installation cost varies depending on the surrounding ground. The product should be put underground as it will be more expensive to put it in bedrock rather than in soil. The treatment plant could be buried by anyone and does not need to be installed by someone at the company, although the company offers to do it. The product is made out of 100% polyeten which means that no machines are needed to bury the product as it is very light. The only part of the design which will be visible is the maintenance hatch, also all of the electronics are placed inside the product which means that there is no control panel.

To avoid smell it is important to have an aeration system connected to the treatment plant, the aeration should be done over the ridge of the house. Newly installed systems do usually smell a bit and it takes a few days for the system to reach a "biological stable" level. The company has a service-deal for their clients, which may simplify for clients to get the right service and spare parts.
The maintenance could be done by yourself, and include sludge emptying which should be done at least once per year. The product has a total weight of 280 Kg. (Biovac, 2022)

3.4.2 Biokube venus

Biokubes treatment plant for one household does fulfill all of the laws for the higher protection requirement and has a cost of around 60 000 SEK. Although the system does only include the chemical and biological part which means that it needs to be supplemented with a sludge separator which could be found from the same company for around 20 000 SEK. The design is very compact to reduce the digging work, although as it needs to be interconnected with a sludge separator, much of the space earned from the smaller design is lost by that. The treatment plant has a total weight of 160 Kg, which makes it easy to dig down by yourself.

This product has a feature called "vacation home", which means that if the system isn't used for a few days, it will go into "vacation hibernation". This saves power consumption, money and is advantageous for the environment. Biokube also has a feature which makes it possible to control and monitor the system from your smartphone. This means that you can easily check suspected errors. The system could also be started from the phone and is therefore able to startup a few days before arrival. This makes the treatment plant ready for usage from the first second when one arrives. Although this requires that there is water left to be purificated when the system starts. (avloppscenter.se, 2022)

3.4.3 Topas plus 5

The Topas model does include the biological and chemical part of the cleaning process, which means that it needs to be added with a sludge separator. The cost of the system is 48 300 SEK from Topas vatten excluding value-added tax, but with the added cost of a sludge separator the total amount will be closer to 80 000 SEK. The model has a total weight of 145Kg which makes it easy to handle but installation help might be required.

This model has an equalization tank to dampen day variations and suddenly higher levels of used water in the household. It also has an adjustable inlet device, which makes it possible to place the treatment plant in different angles depending on the surrounding ground levels and eventual bedrock, and also depending on how it is connected to the house. Topas has, due to its equalization tank, a good possibility to manage longer periods where the system isn't used. This makes it optimal for vacation houses or other places where it is not used day in and day out. A study made at KTH Royal institute of technology showed that the treatment plant can handle 6 months of downtime without any bigger deterioration in the water quality.

The electrical use of the plant is between 400-440 kWh per year.
The treatment plant is easy to supervise but in a presentation by the companies says. "*It is a process equipment that you have in your garden and the property owner receives a permit to conduct "Environmentally hazardous activities". If you get a disruption in the process, knowledge and experience are required to make the right adjustments and you can not ask a property owner to be able to do that. It is very important that there is a strong service organization that backs up the product so that it works well over time"*. The representative also mentioned that there are too many that sell similar products with the argument that "*no expensive service agreements are required*", "*It takes care of itself*" etc. They say it doesn't work that way and it is unfortunately not uncommon for customers to go to them after having bought a product that they do not receive any approved values on and now have to replace.

When the same company representative that was mentioned in the previous paragraph were asked what differed between their product compared to their competitors' products. He said "*Stable process, equalization tank for intermittent flow, sludge escape protection and a very well-developed service organization*". (Topas vatten, 2022) (Avloppscenter, 2022)

3.4.6 Solido Smart

The solido smart model is an all-in-one treatment plant that consists of everything needed for a functioning and legal treatment plant. The sludge in the tank can be cleaned out through a pipe that's connected to the treatment plant. The amount of sludge created is also 15% less than in a conventional treatment plant. The company that constructs the treatment plant is very keen to mention its simplicity and high quality. They also mention that they have a unique treatment method and have a low power usage of 50-55 kWh per person a year. The company also offers a 25 year guarantee on the tank itself and a 3 year guarantee on the other parts if a service agreement is made. If no agreement is made, the guarantee is 2 years on those other parts. (Markgrossen, 2022)

The products cost around 95 000 SEK depending on the retailer. The size of the treatment plant is 2.40 meters in length, 1.36 meters in width and 2.20 meters in height. The treatment plant has 2 operating cycles per 24 hours where clear water drainage happens after a sedimentation phase for 60 - 90 minutes. In every cycle, there are periods of oxygenation so that the treatment plant reaches wanted cleanliness values. The treatment plant is set according to the amount of people concerned and can be adjusted based on the need. All the company's treatment plants reach a "high level of protection" and are CE-branded and are

classified according to EN-12566-3, which addresses the environmental protection in the declaration of performance. (Solido, 2022) (Premier tech, 2022)

3.4.7 Baga Biotank

Baga consists of two tanks, one sewage separator and one for chemical and biological purification. The process is controlled by a sensor that is connected to the automatic cabinet. The doses of the chemical flocculants are added automatically but need to be refilled about once in a year. The system could be connected to a smartphone, which makes it possible to receive an SMS every time something needs to be repaired or refilled. The company offers 10 years guarantee and has service staff available across Sweden. Normally sludge emptying needs to be done twice a year. The system cannot be discontinued if it is supposed to be used in a summer house or other non-consistent usage, although the adding of phosphorus binding additives makes it have a high effect from start, which is a positive aspect for summer houses.

The cost of the system is 90 000 sek for one household, and the operating cost depending on how much it is used. It is mainly the usage of chemical additives that is the highest cost for service. The system has average electronics cost of 60 SEK per month. The two tanks have a total weight of 370 Kg and a height of 1.9 meters, this makes the installation cost high because of its size. It will also be difficult to install it by yourself due to its weight. (Baga, 2022)

3.4.8 Mälaren

Mälaren is a chemical-free treatment plant, which makes it unique. They have a patent on the technique, and it has been intalleted for ca 1000 households across europe. The cost of the treatment plant is around 80-100 000 SEK, depending on its geometry, where 3 different options are available. The product does not need much maintenance because of it has no need of chemicals, although it does need sludge emptying once a year. If anything needs to be repaired, it won't need to be done to the part that is placed underground. Instead, there is a control cabinet, which is driven by an air pump and a control computer. As it is installed over ground there will not be any flood in the electronics. The tank can be placed up to 8 meters from the control cabinet.

The function of the treatment plant is built in three chambers. First the water reaches a chamber where the sewage is separated by a grid, the rest is transported into a smaller chamber where mechanical treatment is done, then the water is transported into the last chamber where the biological part takes place. During the process air is blown from specific membranes at the bottom of the tank. This creates a high concentration of oxygen in the chamber, which makes organisms bind phosphorus. Then when this step is done the tank is emptied and the bound phosphorous creates sludge at the bottom of the chamber. Thereafter the treated water is pumped out to the recipients. The sewage from the last chamber is at the same time transported to the first chamber, and it is this chamber which needs to be emptied once a year. (svensktavlopp, 2022)

3.4.9 Uponor Clean 1

Uponor Clean 1 is a biological/chemical treatment plant made to serve households that's both permanent and made as vacation houses. The company states that it uses the latest cutting-edge technology for wastewater treatment. A new design makes the outer diameter of the plant to a more compact unit. Once installation is complete, two almost invincible lids are the only thing visible of the treatment plant. The plant is made to serve one household or around 5 p.e. It is made to be able to withstand longer breaks because of its vacational automation which creates aeration and circulation to keep the bacteria in the plant alive. The cost of the treatment plant is around 95000 SEK, depending on the retailer.

It has a simpler design to give it a higher operational reliability since more complicated parts have a bigger chance to break. This also makes it more cost effective. It is necessary to fill it up with flocculants a few times a year and you need to pump out the sludge at least once a year. No moving parts beneath the surface of the wastewater need any maintenance. The electrical use is around 330 kWh per year.

The plant has a sludge separator and a process tank. The two lids that will be visible after installation are for removing sludge and to add flocculants. There is also a control cabinet under one of the lids. A remote-control panel is also included in the product and is mounted up the wall of the household. The weight is 240 kg and measures in at 2.40 m in length, 1.92 m in width and 1.30 - 1.40 m in height. (svensktavlopp, 2022)

4. Result

The following chapter will present the differences between the different products. We will focus on the aspects that make the biggest impact for the consumers, such as price, quality, size and maintenance.

4.1 Price

The prices vary between the different products and some of the treatment plants do not come with the sewage separator and therefore cannot be directly compared to the ones with an integrated part. All of the companies that have separated sewage separators do sell their own product beside and therefore the prize that is compiled in this chapter is the sum of the treatment plant and sewage separator. The following ranking goes from cheapest to most expensive.

1. Biovac: 60 000 SEK
2. Topas 5 plus: 60 375 + 17 950 (78 325) SEK
3. BioKube 60 000+20 000 (80 000) SEK
4. Mälaren: 90 000 SEK
5. Baga biotank: 95 000
6. Solido: 95 000
7. Uponor clean 1: 96 625

4.2 Quality

The quality of the different products is hard to tell due to the lack of information and testing. Fortunately, some data is available and estimations can be made due to different companies putting their primary focuses on different things regarding the product.

1. Biovac:

Biovac is a relatively cheap plant compared to others. The data show how well the wastewater is treated in the plant shows it to be clearing all the legal limits and to be somewhat below average compared to the other plants. One interesting thing was that the treatment plant is used by a “nature room” in Laponia (northern Sweden) where temperatures can get very low and access to personnel that can do repairs on the treatment plant is very low. This shows that the treatment plant is reliable and still works in harsh conditions. Otherwise, there is not really anything standing out about this treatment plant other than its low price.

Customers that had bought the Biovac treatment plant say that it smells badly and others complain about the servicemen that were unable to fix the problems. The company that is making this specific product model also seems to have stopped selling them sometime during the making of this report but still have similar products in its inventory. since, some distributors still seem to be selling the product it still exists on the market but only to a limited degree and will likely be gone in the future.

2. Topas:

The Topas treatment plant is a very well cleaning treatment plant compared to the other treatment plants in this report. This treatment plant also happens to have a low weight making it easier to install and an inbuilt system that gives it the ability to stand completely still for up to 6 months without it affecting how well the plant cleans the waste. The thing that stands out about this company's products is the service organization. Many other companies most of the time try to tell you how little needs to be done on the plant to keep it running. Topas has instead done it the other way around and focuses more on the service organization to ensure that the treatment plant not only keeps running but that the outflow reaches the legal limits. The reason for this is that all things break at some point if left unattended, no matter what you do to ensure that it does not. This means that this treatment plant is more for those people that do not want to become “experts” in treatment plants but just want it all to work and to have a reliable service organization to be available when needed. The product needs a separate sludge separator which can theoretically cause problems since both products need to be working. A customer therefore needs to keep that in mind when buying the separator which means that the customer needs to do more work compared to the work needed to buy and install some of the other treatment plants in this report.

3. BioKube

The BioKube does fulfill all the requirements that are needed to reach up to the higher security level. Although the levels of both phosphorus and nitrogen that are presented on their own website, is not reaching up to the competitors. The BOD levels are above 90%, which is good, but they are not competing with the best systems and at the same time it does not come with a sewage separator. This means that it will be more complex to install and will also require more space, even though the main system is smaller than the other alternatives. The company also uses a patented technique to hinder the stopping of the biological process in the plant when not in use by returning water to the plant to keep the biological process going. The company does offer a 2 years warranty for pumps and electronics, but a 20 year functional warranty. The company is based in Denmark but offers service devices in Sweden and Norway as well, although the price of the service is 3500 SEK/year, eventuel spare parts do not come with that price. (Ministry of Environment and food Denmark, 2020)

4. Solido

Solido is a SBR-treatment plant just like many others in this report. What the treatment plant does good compared to the other treatment plants is the reduction of nitrogen, COD and BOD. Unfortunately, the reduction of phosphorus is very low compared to the others (just for the limit) which is a bit concerning. The amount of sludge reduced is also a bit lower than the others which means that it will need to be emptied more often than it would need in other systems. The Solido treatment plant is the next most expensive plant in the report, but it also has a long warranty and is supposed to be cheap to run which should mean that overall price

for the system at its end of life should be around the same as the other systems or even lower. The plant is also said by an employee to be very easy to use. An unique thing about the treatment plant is its air blower which is housed in a sealed “capsule” under the lid in the neck of the tank. Fresh air is sucked in directly to the capsule by a small pipe that needs to be installed next to the tank. This provides a very stable environment for the air blower as it is not exposed to the moist air in the chamber.

5. Mälaren

Mälarens completely biological treatment plant is most likely what people feel is the biggest factor when choosing this system since there are no dangerous chemicals present, only natural bacteria that grow in the plant. The treatment plant is also built upon a polish patent where you provide oxygen periodically to achieve sedimentation. All of this means that both aerobic and anaerobic bacteria are present. Anaerobic bacteria produce a lot of methane when breaking down biological waste. This methane is highly flammable and possibly dangerous when in contact with something that could lead to an ignition. It is therefore important for the plant to seal off the gas and to release it to the atmosphere in a safe manner. In a review found online, a customer who has been in possession of this system for some time said in his review that there was a little smell coming from the plant. This customer does his own service so it could be that the plant has a slight malfunction but if that ain't the case, then this is something for other customers to keep in mind. The price of the treatment plant is a bit more expensive than some of the other systems which most likely has to do with it being all biological. The reduction done in the treatment plant is overall impressive as it does well to reduce all the wastewater in the water compared to other systems where there's usually something that isn’t being reduced as well as the other. This makes the plant an overall solid plant with all the reduction being well over the legal limit. It is also the first chemical free treatment plant made in the Nordics. (Bygga hus forum, 2021)

6. Baga Biotank

The treatment plant consists of two big tanks, where one of them is a sewage separator and the other one does the biological and chemical cleansing part. All the work can be managed from the automatic cabinet, which is placed over one of the tanks which makes it easy to access for maintenance. Baga does fulfill all the requirements and has the best level of phosphorus reduction of our assessed systems. The nitrogen reduction level is above the requirements for high security level although it does only reach 53% which makes it one of the least good in this area. The treatment plant needs 1-2 emptying per year. The company offers 10 years guarantee which is lower than many of their competitors. Baga biotank is suitable for both permanent- and holiday accommodation, the phosphorus binding chemicals makes it possible to start the process from the first second, although the biological part is more effective if it is used constantly but will also work if not.

A customer that had bought the Baga Biotank experienced trouble with the flocculants. It seemed like the treatment plant used way too much even though the customer had changed the flocculant setting on the control panel to minimum distribution. The customer thought that it

might be a problem with the sensors and wanted to fix it himself because he wasn't willing to contact Baga since the service cost would in the customer's opinion be too expensive.

7. Uponor

Uponor is a SBR-treatment plant and reaches the levels for high security in all aspects. Although the results for nitrogen are the least good out of 7 assessed products. The level of phosphorus reduction is the second best. The levels of BOD and COD is excellent and has a 99% reduction of suspended solids. This product does need sewage emptying 1-2 times per year. Uponor has an installation guide, which makes it possible to install it by yourself. The product has a control panel, which should be installed inside the house. This makes it easy to control if everything is working as it should or if anything needs to be refilled, repaired or emptied. The vast majority of the cords are placed so that they are easy to access, but a few of them are at the bottom of the tank. This means that if they break, they are hard to access and therefore might require digging up the whole system to repair. Possibilities to take tests are good but require extra work. To take any test, the tank should be emptied, and the "walls" should be cleaned to avoid misleading results.

4.3 Size

All of the treatment plants have similar sizes, although some of the products have cylindrical shape while some others are quadratic/other. In most cases the size of the system won't be an affecting point for people while choosing their systems, because they are that similar.

Model	Diameter (mm)	Height (mm)	Weight (Kg)
Biovac	1530	2760	280
Biokube	1110	1850	160
Topas	1700	2340	145
Solido	2400x1360 (width, length)	2020	….
Baga	2000	1900	200
Mälaren	1750	2000	…
Uponor	2400x1920 (width,length)	2030	240

4.4 Conclusion

The conclusion is splitted into two scenarios, which is "permanent house" and "vacation house". The reason for this is because the different situations have different requirements. The "vacation house" needs to be quick to start up and many treatment plants takes a few day to build up all of the aerobic bacteria, which makes these treatment plants less good compared to the ones that can be started before arrival to the house. The requirement for the permanent house is for instance that the system should be easy to handle and cheap to run and maintain. Although many of the aspects regarding permanent houses are also represented in what is important in vacation houses and vice versa.

4.4.1 Permanent House

A matrix has been designed to select the best option for a permanent house. The matrix first rate the different desires and requirements, and then rate how good each of the treatment plants fulfills those requirements. The matrix is a Kesselring matrix (Johannesson, 2013). It is done from the perspective of the consumer. The "W" stands for weight and describes how important that criteria is for the product. "V" stands for value and describes how well the product fulfills the criteria. "T" stands for total and is the product of V*W, which tells how many "points" the product gets from a criterion. The total score shows the number of points that every product got and the mean of the value points so that each product can be graded in two different ways, where one is dependent on the weight of the criteria, and one is not. The rank shows how well each product did. The ranking is based upon the total score. Many of the criteria are based upon the values that have been written down earlier in the report (ex. 3.2 comparison (price, quality, size)). Those that are not "Easily accessible components", "Sludge management" and "Design" and are described below.

Easily accessible components:
How easy it is to reach and do maintenance on things like tubes, electronics and pumps. Also includes doing tests on the water.

Sludge management:
How the treatment plant handles sludge and how easy it is to remove it when needed. If a plant requires a separate sludge tank, it will get a very low score since that would demand more work for the consumer.

Design:
How well the plant is designed in terms of how visually noticeable it is when installed, how much it sounds, how much it smells and how many moveable parts there are inside the plant (pumps etc.).

Permanent household	Ideal			Biovac		Topas		BioKube		Solido		Mälaren		Baga Biotank		Uponor	
Criteria	**W**	**V**	**T**	**V**	**T**	**V**	**T**	**V**	**T**	**V**	**T**	**V**	**T**	**V**	**T**	**V**	**T**
Price	5	5	25	5	25	4	20	4	20	3	15	3	15	3	15	2	10
Size	2	5	10	2	4	1	2	1	2	2	4	3	6	3	6	2	6
Weight	2	5	10	1	2	4	8	4	8	2	4	3	6	4	8	2	2
Phousporous reduction	3	5	15	3	9	4	12	2	6	2	6	4	12	4	12	4	12
Nitrogen reduction	3	5	15	2	6	4	12	2	6	5	15	4	12	3	9	2	6
Easy accessible components	4	5	20	4	16	3	12	5	20	5	20	5	20	3	12	4	16
Sludge managment	3	5	15	3,5	10,5	2	6	2	6	5	15	4	12	5	15	5	15
BOD	3	5	15	5	15	5	15	3	9	5	15	4	12	4	12	5	15
Deisgn	3	5	15	3	9	3	9	4	12	4	12	4	12	2	6	4	12
Total score		*5*	**140**	*3,166*	**96,5**	*3,333*	**96**	*3*	**89**	*3,666*	**106**	*3,7777*	**107**	*3,4444*	**95**	*3,333*	**94**
Rank		*Mean*	**MAX**	*6*	**3**	*4*	**4**	*7*	**7**	*2*	**2**	*1*	**1**	*3*	**5**	*4*	**5**

4.4.2 Vacation House

To select the best option for a vacation house, we have designed a matrix to first rate the different desires and requirements, and then rate how good each of the treatment plants fulfills these requirements. The matrix used here is almost the same as the previous one but with the

extra criteria “Quick startup”, which explains how well the plant works after being unused for a longer period of time (ex. half a year).

Vacational household	Ideal			Biovac		Topas		BioKube		Solido		Mälaren		Baga Biotank		Uponor	
Criteria	**W**	**V**	**T**	**V**	**T**	**V**	**T**	**V**	**T**	**V**	**T**	**V**	**T**	**V**	**T**	**V**	**T**
Price	5	5	25	5	25	4	20	4	20	3	15	3	15	3	15	2	10
Size	2	5	10	2	4	1	2	1	2	2	4	3	6	3	6	2	6
Weight	2	5	10	1	2	4	8	4	8	2	4	3	6	4	8	2	2
Phousporous reduction	3	5	20	3	9	4	12	2	6	2	6	4	12	4	12	4	12
Nitrogen reduction	3	5	20	2	6	4	12	2	6	5	15	4	12	3	9	2	6
Easy accessible components	4	5	20	4	16	3	12	5	20	5	20	5	20	5	20	4	16
Sludge managment	3	5	15	3,5	10,5	2	6	2	6	5	15	4	12	5	15	5	15
BOD	3	5	20	5	15	5	15	3	9	5	15	4	12	4	12	5	15
Deisgn	3	5	15	3	9	3	9	4	12	4	12	4	12	3	9	4	12
Quick startup	5	5	25	3	15	5	25	5	25	5	25	2	10	3	15	5	25
Total score		*5*	**155**	*3,15*	**111.5**	*3,5*	**121**	*3,2*	**114**	*3,8*	**131**	*3,6*	**117**	*3,4*	**110**	*3,5*	**119**
Rank		*MAX*	**MAX**	*7*	**6**	*3*	**2**	*6*	**5**	*1*	**1**	*2*	**3**	*5*	**7**	*3*	**4**

4.4.3 Comments

The ranking shows that for a permanent household, Mälaren and Solido seem to be the two best options. Solido smarts unique design and high guarantee shows the quality of the product. The multi-use pipe for both air and sludge removal make it probably the easiest to remove sludge from. It has a lid for the electronics and flocculants that can even be run over with a car. The only “truly” visual part is another small pipe meant for air. The only bad things are the relatively big size of the plant and its reduction in phosphorous (which is still above the legal limit). We also do not know the weight of the plant but due to its size we can estimate that it is somewhat heavier than other plants. Mälarens design is also unique as it doesn’t use the SBR technique like the others and is much more environmentally friendly. The product also has a high score in its reduction and the only visible thing is its control cabinet which can be discreetly positioned if needed. It is a bit more expensive than other treatment plants but since there isn't any need to buy new flocculants, the price overtime eventually evens out. Mälaren is a relatively new product, if not the newest in this report which means that the engineering behind it is fresh, but it also means that there is not a lot of information to find about it from reviews. The references that is published seem to be positive reviews with the only bad one being a slight smell coming from the plant.

For the vacation house, the best products would be Solido and Topas. Both plants have modes built in that are made to keep the microbes in the plant alive when not in use for a longer period of time. The methods vary a bit but the idea is the same, which is to lower the microbes consumption of biological waste and in some way pump water back into the plant to ensure that they do not starve. The problem with the Topas treatment plant is that it doesn’t have a sludge separator. This means that you will have to buy one separately which will increase the size of the whole plant. It is also hard to find any good pictures of the inside of the plant but other information about how it works and so on was relatively easy compared to other products. What's good is that it has good values in its reduction and has the “standby” mode. Other treatment plants that also have built-in “standby” modes are BioKube and Uponor.

5. Conclusion

The overall best product seems to be the Solido treatment plant with a good overall design and high guarantee. Mälaren and Topas also rank high and shouldn't be ruled out since both could still be better than Solido depending on the situation, such as if it is a permanent household or not. A lot also comes down to the individual and what they value to be the most important. If for example you do not want to spend more than you feel is necessary and do not necessarily need the best of the best, then the Biovac treatment plant might be the best for you. This is because it is still a good working treatment plant that is pretty simple and easy to manage given the price you pay for it. Another example is if you want to have a good service agreement. Then the Topas treatment plant can be the best for you since the company puts a lot of effort into creating a good service for its customer.

BioKube did mention on their website that their product was the best in testing by referring to a report made by Länsstyrelsen. This unfortunately does not seem to be the case anymore due to the data gathered in this report, but it likely has to do with a matter of perspective since Länsstyrelsen made their report in a more scientific manner while this report focuses more on the customer. This report therefore takes things into consideration that Länsstyrelsen didn’t and value these things very high which therefore resulted in the products poor result. Länsstyrelsens report also happens to be around 13 years old.

The reason for Uponor’s low score has not anything to do with any fault but instead that it does slightly worse on a few criteria than the others. Overall, it is a good product that works for both permanent- and vacation houses and gives good reduction results except on nitrogen, but also happens to be the most expensive. This most likely being what acts as the product's downfall in this report. Also, it is both relatively big and heavy.

Baga Biotanks problem has to do with it not having the best reduction results, a bit too many moveable parts and not being the best designed. It has also received some bad reviews usually related to bad quality components and expensive customer service. The bad design is mostly inside the plant. For example, taking samples required you to position yourself into some pretty uncomfortable body positions and sometimes required you to reach deep down into the tank and constantly hold a leaver to take the sample you wanna take. (Länsstyrelsen Västra Götaland, 2009) (Bygga hus forum, 2015)

6. Discussion

The discussion part will mainly handle the sources and margins of error, but also surveys into problematic interpretations of laws and cost estimations. The discussion aim to illustrate the downsides and disadvantages of the report.

6.1 Compliance of Laws

The laws regarding treatment plants for private use are in many cases clear, but in other cases the laws are formulated in words that can only be interpreted in subjective ways, and as the laws are on a municipal level it leads to different requirements depending on what municipal you are in. We did ask 3 questions to Bodil Forsberg, who is an investigator at the environmental assessment unit at sea and water-authority (miljöprövningsenheten, vatten- och havsmyndigheten), to receive more info about how the laws are implemented across the country. Below follow the three questions followed by the answers.

- Are there any tests done by the counties to control that private treatment plants do follow the requirements that are set for phosphorus, nitrogen and BOD/COD quotas?

    - The supervision of small treatment plants is responsibility of the county's environmental authorities, and it is up to them how and how often they control it. Not all the counties in Sweden do have private treatment plants, although in some counties there can be very many, for instance in municipals in Skåne. The supervision requirements can vary, but it is common that the authorities require some professional care (normally by a service company connected to the company that delivers the system) at least once per year, which then should be presented to the authorities. The authorities also have the right to do inspections, to check that everything is working as it should. During the last years it has been more focus on increasing supervision on smaller treatment plants, for instance by LOVA project, where many counties have been working together to develop a working system for supervisors.

- Are there any environmental laws that the company that produces treatment plants does need to follow, or does all the laws direct toward the consumers? If the laws are on the consumers, is there a chance that people do not follow the laws as tests are not often made?

    - It is the person that runs the sewage system, in this case the property owner, that is responsible for the treatment plant and that it follows all of the requirements. Before a treatment plant is installed, permission has to be gained from the authorities. In the permit application, information needs to be published, for instance declaration of performance, situation plan and technical description. The permission is normally a general condition that the applicant committed in its application should follow. Usually there are further conditions that can present more specific requirements for the function or care of the

facility. For permission to be gained there is a need for statistical data for the authority to take a stand for. Smaller treatment plants are dimensioned for up to 50 pe, which means that they are covered by the requirements of CE-demand, which is regulated in "byggproduktförordningen". In the prestanda declaration, which should be fulfilled and signed by the selling company before the product is CE-marked, the company should declare for the test results regarding strength and cleaning ability. This information is the companies' guilt to present before the product is available on the market.

- Some of the laws today are formulated from desires that can only be measured by subjective opinions, often something along the lines of "... should be taken into account". Does this mean that all the counties have their own interpretation of the laws or are they relatively equal judging across the country?

    - HaVs (the authority) has a supervisory guidance for small treatment plants that can help counties to interpret the laws so that the supervision of the law is equal across the country, although every county is independent, and every matter is made out of consideration of certain circumstances. The guidance can only be general and the assessment and decisions that are made is up to the county itself. There can therefore be differences across the country, but this can also be explained by the circumstances where the sewage system is placed.

6.2 Product Selection

A negative aspect is that the selection is made from what companies we first did find, often the most used ones on today's market. The selected treatment plants are based on the same principle and very similar to each other. It would have been more interesting if we would have found some startup or a system that is completely different to the ones that has been picked. Another aspect is that we have made a restriction to keep down the amount of products, to have time to make a correct analysis of every one of them. This means that our result is the best of the ones in our investigation, but there might be other companies in the Nordic countries that do construct better systems. Therefore, the report can only be used to compare between these systems and not as a guide for someone who is looking to invest in a treatment plant.

6.3 Ranking Method

The ranking method in the matrix is based on subjective opinions compared with rules. One of the issues with rank is that we had to decide from what perspective the treatment plant should be ranked from. For instance, it could be made from an environmental perspective, which would have made the BOD/COD levels, phosphorous and nitrogen reduction to be the most important factors. Our decision was to rank the systems from the consumers perspective, this means that the factors such as price, size, maintenance were the most important factors. There is a problem with this perspective also because it depends on each situation. Every person has their own way of what is most important, some people are only looking for the cheapest option that is good enough, while others care more about having the very best from an environmental perspective.

6.4 Research information

A big part of the information about the treatment plants is picked from their own websites, this might cause some problems when it comes to the levels of phosphorus, nitrogen and BOD/COD, as many companies do not publish any information about how the tests have been done, although some data has been released at stately/county level which in many cases prove some of the results as realistic. One of the reports was found at region base and did include many of the products that we were about to compare, this made some of the results comparable to the real world. Some of the companies' websites have inadequate information on their websites and product sheets. This has led to us contacting the companies to get more information, but some information has not been found at all, therefore we have been forced to make qualified estimation for weight and total sum of size for the companies that need separate sewage separators.

6.5 Cost Estimation

Our estimated costs have downsides, the biggest concern is that many of the companies are newly established and therefore might not be a long-term option, as the companies might be closing or going into bankruptcy. This can lead to increased service costs or problems with finding spare parts. This is an advantage for the older companies as they might be more reliable. Our cost estimation has been made with the adoption that every treatment plant has the same installation cost, which might differ from company to company. Although there will not have any noticeable impacts on the total cost estimation.

The most noticeable margin of error is the service cost. The service cost has been put into consideration in the Kesselring matrix, although not as the cost estimation. If the treatment plant is invested and expected to be used for 25 years, the service cost will be one of the major impacts on the total price. Much of the service work can be done by people themself and therefore money can be saved, this is also worth taking into consideration and complicates the price estimation.

7. Future Development Aspects

The future development aspects that we can come up with is to make the systems smaller and more compact. Many of the systems take very much place and are difficult to install, if they could be designed more rectangular and smaller, they would be easier for private persons to install by themself, and the digging work could be less expensive.

Some of the treatment plants could have been smarter constructed by having less loose parts in areas that are difficult to reach. Like having hoses and cables placed in a high position, this would make it easier to see what is broken if the system is not working, it would also be easier to solve the problem by having easy access to the components. This is one of the main prosecutes from the product that Soldio has developed, they have tried to minimize the number of hoses that are needed for the systems, and the hoses that do exist are very easy to reach.

Another thing that solido does better than everybody else is the easy access to the sludge tank, by having a separate pipe. The other companies have chosen to have the sludge tank in direct connection to everything else. For private persons that want to do the job by themself, Solidos option stands above the others. This is something that the other companies should inspire from.

Some of the treatment plants have big parts that are placed above the ground, this causes esthetical problems as they often are placed in the garden. In some cases, there is a control cabinet that takes up an area in the garden, this is both a waste of space and would also be better if the system was placed inside the house to increase the comfort, but that would cause lost space inside. Some of the companies have come up with systems that are being regulated by phone and are therefore not in need of a controlled cabinet.

A future development aspect could also be to minimize the chemical agents that are used. By taking a look at Mälaren, it can be seen that this is already possible. Mälarens has a patent that is built on periodic oxygen supply to keep the system doing the same thing repeatedly, which makes it possible to create both aerobic and anaerobic bacteria. The company is very vague with their formulations and explanation about how the system works on their website and was not willing to give an explanation over the phone.

Biokube has solved the start-up problem, by having a service on the phone so that the treatment plant can go into “vacation dormancy”. By turning off the system when one is leaving the house and having unprocessed sludge, means that you can turn it on a few days before you arrive again, and therefore the bacteria will be up and going and ready for normal use when one arrives. This idea requires that there is a certain amount of unprocessed water when the treatment plant is turned off.

References

Avloppscenter. (2022). *Topas plus 5*. Retrieved from Avloppscenter.se: https://www.avloppscenter.se/vara-produkter/reningsverk/reningsverk-ett-hushall/topas-5-plus-1-hushall.html?gclid=CjwKCAiA9tyQBhAIEiwA6tdCrBXcnZU2u9XTQwILFnaB080d1VXFRfZKWX1qZ8NAAvR3okcBY0KREhoCRAQQAvD_BwE

avloppscenter.se. (2022). *BIOKUBE VENUS 1850*. Retrieved from avloppscenter.se: https://www.avloppscenter.se/vara-produkter/reningsverk/reningsverk-ett-hushall/biokube-venus-1850.html?gclid=CjwKCAiA9tyQBhAIEiwA6tdCrGezmHmB8ipbRQmAePs8D63kiaiCRJgcdJOA9HK184w337DCAW0LgRoC0icQAvD_BwE

Avloppsguiden. (2022). *Minireningsverk och kompakta lösningar*. Retrieved from Avloppsguiden.se: https://avloppsguiden.se/informationssidor/anlaggningar/#info-minireningsverk-och-kompakta-losningar

Azchemistry. (2018). *chemicals used in wastewater*. Retrieved from Azchemistry.com: https://azchemistry.com/list-of-chemicals-used-in-wastewater-treatment-plants

Baga. (2022). *Baga Biotank*. Retrieved from Baga.se: https://markgrossen.se/enskilt-avlopp/minireningsverk/solido-minireningsverk/?gclid=CjwKCAiA9tyQBhAIEiwA6tdCrOo8C9Lw1ChFsqZHqtcwg6IQ40S82xZ9WWE5D-sUncA6iTiwq8YmsBoCwaUQAvD_BwE

Baker, T. (1981). *The quest for pure water – The history of the twentieth century.*

Biovac. (2022). *Biovac FD 5 N PEH*. Retrieved from Biovac.se: https://www.biovac.se/minireningsverk/fd-5-n-peh-for-nedgravning/

Bygga hus forum. (2015). *Baga Easy erfarenhet.* Retrieved from https://www.byggahus.se/forum/threads/baga-easy-erfarenhet.146587/page-5

Bygga hus forum. (2021, 11 18). minireningverk mälaren 6. Retrieved from https://www.byggahus.se/forum/threads/minireningsverk-maelaren-6.364998/

Godkändaavlopp. (2022). *Mälaren12*. Retrieved from Godkändaavlopp.se: https://markgrossen.se/enskilt-avlopp/minireningsverk/solido-minireningsverk/?gclid=CjwKCAiA9tyQBhAIEiwA6tdCrOo8C9Lw1ChFsqZHqtcwg6IQ40S82xZ9WWE5D-sUncA6iTiwq8YmsBoCwaUQAvD_BwE

Havochvatten. (2022). *Miljöpåverkan och åtaganden*. Retrieved from https://www.havochvatten.se/miljopaverkan-och-atgarder/miljopaverkan/fororeningar-och-farliga-amnen/avlopp.html

Havs- och vattenmyndigheten. (2016). *Havs- och vattenmyndighetens allmänna råd om små reningsverk*. Retrieved from https://www.havochvatten.se/download/18.1d58828a15f50337fd4466c4/1633079597927/HVMFS-2016-17-ev.pdf

Johannesson, P. P. (2013). *Produktutveckling, effektiva metoder för konstruktion och design.*

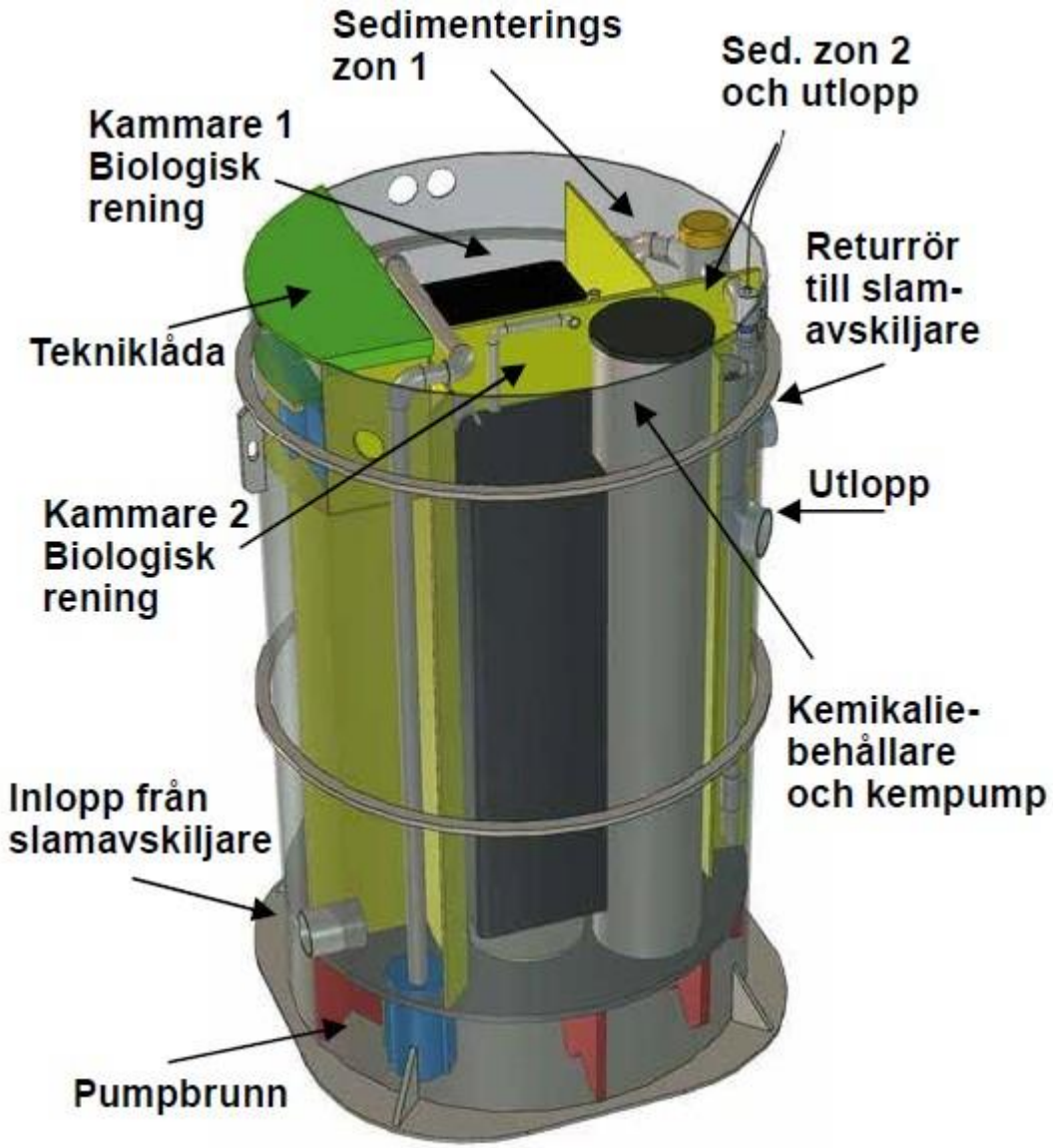
Länsstyrelsen Västra Götaland, S. o. (2009). *Tillsyn på minireningsverk.* Retrieved from https://www.topasvatten.se/upl/files/123089.pdf

Markgrossen. (2022). *solido minireningsverk*. Retrieved from Markgrossen.se: https://markgrossen.se/enskilt-avlopp/minireningsverk/solido-

minireningsverk/?gclid=CjwKCAiA9tyQBhAIEiwA6tdCrOo8C9Lw1ChFsqZHqtcwg6IQ40S82xZ9WWE5D-sUncA6iTiwq8YmsBoCwaUQAvD_BwE
Ministry of Environment and food Denmark. (2020, august). *wastewater and circular economy with focus on third world.* Retrieved from mst.dk: https://www2.mst.dk/Udgiv/publikationer/2020/wastewater.pdf
Miva. (2022). *Så funkar vatten och avlopp*. Retrieved from Miva.se: https://miva.se/vatten-och-avlopp/sa-funkar-vatten-och-avlopp/avloppsvatten/avloppsreningsverk
Nisha Rani. (2019). *mircobes wastewater treatment.* Retrieved from Sciencedirect.com: https://www.sciencedirect.com/science/article/pii/B9780128168097000051
Premier tech. (2022). *SBR minireningsverk Solido Smart +P*. Retrieved from premiertechaqua.se: SBR minireningsverk Solido Smart +P
Solido. (2022). *Minireningsverk*. Retrieved from starwebserver.se: https://cdn.starwebserver.se/shops/velltra-se/files/tolago-solido-smart-schwedisch-8-seiter-1.pdf?_=1638626635
Svenska Miljöemissionsdata. (2022). *uppdatering av kunskapsläget och statistik för små reningsverk*. Retrieved from http://www.smed.se/vatten/3709
Svenskt vatten. (2012). *Råd vid mottagande av avloppsvatten från industri och annan verksamhet.* Retrieved from https://www.svensktvatten.se/globalassets/avlopp-och-miljo/uppstromsarbete-och-kretslopp/p95-rad-vid-mottagande-av-avloppsvatten.pdf
svensktavlopp. (2022). *Minireningsverk clean 1*. Retrieved from svensktavlopp.se: https://www.svensktavlopp.se/produkter/minireningsverk/minireningsverk-clean-1.html
svensktavlopp. (2022). *Mälaren12*. Retrieved from Svensktavlopp.se: https://markgrossen.se/enskilt-avlopp/minireningsverk/solido-minireningsverk/?gclid=CjwKCAiA9tyQBhAIEiwA6tdCrOo8C9Lw1ChFsqZHqtcwg6IQ40S82xZ9WWE5D-sUncA6iTiwq8YmsBoCwaUQAvD_BwE
svensktvatten.se. (2022). *Avloppsfakta*. Retrieved from https://www.svensktvatten.se/fakta-om-vatten/avloppsfakta/
Sveriges vattenmiljö. (2021). *Övergödning*. Retrieved from Sverigesvattenmiljo.se: https://www.sverigesvattenmiljo.se/sa-mar-vara-vatten/2019/sammanfattningar/0/0/4
Topas vatten. (2022). *Minireningsverk*. Retrieved from topasvatten.se: https://www.topasvatten.se/minireningsverk
Waterworld.com. (2000). *Automated Decanter Helps SBR Performance*. Retrieved from Waterworld: https://www.waterworld.com/drinking-water/treatment/article/16191660/automated-decanter-helps-sbr-performance
WWdmag. (2021). *what is total Suspended solids (TSS)*. Retrieved from wwdmag.com: https://www.wwdmag.com/suspended-solids-monitors/what-total-suspended-solids-tss

Appendix A

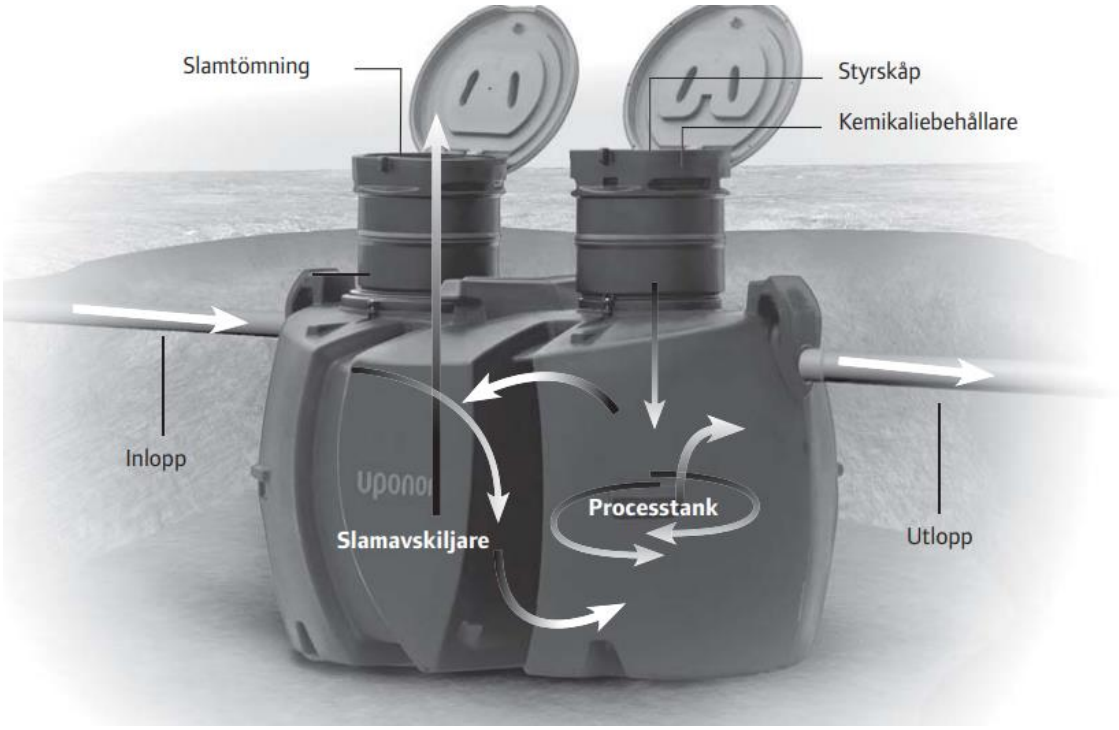
Baga biotank (Baga, 2022)



BioKube (avloppscenter.se, 2022)

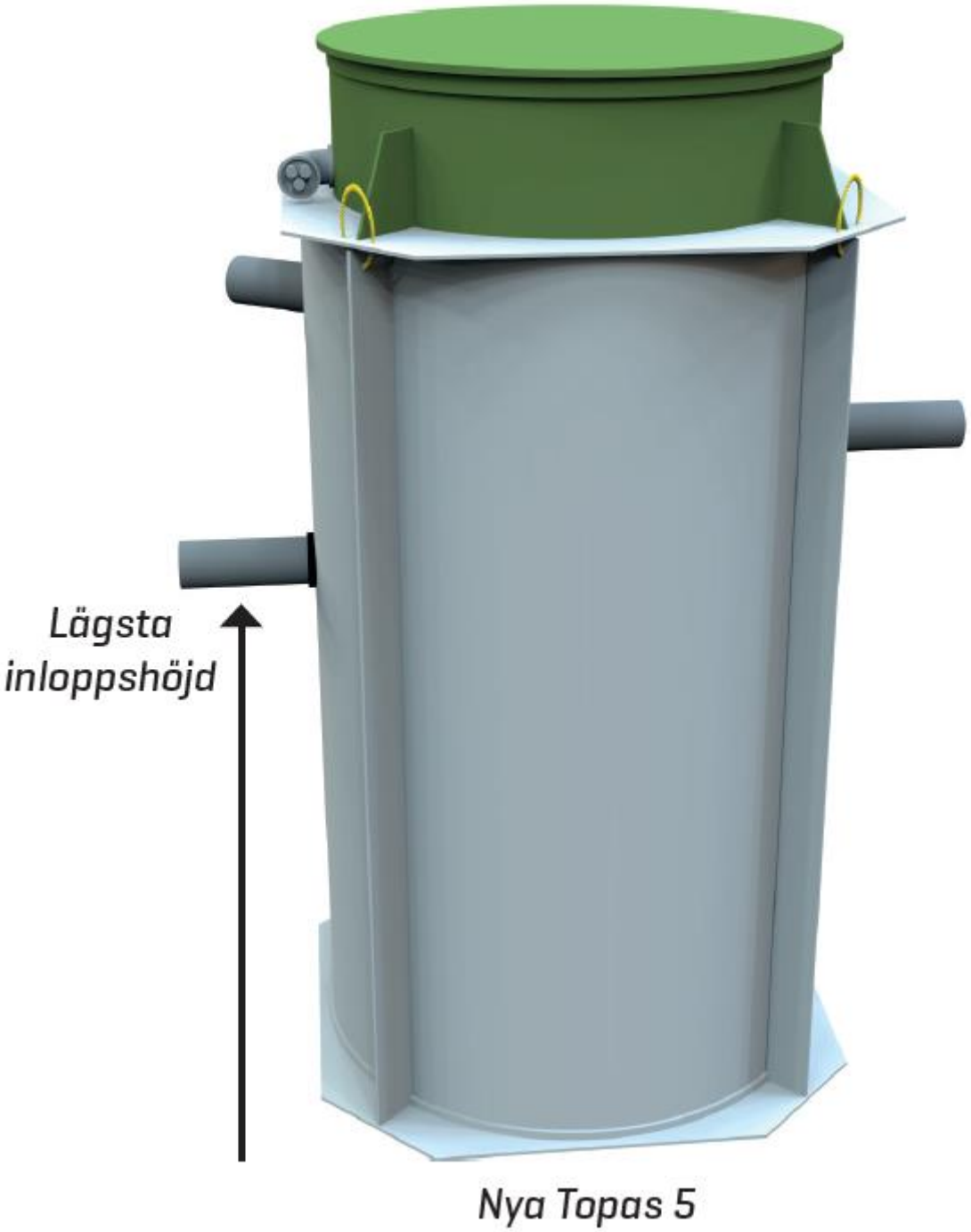
biovac (Biovac, 2022)

Mälaren (Godkändaavlopp, 2022)



uponor (svensktavlopp, 2022)

Solido (Markgrossen, 2022)



topas (Avloppscenter, 2022)