CHALMERS
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# Filtration or sedimentation – An analysis of choice of technology for primary treatment

## Investigating surface area requirement, energy usage and climate footprint

Master's thesis in Infrastructure and Environmental Engineering
Master's thesis in Industrial Ecology

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MASTER’S THESIS ACEX30

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Aerial image of a wastewater treatment plant in Saudi Arabia.

Department of Architecture and Civil Engineering
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ABSTRACT

This study aims to investigate and to compare the conventional sedimentation method with a novel technology known as Drum Screening Liquid Filter (DSL) in the primary treatment step. The primary objective is to assess the viability of DSL as an alternative approach by examining factors such as surface area utilization, energy usage, and environmental impact. To determine the surface area requirements, a devised methodology based on the settling velocity of particles has been employed to calculate the dimensions of the sedimentation basins. Additionally, information and design methodologies pertaining to DSL filters have been sourced from HUBER wastewater technology. In order to evaluate the environmental implications, a comprehensive Life Cycle Assessment has been conducted. The findings of this research demonstrate that DSL filters offer favorable performance characteristics, particularly when addressing challenges related to limited surface area availability, energy efficiency, and environmental sustainability. The results confirm that DSL filters occupy a smaller surface area, consume less energy, and generate a reduced amount of $CO_2$ emissions compared to conventional sedimentation methods, thus highlighting their potential as a promising alternative for wastewater treatment plants.

Key words: Sedimentation, filtration, drum filter, life cycle assessment, environmental footprints

# Contents

# List of Tables

# List of Figures

# Preface

This study compared conventional sedimentation basins made out of concrete and the ‘Drum Screen Liquid’ filter technology provided by Huber Technology. The study was conducted between January 2023 and June 2023 and was intended to compare the two methods or primary clarification of municipal wastewater and determine how much space they require, how much electricity they use, how the investment cost and operational cost over an assumed use time of 20 years and lastly, how much greenhouse gases they emit during their lifespan. The study was conducted at the department of Water Environment Technology at Chalmers University of Technology, Sweden.

The project has been carried out with help from Isabella Fröderberg at Huber Technology Nordic AB as supervisor, and Professor Britt-Marie Wilén at Chalmers as the examiner. We would like to thank Britt-Marie and Isabella for all the help during our project, and John Skantze for constantly supporting our work. We would also like to thank Alexander Hollberg and Anna Wöhler from Chalmers for supporting us in regards of conducting the life cycle assessment.

Gothenburg June 2023

Reza Gholizadeh Namaghi, Marcus Österman

# Notations

## Acronyms

| | |
|---|---|
| CAC | Calcium Aluminate Cement |
| DSL | Drum Screen Liquid |
| EPD | Environmental Product Declaration |
| GHG | Greenhouse Gas |
| GTP | Global Temperature Potential |
| GWP | Global Warming Potential |
| LCA | Life Cycle Assessment |
| LCI | Life Cycle Inventory |
| LCIA | Life Cycle Impact Assessment |
| RT | Running Time |
| TSS | Total Suspended Solids |

## Variables

| | |
|---|---|
| $A$ | required area ($m^2$) |
| $L$ | tank length (m) |
| $OR$ | overflow rate ($m^3/m^2/d$) |
| $Q$ | average or maximum flow ($m^3/d$) |
| $W$ | width of tank (m) |
| $a$ | constant number |
| $b$ | constant number |
| $d$ | diameter pf particles (m) |
| $f$ | Darcy – Weisbach friction factor (unitless) |
| $g$ | acceleration due to gravity (9.81 $m/s^2$) |
| $k$ | constant that depends on the type of material being scoured (unitless) |
| $s$ | specific gravity of particles |
| $t$ | retention time |

# Units

| | |
|---|---|
| kg $CO_2$ eq | Kilogram carbon dioxide equivalent |
| $^oC$ | Degree Celsius |
| p.e | Population equivalent |
| m | Meter |
| $m^2$ | Square meter |
| $m^3/m^2/d$ | Cubic meter per square meter per day |
| $m^3/d$ | Cubic meter per day |
| $m/s^2$ | Meter per square second |
| l/s | Litre per second |
| ton/year | Ton per year |
| kW.h/year | Kilo watt hour per year |
| mg/l | Mili gram per litre |
| h | Hour |
| h/day | Hour per day |
| kg | kilogram |

# 1 Introduction

Wastewater treatment is an important part of modern societies all over the world, and often seen as one of the most vital parts of infrastructure to keep both the environment and population safe.

Increasing urbanization and global population put increasing pressure on wastewater treatment systems. With increasing population density comes the need for more efficient and large-scale wastewater treatment plants, which in turn presents a plethora of challenges and considerations that need to be addressed in design. One of the considerations is the location and space requirements of the treatment systems, something that can be a limiting factor in plants built in urban areas where space is sometimes scarce. The Swedish government, in compliance with the regulations from the European Union (Pistocchi et al., 2019), is enforcing more and more strict contaminant removal regulations on the wastewater treatment plants in Sweden (Miljödepartementet, 2022), which leads to additional add-ons and retrofitting having to be made to the systems. With time, with more and more additions having to be made, there is a risk of running into problems with having enough space to retrofit the plants properly, which calls for solutions with a smaller footprint.

An important concern regarding wastewater treatment is the use of electricity. In order to achieve treatment that removes contaminants such as phosphorous - and nitrogen to low concentrations in receiving waters, typically large amounts of electricity are needed to aerate and pump the water to maintain optimal microorganism growth and oxidation of compounds (Chen et al., 2022). Depending on the electricity mix of the region where the treatment plant is located, this can have varying effects on the environment through the means of electricity production, and also on the cost that can vary based on this. This can make different process solutions better for different regions, which is why a systematic life cycle perspective is important to assess the solution best fit for every case. Also, the amount of concrete used in the basins can be a considerable factor for energy usage as well as costs. Green concrete can be used as an alternative to reduce both mentioned factors in constructing phase of basins.

# 2 Background

The importance of wastewater treatment in relation to societal and environmental well-being cannot be overstated. Optimizing and making efficient wastewater treatment helps reducing point emissions from larger urbanized areas, which may contain high concentrations of phosphorous and nitrogen, among other things, which can cause a lot of environmental degradation such as eutrophication. There are different technologies and ways to carry out the treatment process, and one step where there are different ways to do it is in the primary treatment phase. The primary treatment phase of wastewater typically relies on sedimentation in concrete basins, utilizing gravity to settle suspended solids. However, this conventional method has its drawbacks, including large space requirements and high costs in terms of construction.

As an alternative, the HUBER company has developed the Drum Screening Liquid (DSLs) technology. The system consists of a tank with a rotating stainless mesh screen of varying sieve sizes, through which wastewater flows. The mesh separates solids, and the rotating action helps remove any stuck solids via washing flushers. The flushed sludge is then subjected to further dewatering and thickening.

To design both methods, three sites with difference in population equivalent have been assumed as model sites for incoming flow and treatment conditions. They are:

- Site A, receives wastewater flow of approximately 1.000.000 p.e., which is considered a large plant.
- Site B, which receives wastewater flow from approximately 40000 p.e. which is considered to be a medium sized plant.
- Site C, which is the smallest plant receiving flow from approximately 3500 p.e..

The data are gathered from actual treatment plants and are used in order to have better initiatives for the design methods and processes (Kungsbacka Kommun, n.dperhaps; Sonander & Tord, n.d.; Videbris, 2021).

# 3 Theory

This section will present and outline of some of the theory behind design methods and life cycle assessment.

## 3.1 Sedimentation Basins

Sedimentation basins can be used both in primary treatment and in the secondary treatment steps. The basins have large dimensions in length, width, and depth. The suspended particles settle by gravity at laminar flow conditions and provides a certain retention time for the slowly settling sludge to settle. The suspended solids that have a higher unite weight than water will settle during the retention time, and some will float on the surface of the water. Chain scrapers will then be used to collect and transfer the accumulated solids from the bottom and the surface of the primary sedimentation basin.

The design process of the sedimentation tanks has been performed for the 3 sites with different population equivalents. Based on the Wastewater Engineering Book (Metcalf & Eddy, 2014) method the average and peak flow rate of treatment plant has been used to design the dimensions of the sedimentation basins and calculate the retention time.

In the start of the design, process, the number and width of the needed tanks in the treatment plant is estimated.

- **Calculate the Required Area**

Based on the assumed overflow rate (OR), the required surface area can be calculated from the Equation (3.1).

$$A = \frac{Q}{OR} \tag{3.1}$$

$A$ = required area ($m^2$)
$Q$ = average flow ($m^3/d$)
$OR$ = overflow rate ($m^3/m^2/d$)

- **Calculate the Length of Tanks**

By assuming the width of the tank, the length can be calculated based on the required area using Equation (3.2).

$$L = \frac{A}{W} \tag{3.2}$$

$L$ = tank length (m)
$A$ = required area ($m^2$)
$W$ = width of tank (m)

- **Retention Time and Overflow Rate (Average Flow and Peak Flow)**

Retention time and overflow rate must be calculated for both maximum flow and the average flow in this method using Equation (3.3) and (3.4).

$$Overflow\ Rate = \frac{Q}{A} \tag{3.3}$$

$Q$ = average or maximum flow ($m^3/d$)
$A$ = required area ($m^2$)

$$Retention\ Time\ (t) = \frac{V}{Q} \tag{3.4}$$

$Q$ = average or maximum flow ($m^3/d$)
$V$ = tank volume ($m^3$)

- **Scour Velocity**

Scour viscosity or horizontal velocity is a value that should kept significantly low to avoid the resuspension of settled particles and can be calculated using Equation (3.5).

$$Scour\ Velocity\ = [\frac{8.k.(s-1).g.d}{f}]^{0.5} \tag{3.5}$$

$k$ = constant that depends on the type of material being scoured (unitless)
$s$ = specific gravity of particles
$g$ = acceleration due to gravity (9.81 $m/s^2$)
$d$ = diameter pf particles (m)
$f$ = Darcy – Weisbach friction factor (unitless)

- **Removal Rate**

At this step the removal rate of TSS is being calculated based on the Equation (3.6) to see if the process meets the acceptable range for sedimentation basins.

$$Removal\ Rate\ = \frac{t}{a + b \times t} \tag{3.6}$$

$t$ = retention time
$a$ = constant number
$b$ = constant number

After calculating all forementioned parameters, horizontal velocity at peak flow and average flow must be less than Scour Velocity; otherwise, the settled matter will be resuspended, and design process should be performed again and should assume other values for width.

## 3.2 DSL Filters

In order to remove coarse materials and separate the suspended solids, mechanical pre-treatments can also be used. A solution that is posed for this step of treatment must be cost-effective, achieve the target removal efficiency of suspended solids and provide enough capacity. One special solution is to use Drum Screening Liquid filters (DSL). DSLs have horizontally installed screen baskets, which can be situated in a channel or a tank which can be seen in **Figure 1** and **Figure 2** .

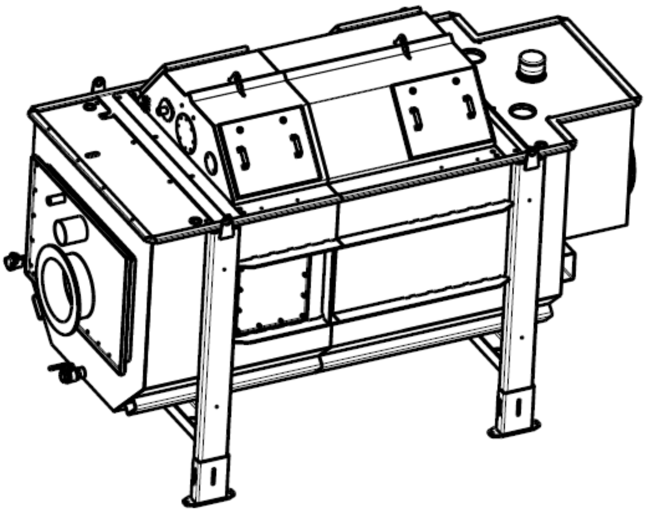

***Figure 1.*** *Example of installing DSL filters in steel case*

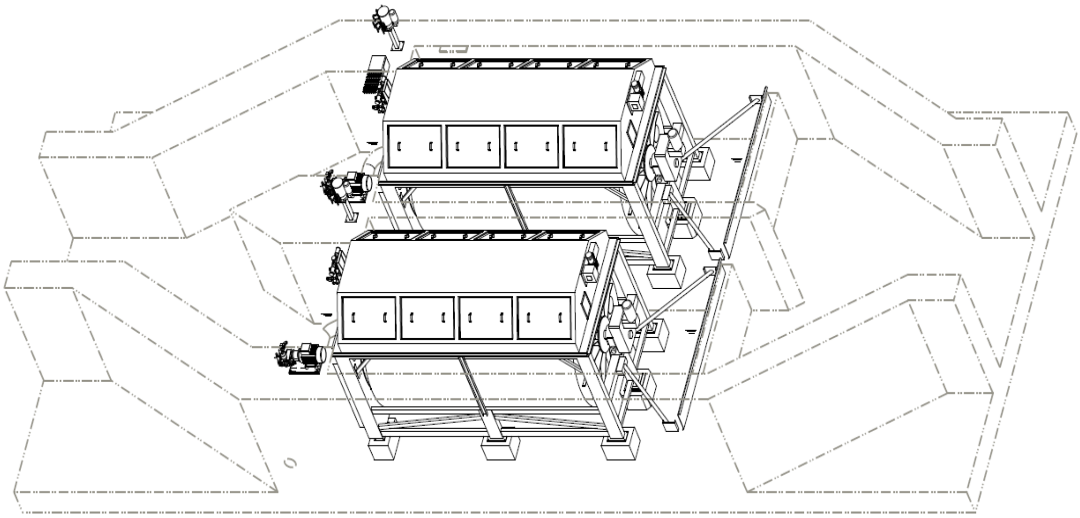

***Figure 2**. Example of installing DSL filters in concrete channels*

In order to treat the wastewater, it passes through the basket from the inside to the outside. As the wastewater enters the open front of the screen basket, solid particles are retained within the drum, while the liquid portion continues to flow through. A specialized seal between the channel and the front-end opening of the screen basket ensures that untreated wastewater is prevented from bypassing the screen basket.

Over time, the solid particles settle on the surface of the drum, start to clutch, and blind. Consequently, the water level upstream of the screen gradually rises. Once the predefined maximum water level is reached, the screen basket initiates rotation around its axis to clean its surface. At the top of the drum, a spray nozzle bar sprays water onto the drum surface from the outside, effectively flushing the accumulated solids. These solids are then directed into a trough located inside the drum basket and are subsequently discharged by gravity. Alternatively, the screenings can be pumped to a higher level if required (*HUBER Drum Screen LIQUID,* n.d.).

DSL filters are designed to accommodate the inflow of wastewater, and the concentration of suspended solids entering treatment plants. These filters are available in various sizes to accommodate a wide range of flow rates and site limitations. The 0.2-millimeter mesh size is the most commonly used size for DSL filters. The dimensions of DSL filters, such as length and mesh diameter, can be adjusted to meet specific site requirements. Graphical representations aid in identifying the appropriate filter type based on wastewater inflow and suspended solids concentration.

Additionally, DSL filters can be installed in either stainless-steel cases or concrete tanks. The choice of filter housing material should be made after weighing the advantages of stainless-steel cases against the amount of concrete work required for installation.

## 3.3 Calcium Aluminate Cement (CACs)

The materials that are used in both treatment technologies are of concern in terms of environmental impacts and carbon footprints. With that said sedimentation basins are mainly made out of concrete. The concrete used in the wastewater facilities must be resistant against the corrosion caused by the constituents of the wastewater, out of which the sulphate compounds are often the most prominent corroders. For this study it is an important factor to consider differences between normal and sulphate resistance cement and concrete in terms of carbon emission and environmental impacts which will be introduced in this section.

Calcium aluminate cements, typically known as sulphate resistant cement, are commonly used in wastewater applications due to being more resistant to corrosion and weathering due to the exposure to wastewater and chemicals in the processes.

The primary raw materials utilized in the production of calcium aluminate cements (CACs) are limestone and bauxite. CACs are characterized by a chemical composition consisting of approximately 30-40% by weight of calcium and aluminium oxides, along with up to 20% iron oxides and trace amounts of silica. Additionally, CACs contain small quantities of titania, magnesia, and roughly 0.5% sulphate or sulphide.

The concrete made from CAC has unique characteristics of gaining rapid strength, high chemical resistance and additionally, its strength can be maintained during high temperature and aggressive conditions.

In addition to their chemical composition, CACs also possess distinct physical characteristics. Although their durability, when compared to Portland cement, is a significant factor in their selection for construction projects, the primary objective is to produce and to utilize a material that exhibits acceptable performance and durability in harsh chemical environments. It is worth noting that poor performance can be attributed to various factors, such as water-to-cement ratio or low-quality cement content, and these factors should be taken into account when considering the use of both CACs and Portland cement (Ideker et al., 2019)(Klein et al., 2022)

In this report the gas emission and carbon footprints of concrete in both treatment methods is of concern. The most carbon emission part in cement production of concrete is related to clinker which made of limestone and aluminosilicate materials like clay and will be produced by heating the constituents until 1400-1500 $^{o}$C. The amount of clinker used in both ordinary Portland cement and sulphate resistance cement is the same and carbon footprint can be assumed to be equal for both type of cements (Civil Today, n.d.; Costa & Ribeiro, 2020; Nie et al., 2022; Shao et al., 2022).

A lot of corrosion resistant concretes are rated for 30 MPa loads, so combining this fact with the fact that ordinary Portland cements and sulphate resistant ones it is a fair assumption that investigating the emissions linked to 30 MPa load rated concrete will give a good idea of the emissions linked to this production. Carrying out a sensitivity analysis, which is a common concept in life cycle analysis studies, could further quantify this assumption and how much estimation error it can cause.

## 3.4 Life Span

The lifespan of the Life Cycle Assessment (LCA) section of this report has been determined to be 20 years. It is important to note that concrete is estimated to have a lifespan of 50 to 100 years for construction use. However, a shorter lifespan of 20 years has been adopted for the purpose of this study due to the possibility that population growth during this period could impact the capacity of a wastewater treatment plant.

This may prompt authorities to consider changing or designing additional systems to increase capacity, even if the existing concrete structures are still functional and not yet obsolete. (Andersen & Negendahl, 2023)

## 3.5 Life Cycle Assessment

The overall philosophy of the LCA conducted in this thesis is to assess commercially available materials used in the production and building of the products; thus, maybe excluding some unreasonably expensive options that might have preferential properties over the investigated ones. Excluded materials could for example be some types of green concrete, which would have less accumulated emissions than regular concrete production, but that aren't readily available to purchase for contractors and constructers, or at a cost which would be unreasonable to assume feasible.

According to the ISO 14040 (Swedish Standards Institute, 2006a) and ISO 14044 (Swedish Standards Institute, 2006b) standards, there are four main stages that make up the LCA study: Goal and scope, Inventory analysis, Impact assessment and lastly interpretation and limitations. These four stages and how they are generally used in an LCA study will be explained briefly in the upcoming subsections.

### 3.5.1 Goal and scope

Here the general purpose of the study is set and in what context the study is intended to be used. One of the most important parts of an LCA study is to be fully transparent about the intended use of the study. Since there are a lot of assumptions, simplifications and the system boundaries can be quite restrictive, which exclude a lot of potential considerations outside of the system that can feel like they're important for the results. Thus, the intended use of the study and why it was conducted in the first place is vital to avoid misuse of the results.

### 3.5.2 Inventory analysis

For the inventory analysis, the processes and flows of the system are defined and quantified. There are different ways of accomplishing this depending on the purpose of the study and how precise it can be. It can also be affected by a target audience. As an example, if a company is to conduct an 'Environmental Product Declaration' (EPD), there are very specific rules as to what data must be included and how to present it. But instead, if a more overarching study is to be performed to get a rough estimate assessment of environmental impacts, more niche data generated by the stakeholder themselves can be used, but it can also lead to issues with the reliability and impartialness of that data.

### 3.5.3 Impact assessment

In the impact assessment, the materials used, the processes to produce them and the products you intend to investigate, and the transports and all of their emissions is summed up, after which they are assessed to see the total emissions. What emissions and end points that is to be assessed can somewhat vary to fit the purpose of the study. Some of the most used impact categories are acidification, climate change, ecotoxicity, human toxicity, eutrophication, land use, particulate matter to name a few. All of these categories are measured using a standardised and normalised quantitative unit. For climate change, which is the impact category investigated in this study, the unit is “kg of $CO_2$ equivalent”, and likewise all other categories have other standardised units.

### 3.5.4 Interpretation and limitations

The final section of the LCA study is meant to provide some sort of answer and decision-making guidance in relation to the purpose of the whole LCA study that is stated in the goal and scope.

### 3.5.5 Impact categories

The **Global Warming Potential (GWP)** is the integrated **radiative forcing** over the course of either 20 or 100 years, calculated on the emission impulse at a given time (IPCC, 2014). Since the GWP considers all GHG emissions and their accumulative radiative forcing on the atmosphere, the impact category has to take into consideration the different average lifespans of different GHGs. For example, methane ($CH_4$) has an average life span of 12 years (International Energy Agency, 2022), whilst $CO_2$ is basically inert, and have to be taken up and sequestered instead of degrading into something else.

The **Global Temperature Potential (GTP)** is the total effect the emissions would have on the average surface temperature of the earth after a given amount of time (IPCC, 2014). This category involves more complex calculations and assumptions than the GWP but can in certain cases give a more complete picture than the GWP.

### 3.5.6 Data reliability

Data reliability is an important aspect of your inventory analysis, why there are some major databases that are used internationally and by a lot of companies and government agencies, which add to the reproducibility and reliability of the inventory analysis. These databases are constantly reviewed, and new releases keep the data updated as much as possible, something that is very hard to do for individual companies or groups of LCA practitioners themselves, why having a third party that is fully impartial and unbiased is a great way to increase reliability.

### 3.5.7 Important assumptions

This section will outline some of the most important working assumptions made for the LCA study to make it useable and use as high quality of data sources as possible. To keep the data consequent, as much data as possible is taken directly from the ecoinvent database and thus some assumptions had to be made to make it fit this study.

#### 3.5.7.1 Sulphate Resistance Cement having the same emissions as Portland cement

One of the most important assumptions for this study, is how using CAC or Portland cement affects the emissions from the concrete construction. According to (Nie et al., 2022), the GHG emissions from CAC is approximately the same as from using Portland cement, which is why it is a fair assumption to make.

### 3.5.8 Ecoinvent life cycle inventory database

Ecoinvent is based mainly on literature values of emissions related to supply chains and raw materials. It is an internationally recognized database used by universities, governmental agencies, companies, and NGOs all over the world. It is a general-purpose background life cycle inventory database, meaning that it has emission data related to a lot of different types of industries, where others might for example be focused solely on food production and agriculture.

One downside to only using a general, all-purpose database is that you can't include some application specific data. Instead, you would have to work around it with certain assumptions or simplifications, losing some resolution of the results but making it more widely applicable.

# 4 Method

In order to start the design process of both technologies, in this section, some parameters have been gathered and investigated accordingly.

## 4.1 Design of Primary Sedimentation Basins

Sedimentation basins had been designed for three mentioned sites. Based on the equations in **Section 3.1** the parameters which were needed to use in the designed process had been gathered from environmental reports and directly contacting the engineers at the treatment plants. Aforementioned data has been presented in **Table 1** (Kungsbacka Kommun, n.d.; Sonander & Tord, n.d.; Videbris, 2021).

***Table 1.*** *Needed Parameters for Sedimentation Basins Design*

| | Population Equivalent | Average Flow ($m^3/d$) | Peak Flow ($m^3/d$) |
|---|---|---|---|
| **Site A** | 889543 | 354240 | 604800 |
| **Site B** | 39450 | 20180 | 51250 |
| **Site C** | 3400 | 1500 | 2100 |

## 4.2 Design of DSL Filters

The design of DSL filters depends on the entering wastewater flow to the system and also the amount of suspended solids going into the sedimentation basins. The data needed for the design of DSL filters were gathered in **Table 2** (Sonander & Tord, n.d.) For the design method for machines, average flow and suspended solids were used.

- In the first step of the design, the amount of Total Suspended Solids entering to the wastewater treatment plant has to be determined and change the unite into mg/year. The same process should be carried out for incoming wastewater flow and change the unite into l/year.
- In this step the amount of SS in mg/l is calculated in the wastewater flow and can be determined by dividing the TSS by average wastewater flow that gathered in previous step.
- By having average wastewater flow in l/s and SS in mg/l from previous steps it is possible to determine the type and size of DSL filters by looking at **Figure 3**. It should be also mentioned that the theoretical capacity of every machine could be calculated based on an equation for every filter that has been provided by HUBER company in the design graphs (exact equations are confidential information).

***Table 2.*** *Needed Parameters for DSL Design*

| | Average Flow ($m^3/d$) | Total SS (ton/year) |
|---|---|---|
| **Site A** | 354240 | 54124 |
| **Site B** | 20180 | 2700 |
| **Site C** | 1500 | 34 |

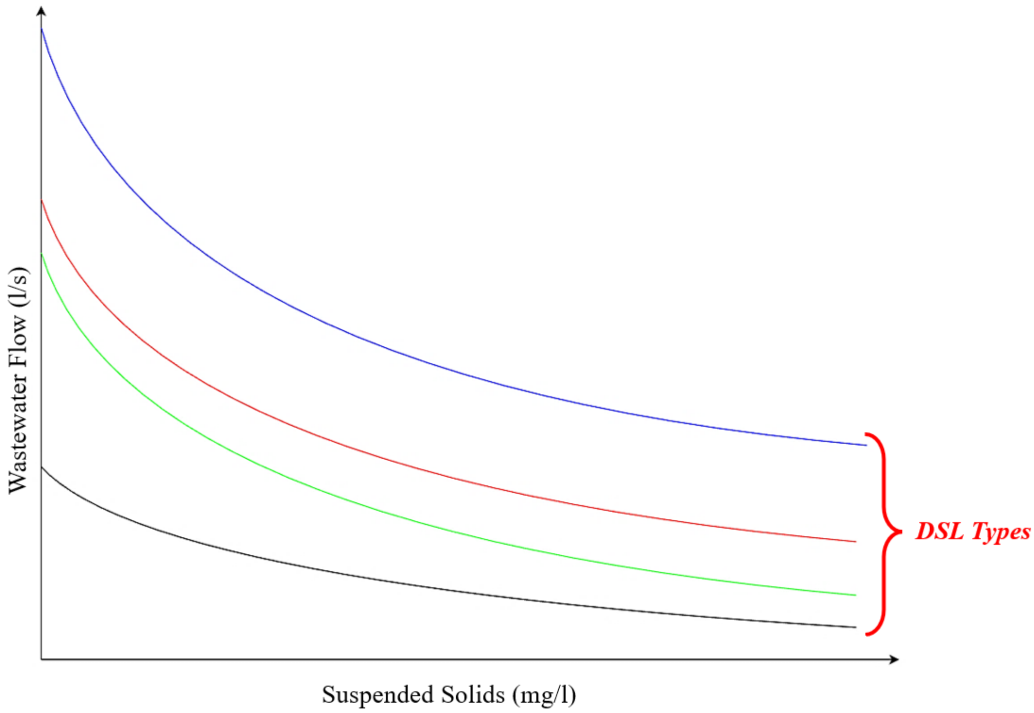


***Figure 3.*** *Design graph for DSL filters* [1]

## 4.3 LCA

For the LCA study that is part of this study, the basis of the emissions data was from the ‘ecoinvent’ life cycle inventory database. The version of their database that was used is the ‘ecoinvent 3.8 cut-off’, which provided a lot of useful inventory to assess the processes and their emissions. The general philosophy of the LCA was to use widely applicable data found through the ecoinvent LCI database in order to make the study more generally useful for different cases and geographical locations, although mainly focused on Sweden and Swedish conditions, specifically for energy usage and emissions caused by it, national data for Sweden was used. It was also decided to go exclusively with using the ‘Market for …’ providers in the database. The market providers included the typical source and; thus, emissions linked to different materials for a specific region, which in the case of all the physical materials in the study was either global, or ‘rest of world’. Rest of world is the general global average production

[1] The figure has been made vague deliberately for confidentiality.

and thus, the most general case you can do, that was broadly applicable to markets all over the world regardless of where you model your system.

## 4.4 Choice of functional unit

To be able to compare two systems that are comprised of so widely different technologies to achieve the end-goal of the treatment system, namely a reduction of at least 50% of incoming suspended solids, the functional unit of choice was: “A primary clarification treatment system capable of providing a reduction of at least 50% of incoming suspended solids in municipal wastewater over a service lifetime of 20 years”.

## 4.5 Life Cycle Inventory modelling

The LCI consist solely of data from the ‘ecoinvent 3.8 cut-off’ database. The upcoming subsubsections would outline the included materials in the software and how the modelling process of the LCI was conducted.

### 4.5.1 Sensitivity analysis of concrete

This section would outline the main findings from the LCA study and show relevant graphs and comparisons between the two options. First off, a sensitivity analysis was conducted to determine the effect of different types of concrete that are hard to quantify exactly for systems containing such large amounts of material. The analysis carried out was to compare the 30MPa rated concrete, which was used in the LCI, to the 50MPa rated concrete, which would contain more cement and binders and thus also reasonably cause larger emissions.

### 4.5.2 Sedimentation basins

The amount of concrete presented in **Table 5** was put into the OpenLCA software, using the inventory data from ecoinvent 3.8 for “concrete, 30MPa” provided by the “market for concrete, 30MPa | concrete, 30MPa| Cutoff, U – RoW”, along with “reinforcing steel” provided by the “market for reinforcing steel | reinforcing steel | Cutoff U - GLO ” and lastly “steel, chromium steel 18/8” provided by the “market for steel, chromium steel 18/8 | steel, chromium steel 18/8 | Cutoff, U – GLO” for the chain scrapers. These were used as inputs for the sedimentation basins for all three sites in varying amounts corresponding to tables **Table 5**, **Table 6**, **Table 13**. These unit processes provided outputs of 1x finished treatment of three different sizes, each corresponding to the Site A, B and C sizes calculated. This output of 1x ready-to-use treatment system was then used as input into the use phase of the treatment systems, presented in **section 4.5.4**.

### 4.5.3 DSL filter systems

Much like the described process for the sedimentations basins in **Section 4.5.2**, the DSL filters were modelled in a similar way but with the material needed to make the DSL finished treatment systems. Here, firstly the production of both the “Drum Filter DSL MESH 2200/0,2/4000” and “Drum Filter DSL MESH 1300/0,2/1100” were modelled separately. It is assumed that the stainless steel would make up almost all of the GHG emissions for the drum filters, so only the stainless steel required was modelled as input material. For this purpose, the "steel, chromium steel 18/8" provided by the "market for steel, chromium steel 18/8 | steel, chromium steel 18/8 | Cutoff, U – GLO" was used. The amounts of steel needed for the two filters were presented in **Table 12**. These were then treated as outputs from these separate unit processes and used as input into the making of the finished DSL treatment system.

To model the finished DSL treatment systems, the numbers of filters needed for each, and which type was input as input data, see **Table 7**. Alongside with the input of the DSL filters, for site A and B, where concrete channels were decided as the construction option, inputs for "concrete, 30MPa" provided by the "market for concrete, 30MPa concrete, 30MPa| Cutoff, U – RoW", along with appropriate amounts of "reinforcing steel" provided by the "market for reinforcing steel | reinforcing steel | Cutoff U - GLO". The amounts of concrete and reinforcing steel needed for construction of the DSL filter system for Site A and B respectively could be seen in **Table 13** and **Table 12**.

These three-unit processes for finished DSL treatment systems were then used as input to their respective use phase, presented in **Section 4.5.5**.

### 4.5.4 Use of sedimentation basins

To model the use phase of 20 years for the sedimentation basin, the complete sedimentation basin was used as an input for the system, alongside with 20 years' worth of electricity usage. For the electricity, the input of "electricity, medium voltage" was used, with the provider "market for electricity, medium voltage | electricity, medium voltage | Cutoff, U – SE", giving the Swedish electricity mix emissions.

This unit process of one treatment system and it generated an output of one used system at its end of life. In a study that includes focusing on end-of-life fates and possibilities to recycle materials, this output would be examined in more depths, but for this study only the accumulative emissions caused by the use phase was of interest.

### 4.5.5 Use of DSL filter systems

To model the use phase of the DSL filter systems for 20 years of use, in similar fashion to the modelling of use phase of the sedimentation basin, the input of the finished production of one DSL filter system was used as input for every site respectively, followed by 20 years' worth of electricity, tap water for the high-pressure cleaning of the filters and some additional stainless steel for the major replacement parts needed for the DSL filters during its 20 year technical lifespan. The amount of input materials could be seen in **Table 12**. Similarly, to the use of sedimentation basin, the end-of-life was not investigated further than calculating the emissions caused by the production and use of the DSL filter systems for site A, B and C, respectively. These emissions and how they were relative to each other could be seen in **Table 15**.

## 4.6 Life Cycle Impact Assessment Method

For the purpose of this LCA study, which is solely to assess the climate footprint of the two different technologies, the impact assessment method "IPCC 2013" was used. This assessment method includes the impact categories of the *Global Warming Potential (GWP)* for a 20-year period, and a 100-year period, and it estimates the *Global*

*Temperature Potential (GTP)* for 20 years and 100 years (IPCC, 2014). The unit to measure the greenhouse gas emissions that both impact categories use is “$CO_2$ equivalents”, which is all the greenhouse gases emitted and then weighed against a $CO_2$ baseline of radiative forcing, which gives a certain amount of actual $CO_2$ needed that would cause the same amount of radiative forcing as the greenhouse gas that is actually emitted. There were also a few built-in correction factors that adjusted this number for the difference in turn-over rate and atmospheric lifetime.

## 4.7 Interpretation of LCA study

The final part, the interpretation of the findings of the LCI and LCIA, was used to support our findings and conclusions about the overall upsides and downsides of the two treatment technologies. Since the LCA was meant to help assess electricity usage and climate footprints, these were the only things investigated and discussed further from the LCA study.

# 5 Results

This section presents the findings obtained by gathering and analyzing data using the theoretical and methodological approaches outlined earlier in the report.

## 5.1 Sedimentation Basin

According to the provided data in **Table 2**, surface requirements and the number of sedimentation tanks to deal with the entered wastewater into all treatment plants had been calculated and presented in **Table 3** (Kungsbacka Kommun, n.d.; Sonander & Tord, n.d.; Videbris, 2021).

***Table 3.*** *Surface Area Requirement and Tanks Dimensions*

| | **Surface Area ($m^2$)** | **Number of Basins** | **Length (m)** | **Width (m)** | **Depth (m)** | **Concrete Wall Thickness (m)** |
|---|---|---|---|---|---|---|
| **Site A** | 6528 | 12 | 68 | 8 | 4 | 0.3 |
| **Site B** | 336 | 3 | 28 | 4 | 3 | 0.25 |
| **Site C** | 72 | 1 | 18 | 4 | 3 | 0.25 |

### 5.1.1 Sedimentation Basins Power Usage

In sedimentation basins the motor of the scrapers drive consumed most electrical energy. The power usage of the scraping drives can vary and depend on the waste load and size of the sedimentation tank. It is noteworthy that the scrapers operated continuously, 24/7, in order to mix, scrape, and skim the surface and bottom of the tanks. The electrical usage of primary sedimentation was quite low and in case of chain scrapers can be calculated by 0.1 kWh/(PE.a) (HUBER Company, n.d.; *PROBIG*, n.d.).

Regarding Site A, power consumption related to the scrapers are gathered in **Table 4** which included power consumption of the pumps and drive unite of the chain scrapers. The electricity consumption for one sedimentation tank regarding the scrapers has been estimated to 525 kW/year and total consumption for all sedimentation basins is calculated to 6302 kW/year. It is notable to say that the running time and the number of tanks has been considered in the power consumption as well as pumps. In the case of Site B, the power consumption has been calculated based on the population equivalent of the site. With the help of a contact in a similar small treatment plant for Site C primary sedimentations, the power consumption of the only settling clarifiers was estimated to be 4.5 kWh/day and also there would be two pumps with power consumption of 2.2 kW/day. Accordingly, the yearly consumption for all sites had been calculated.

*Table 4.* *Power Usage of Sludge Scrapers*

| | Sludge Scrapers 1X (kWh/year) |
|---|---|
| **Site A** | 110300 |
| **Site B** | 8000 |
| **Site C** | 4380 |

### 5.1.2 Materials Used in Sedimentation Basins

It is assumed that the sedimentation basins for all three sites were constructed using concrete. One of the main characterizations of the concrete in basins was to be resistant against the erosion caused by sludge created from the wastewater. The amount of concrete was used in the three studied sites have been calculated based on the dimensions of sedimentation tanks designed in **Section 5.1** . As it can be seen from the **Table 5** the approximate amount of concrete used in the Site A primary sedimentation tanks is around 4000 $m^3$, and it is high volume compared to the other two sites due to the number of sedimentation tanks and the very high capacity of the treatment plant. For Site B and Site C the volume of concrete 228 and 51 $m^3$ respectively. Moreover, the concrete in the basins at all sites had been reinforced by the steel. To calculate the amount of reinforced steel required, an average percentage of 1-2% had been applied to the concrete volume in all three sites (Arafah, 2000).

*Table 5.* *Amount of concrete used and weight of reinforcing steel.*

| | Concrete Volume ($m^3$) | Reinforcing Steel Weight (kg) |
|---|---|---|
| **Site A** | 4148 | 663552 |
| **Site B** | 228 | 36480 |
| **Site C** | 51 | 8160 |

Additionally, in rectangular basins, chain scrapers were used to scrape the sludge in the tanks. Two rows of chains were used to fix scraping blades in between and fitted in between the shafts. By using the wheel in every corner of the channels, a continuous revolving and moving process is going on in an endless loop and scraping the sludge from bottom and surface of the basins. The most common scrapers were chains scraper system. Mentioned scrapers included chains, sprockets which were located in every corner of channels, scraper flights that carry and scrape the sludge, main shafts that hold scraper flights and drive unite which act as engine to the system and revolve the whole operation. According to a provider of chain scrapers, materials available for all parts of scrapers were carbon steel or different stainless-steel grades such as $AISI_{304}$, $AISI_{316L}$, etc (Finnchain, n.d.).

For the studied sites, the amount of steels were used in the sedimentation basins had been calculated by measuring the length of steel chains used in the settling clarifiers with the help of blueprints and the designed dimensions of the tanks. According to **Table 6** the approximate length of steel chain scrapers had been gathered and measured.

***Table 6.*** *The Length and Weight of Chain Scrapers*

| | Scrapers Length 1x (m) | Weight of Scrapers (kg) |
|---|---|---|
| **Site A** | 260 | 7488 |
| **Site B** | 120 | 864 |
| **Site C** | 80 | 192 |

## 5.2 DSL Filters

Based on the graphs provided by HUBER wastewater technology, the number of DSL filters needed to deal with the amount wastewater in all three sites had been calculated and presented in **Table 7** below. Furthermore, based on the dimensions and sizes of the machines, the surface area for DSL filters in all three sites have been calculated to be able to compare with the sedimentation basins. It should be mentioned that a filter with 1300/0.2/1100 means diameter of 1300 mm, 0.2 mm of stainless mesh and length of 1100 mm.

***Table 7.*** *Designed Parameters for DSL Filters*

| | Average Flow ($m^3$/d) | Total SS (ton/year) | Number of DSLs | Surface Area ($m^2$) | Type of DSL |
|---|---|---|---|---|---|
| **Site A** | 354240 | 54124 | 20 | 942.5 | 2200/0.2/4000 |
| **Site B** | 20180 | 2700 | 2 | 138 | 2200/0.2/4000 |
| **Site C** | 1500 | 34 | 1 | 6 | 1300/0.2/1100 |

In this study, Site A is the largest treatment plant with almost 1000000 PE connected. For DSL design at Site A, the average flow has been used for calculation (Videbris, 2021) which was 4000 l/s. The total suspended solids were calculated to be 167 mg/l for Site A. The calculation was conducted for 20 DSL filters with dimensions of 2200 mm in diameter, 0.2 mm in stainless mesh and 4000 mm length. It was also possible to use smaller size filters like 2200/0.2/3300, but as Site A was a large treatment plant with high wastewater flow, it is more reasonable to be able to handle higher flows. Regarding Site A, since the number of filters was large, it is recommended to use the concrete tanks and channels with pumps and pipes instead of using stainless steel case.

According to the **Table 7** for Site B which was the second large treatment plant in this study, the value for total suspended solid was calculated to $8.4\times10^{11}$ mg/year with a wastewater flow of approximately $47\times10^{5}$ l/year. Consequently, the amount of suspended solids for Site B treatment plant was computed to be 120 mg/s. According to the design graphs for 120 mg/s suspended solids and wastewater flow of 350 l/s, was decided to use two DSL filters with dimensions of 2200 mm diameter, 0.2 mm stainless mesh and 4000 mm length. It should be mentioned that the theoretical capacity of designed DSL filters is around 220 l/s for only one and in order to consider the safety using two of mentioned filters can satisfy and handle the entered wastewater flow even in higher range.

The total suspended solid had been measured for the Site C treatment plant for every year in **Table 7**. The amount of suspended solid in mg/l was calculated to be approximately 142 mg/l. Upon reviewing the graphs provided by HUBER company, it was observed that a single DSL filter is capable of accommodating a wastewater flow of 28 l/s when the incoming suspended solid concentration is 142 mg/l. The DSL filter chosen for this application has dimensions of 1300 mm in filter diameter, a stainless-steel mesh with a mesh size of 0.2 mm, and a filter length of 1100 mm. Moreover, the theoretical flow capacity of this selected DSL filter is approximately 40 l/s, confirming its suitability for handling the current and potential future flow rates.

However, it is essential to address the issue of redundancy in the design. Malfunctions in the system may occur, necessitating the removal of a filter for maintenance purposes. In such situations, it is more practical to include two filters in the design or construct a small sedimentation basin to bear the load during emergencies. Nevertheless, it should be noted that Site C was a relatively small site with low wastewater flow, even during the peak seasonal periods. Consequently, considering the occurrence of maximum flow for design may not be a crucial factor. Therefore, constructing an additional DSL filter or sedimentation tank solely to decrease redundancy may not be cost-effective.

### 5.2.1 DSL Power Usage

DSL filters are composed of parts that need electrical powers to run including drum screen driving unit, spray bat pump, regular flushing, high pressure cleaning with drive. The filters can be programmed and designed to run in a specific number of hours during a day according to amount of SS load.

For the three study sites in this report two different models of DSL filters were assessed. In **Table 8** the specific data and capacity of the two filters hare summarized. The running time for two machines is 10 hours, and they can handle 170 mg/l amount of sludge. The most significant difference of machines apart from the size is maximum flow capacity in DSL filters.

*Table 8*. *Capacity and Running Time of DSLs*

| | Qmax (l/s) | SS (mg/l) | Running Time (h) |
|---|---|---|---|
| **2200/0.2/400** | 168.4 | 170 | 10 |
| **1300/0.2/1100** | 28 | 170 | 10 |

Additionally, in **Table 9**, **Table 10** and **Table 11** water demand and total energy usage for all three sites and machines are presented. The drive unites in DSLs consume electricity and has a specific designed Running Time (RT). At the moment that upstream water in DSL filters exceeded the marked level, the drive starts to rotate the drum and drum screen spray bar pump will use water to clean the stuck sludge to the sieve which the amount of consumed water in that case is also presented.

The regular flushing run when the drum was rotating and removed the particles from the mesh during regular apportion. On the other hand, the high-pressure cleaning was manual cleaning process in the drum filters and ran much more seldom compared to the regular flushing to make sure the mesh was clean, and no particle build up or fouling was happening in the mesh.

***Table 9.*** *Power Usage in Site A*

| Site A | Number of Machines | Consumed Power (kW) | RT (h/day) | Actual Water Demand (l/s) | Total Power Consumption (kW.h/day) |
|---|---|---|---|---|---|
| **Drum screen driving unit** | 20 | 2.25 | 7.36 | - | 331 |
| **Drum Screen Spray bar pump** | 20 | 3.85 | 7.36 | 1.3 | 567 |
| **Drum screen regular Flushing** | 20 | - | 0.1 | 0.4 | - |
| **Drum screen high pressure cleaning + Drive** | 20 | 4.634 | 0.2 | 0.25 | 18.5 |

***Table 10.*** *Power Usage in Site B*

| Site B | Number of Machines | Consumed Power (kW) | RT (h/day) | Actual Water Demand (l/s) | Total Power Consumption (kW.h/day) |
|---|---|---|---|---|---|
| **Drum screen driving unit** | 2 | 2.25 | 7.88 | - | 35.4 |
| **Drum Screen Spray bar pump** | 2 | 3.85 | 7.88 | 1.3 | 60.7 |
| **Drum screen regular Flushing** | 2 | - | 0.1 | 0.4 | - |
| **Drum screen high pressure cleaning + Drive** | 2 | 4.634 | 0.2 | 0.25 | 1.9 |

*Table 11.* *Power Usage in Site C*

| Site C | Number of Machines | Consumed Power (kW) | RT (h/day) | Actual Water Demand (l/s) | Total Power Consumption (kW.h/day) |
|---|---|---|---|---|---|
| **Drum screen driving unit** | 1 | 0.825 | 8.4 | - | 6.9 |
| **Drum Screen Spray bar pump** | 1 | 1.54 | 8.4 | 1.3 | 13 |
| **Drum screen regular Flushing** | 1 | - | 0.1 | 0.4 | - |
| **Drum screen high pressure cleaning + Drive** | 1 | 3.059 | 0.2 | 0.25 | 0.6 |

### 5.2.2 Materials Used in DSL Filters

In this section, the materials that were used in the different parts of DSLs were discussed, and the total weights are presented. The wastewater flow ran into the machines where a stainless mesh was rotating and carrying the sludge stuck the stainless sieve. The drive unit carried out the rotating process. Suspended particles which were stuck to the mesh were removed from the sieve by water spray bar pumps as the mesh was rotating. The removed sludge was then transferred back by pumps to be dewatered or added to the process again. It should be mentioned that the DSL filters could be installed in either steel cases or in the designed concrete channels and it depends on every project and the number of DSLs needed. The amount of steel used in the DSL filters can be calculated by the weight of the filters and then weight of steel case would be added to it if it was determined to use steel tanks. Otherwise, DSLs are installed in concrete tanks which the amount concrete can be calculated by help of blueprints.

Based on the **Table 12** the weight for two types of filters had been measured and presented. For Site C the designed filter has a weight of 1500 kg with a steel case that the device is installed in. For Site A and Site B it was decided to use the same size of filters; therefore, the weight of the machine itself is 6950 kg and the drive weight for designed filters are 200 kg for the smallest site and 300 kg for other two sites. By having the weight of steel for every machine, it is easy to calculate the amount of steel that is used in every site with the use of unite weight of steel.

*Table 12.* *Weight of DSL Machines*

| | Drive Weight (kg) | Machine Weight (kg) |
|---|---|---|
| **Site A** | 300 | 6950 |
| **Site B** | 300 | 6950 |
| **Site C** | 200 | 1500 |

If it had been determined to use concrete and install DSL machines in concrete channels, the amount concrete that was used in the project could have been of concern when it comes to finding out the environmental impacts and materials that would be needed. It was decided to use concrete channels in Site A and Site B and the amount of concrete used in the two sites were calculated and presented in **Table 13**. It should be mentioned that in Site C it had been decided to use a steel case for DSL filters.

***Table 13.*** *Amount of concrete used and weight of reinforcing steel in The Channels*

| | **Concrete ($m^3$)** | **Reinforcing steel (kg)** |
|---|---|---|
| **Site A** | 337 | 53920 |
| **Site B** | 80 | 12800 |
| **Site C** | - | - |

## 5.3 Life cycle assessment

This section will outline the main findings from the LCA study and show relevant graphs and comparisons between the two options.

### 5.3.1 Result of sensitivity analysis of concrete

**Figure 4** showed a comparison made between equal volumes of 30MPa concrete and 50MPa concrete, namely 1000 $m^3$ each. As seen in the figure, the 50MPa concrete emits 403200 kg of $CO_2$ equivalents while the 30MPa emits only 276059 kg of $CO_2$ equivalents, making up 59.36% and 40.64% respectively of their combined emissions. Since the 30MPa concrete was deemed to be the most accurate rated concrete production mix for the purpose of this LCA, it was deemed that at worst the emissions could be approximately 40-50% higher if the construction would require the use of 50MPa concrete instead of 30MPa.

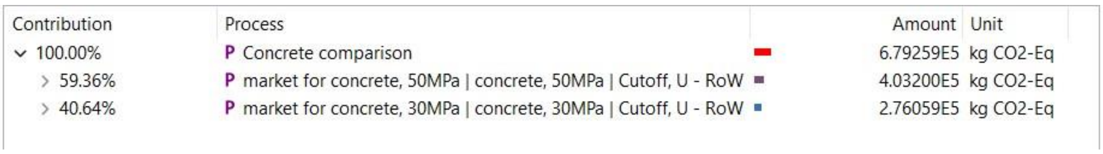


***Figure 4.*** *The contribution tree of a fictive system for comparing 1000 cubic meters of 30 MPa rated concrete against 1000 cubic meters of 50 MPa rated concrete.*

### 5.3.2 Comparison between the technologies

**Table 14** shows the amount of $CO_2$ equivalents in kg for all the sites using the **GWP20 impact category**. **Table 15** shows the relative impacts for the **GWP20** between the sedimentation basins and the DSL filter systems, comparing the one that emits less to a 100% baseline of the larger emitter.

***Table 14.*** *Table showing kg of CO2 eq. emissions for all the sites for the DSL and sedimentation basins systems respectively according to the GWP20 impact category.*

| | Drum Screen Liquid [kg $CO_2$ eq.] | Sedimentation Basin [kg $CO_2$ eq.] |
|---|---|---|
| **Site A** | 1361760 | 2980740 |
| **Site B** | 171491 | 180260 |
| **Site C** | 16214 | 39206 |

***Table 15.*** *The relative emissions between the DSL and the sedimentation basins system for each site.*

| | Drum Screen Liquid | Sedimentation Basin |
|---|---|---|
| **Site A** | 46% | 100% |
| **Site B** | 95% | 100% |
| **Site C** | 41% | 100% |

### 5.3.2.1 SITE A:

Using the materials listed in **Table 5, Table 6, Table 12, Table 13** to model the system, **Figure 5** shows the relative emissions between sedimentation basin system and the DSL filter system for site A. Note that the relative emissions for all four impact categories are 46% compared to the concrete emission within the same category, so within +/- one percent, covering for any rounding to integer percentages, of each other comparing between the categories.

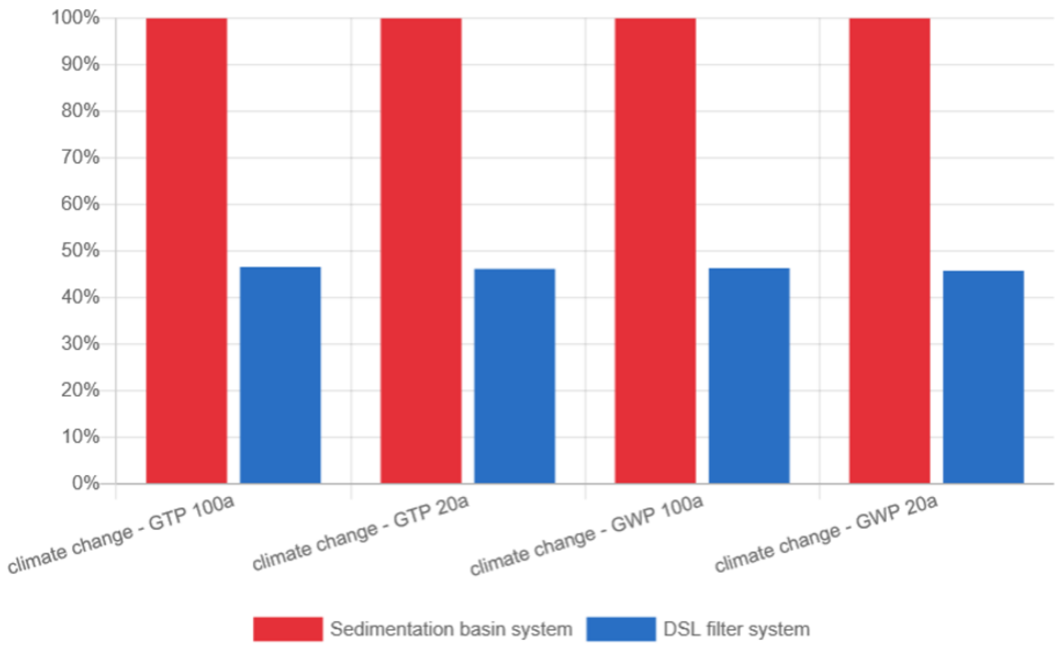


***Figure 5.*** *Relative emissions between the sedimentation basins and the DSL filter system for site A. All four impact categories of the IPCC 2013 are shown.*

Given that the relative emissions for the four impact categories are so similar, and the relative emissions between the two systems are the focus of this study and not absolute numbers, only one result with absolute numbers will be presented for all the sites. The one presented is the Global Warming Potential 20 years, which is the impact category resulting in the most $CO_2$ equivalent emissions. **Figure 6** shows the emissions of the sedimentation basin for the GWP20 impact category.

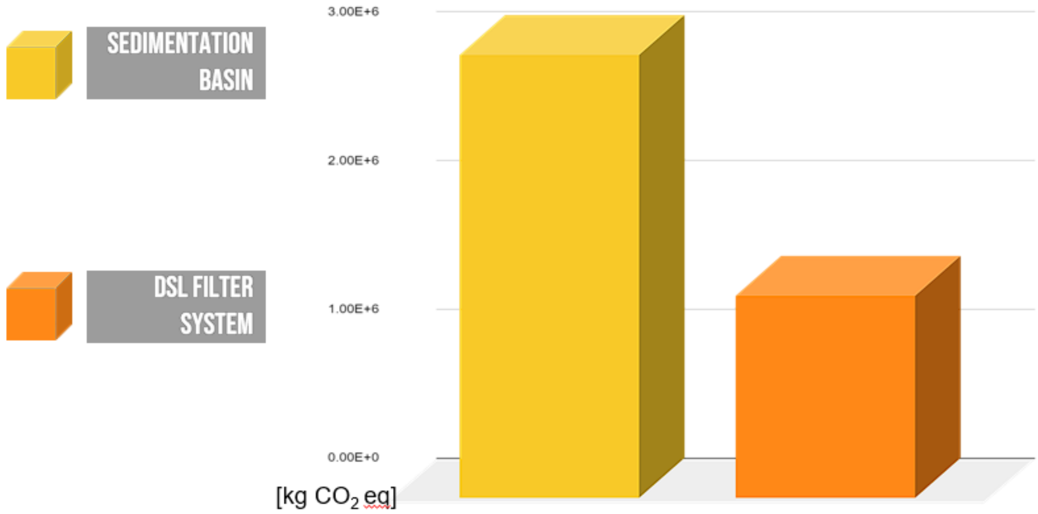


***Figure 6.*** *kg of CO2 eq. for the Site A sedimentation basins and DSL filter system.*

**Figure 7** shows how the emissions for the sedimentation basins is divided between the construction of the basins and the electricity usage for 20 years given Swedish conditions, whilst **Figure 8** show what contributes for the DSLs.

| Contributi... | Process | Amount | Unit |
|---|---|---|---|
| 100.00% | P Use of Site A sed basin | 2.98074E6 | kg CO2-Eq |
| 99.80% | P Site A sed basin | 2.97469E6 | kg CO2-Eq |
| 00.20% | P market for electricity, medium... | 6042.57268 | kg CO2-Eq |

***Figure 7.*** *Contribution tree for usage of site A sedimentation basins.*

| Contributi... | Process | Amount | Unit |
|---|---|---|---|
| 100.00% | P Use of Site A DSL filter | 1.36176E6 | kg CO2-Eq |
| 75.66% | P Site A DSL filter | 1.03027E6 | kg CO2-Eq |
| 23.58% | P market for electricity, medium... | 3.21040E5 | kg CO2-Eq |
| 00.77% | P market for steel, chromium ste... | 1.04424E4 | kg CO2-Eq |
| 00.00% | P market for tap water \| tap wat... | 11.82657 | kg CO2-Eq |

***Figure 8.*** *Contribution tree for usage of site A DSL filter system.*

#### 5.3.2.2 SITE B:

**Figure 9** shows the relative emissions from site B. Once again, the relative emissions between the four impact categories are so similar that only the GWP20 absolute emissions is interesting to look at.

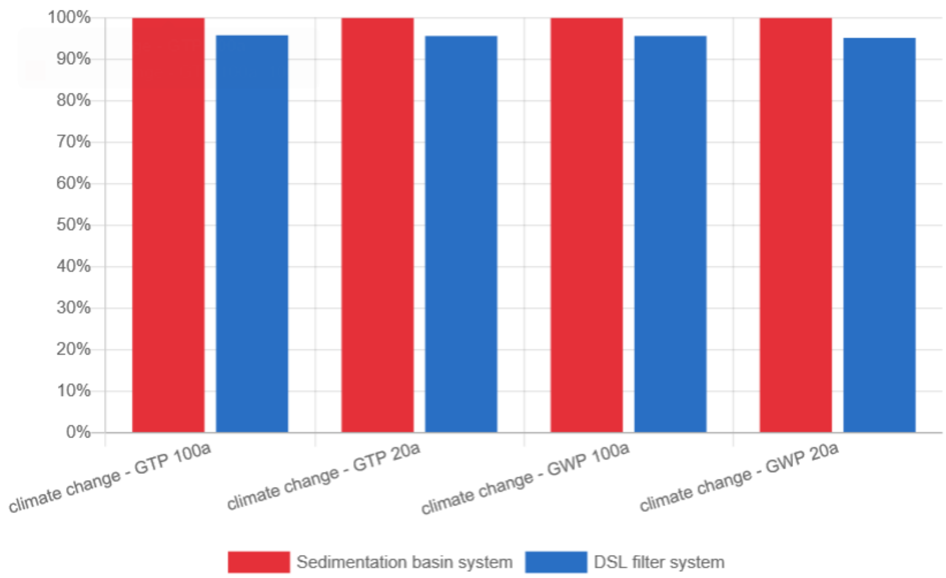


***Figure 9.*** *Relative emissions between the sedimentation basins and the DSL filter system for site B. All four impact categories of the IPCC 2013 are shown.*

**Figure 10** shows that at Site B, the emissions for the two technologies are much more similar.

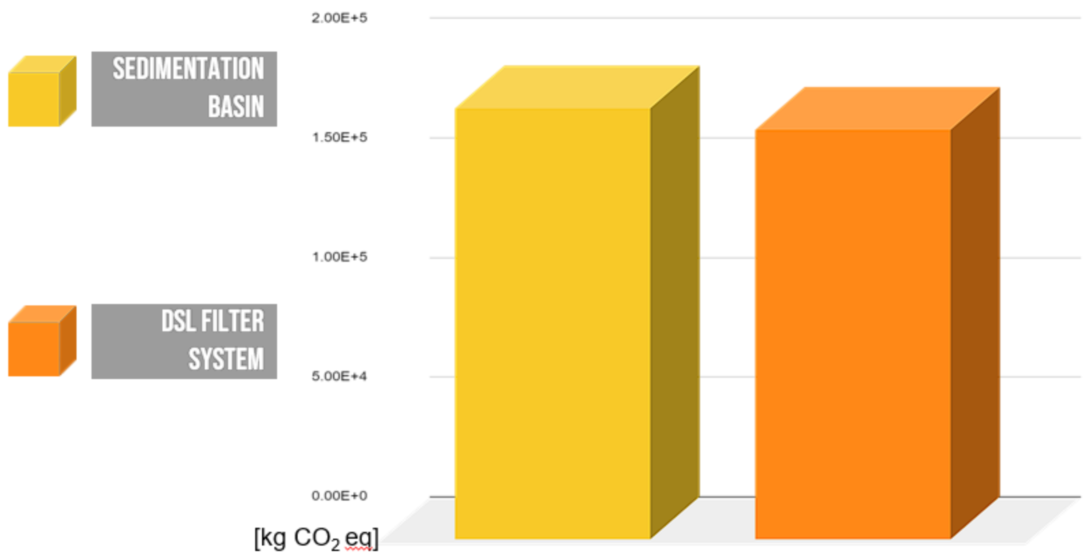


***Figure 10.*** *kg of CO2 eq. for the Site B sedimentation basins and DSL filter system.*

**Figure 11** shows what contributes to what part of the emissions of the sedimentation basins, and **Figure 12** shows the contribution for the DSL filter system for site B.

| Contributi... | Process | Amount | Unit |
|---|---|---|---|
| 100.00% | P Use of Site B sed basin | 1.80260E5 | kg CO2-Eq |
| 91.61% | P Site B sed basin | 1.65131E5 | kg CO2-Eq |
| 08.39% | P market for electricity, medium... | 1.51295E4 | kg CO2-Eq |

***Figure 11.*** *Contribution tree for usage of site B sedimentation basins.*

| Contributi... | Process | Amount | Unit |
|---|---|---|---|
| 100.00% | P Use of Site B DSL filter | 1.71491E5 | kg CO2-Eq |
| 79.38% | P Site B DSL filter | 1.36127E5 | kg CO2-Eq |
| 20.01% | P market for electricity, medium... | 3.43190E4 | kg CO2-Eq |
| 00.61% | P market for steel, chromium ste... | 1044.23584 | kg CO2-Eq |
| 00.00% | P market for tap water \| tap wat... | 0.98555 | kg CO2-Eq |

***Figure 12.*** *Contribution tree for usage of site B DSL filter system.*

### 5.3.2.3 SITE C:

**Figure 13** show the relative emissions between the four impact categories for site C. Here, too, the relative emissions are so similar that only the GWP20 is interesting to look at for the absolute numbers.

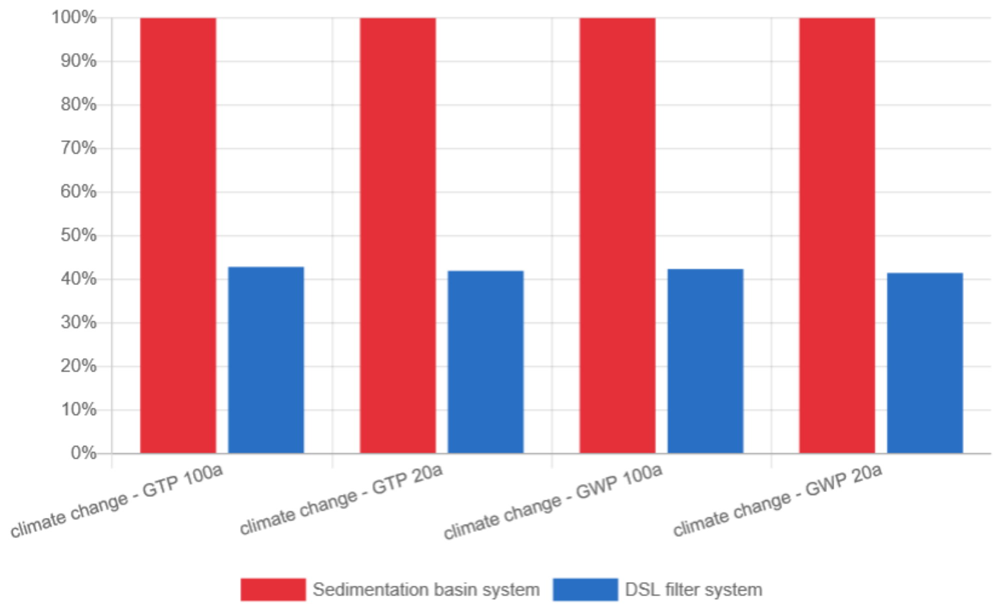


***Figure 13.*** *Relative emissions between the sedimentation basins and the DSL filter system for site C. All four impact categories of the IPCC 2013 are shown.*

**Figure 14** shows that for site C, the DSL filter system has a significantly lower total emission of greenhouse gasses during its technical lifetime.

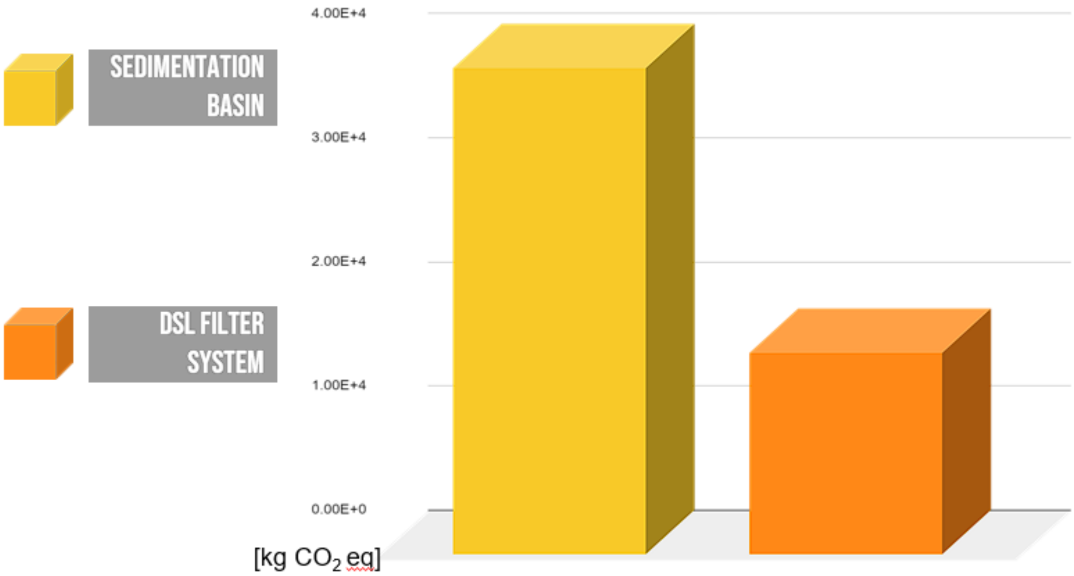


***Figure 14.*** *kg of CO2 eq. for the Site C sedimentation basins and DSL filter system.*

Like the other sites, **Figure 15** shows the contribution tree of the sedimentation basin, and **Figure 16** shows the contribution of the DSL filter system.

| Contributi... | Process | Amount | Unit |
|---|---|---|---|
| 100.00% | P Use of Site C sed basin | 3.92057E4 | kg CO2-Eq |
| 95.98% | P Site C sed basin | 3.76304E4 | kg CO2-Eq |
| 04.02% | P market for electricity, medium... | 1575.27122 | kg CO2-Eq |

***Figure 15.*** *Contribution tree for usage of site C sedimentation basin.*

| Contributi... | Process | Amount | Unit |
|---|---|---|---|
| 100.00% | P Use of Site C DSL filter | 1.62144E4 | kg CO2-Eq |
| 52.50% | P Site C DSL filter | 8512.79224 | kg CO2-Eq |
| 44.28% | P market for electricity, medium... | 7178.95687 | kg CO2-Eq |
| 03.22% | P market for steel, chromium ste... | 522.11792 | kg CO2-Eq |
| 00.00% | P market for tap water \| tap wat... | 0.49277 | kg CO2-Eq |

***Figure 16.*** *Contribution tree for usage of site C DSL filter system.*

# 6 Discussion

As it can be seen from results in **Table 3** and **Table 7** that the surface area required for all sites have been calculated for both methods. In Site A the surface area required for sedimentation basins is approximately 6500 $m^2$ which in case DSL filters it is almost 7 times lower. The design plans for installing the DSL filters are considered to be as a rectangular concrete channel with 20 filters that corresponds to 10 filters in each side. In this regard, it can be designed in a way to decrease the surface area even more. Since the in some projects DSL filters are going to be used in treating plants that already had some sedimentation basins, it is possible to use the tanks as areas for installing the DSLs and build them on top of each other. Consequently, the surface area required to build the DSLs will decrease more significantly. For Site B the comparison still shows that sedimentation basins need more surface area, but it is notable to say that in this site the larger size of filters and concrete channels have been chosen to push the DSL filters into the limits but even by designing in that way the required surface area is half of the sedimentation basins.

In the smallest site, Site C, in case sedimentation basins, one tank is needed to handle the wastewater flow and the required area is almost 340 $m^2$. On the other hand, only one DSL filter can handle the whole flow and it is in a way that the capacity of this machine is so much bigger than the actual wastewater flow and is determined to be built in steel case. Therefore, surface area requirement for this machine is 6 $m^2$ which is considerably smaller than that of sedimentation basins.

The energy usage in the sedimentation basins is mainly due to the chain scrapers that are up and running 24/7 and also for the pumps. In case of DSL filters the electricity, consumption is in more optimized level since the pressure pumps and drives will run based on a calculated running time and start washing the mesh when the water level at upstream exceeds a designed height.

The energy consumption for all three sites has been compared in the **Figure 17**. As it can be seen in the graph, for all sites sedimentation basins are consuming considerably less energy than the DSL filters.

In order to handle the amount of wastewater flow in Site A, it has been designed to have 20 machines which justify the huge spike in term of power usage. In this regard, it is possible to decrease the power consumption in DSL filters by using one pump for multiple machines, but it should be considered that to reach a fair comparison, the sedimentation basins must be designed in a way that their SS removal rate is equal to that of DSL filters.

Based on the design method mentioned in this report for sedimentation basins, to get higher SS removal rate in the sedimentation basins the retention time of particles in the tank must be increased. On the other hand, retention time is dependent on the basins volume and to get higher retention time, it is needed to increase the volume of tanks which will lower the overflow rate. As a result, the surface requirement for the sedimentation basins will increase and based on the design results in order to achieve around 70% of SS removal in the biggest site, double surface requirement is needed.

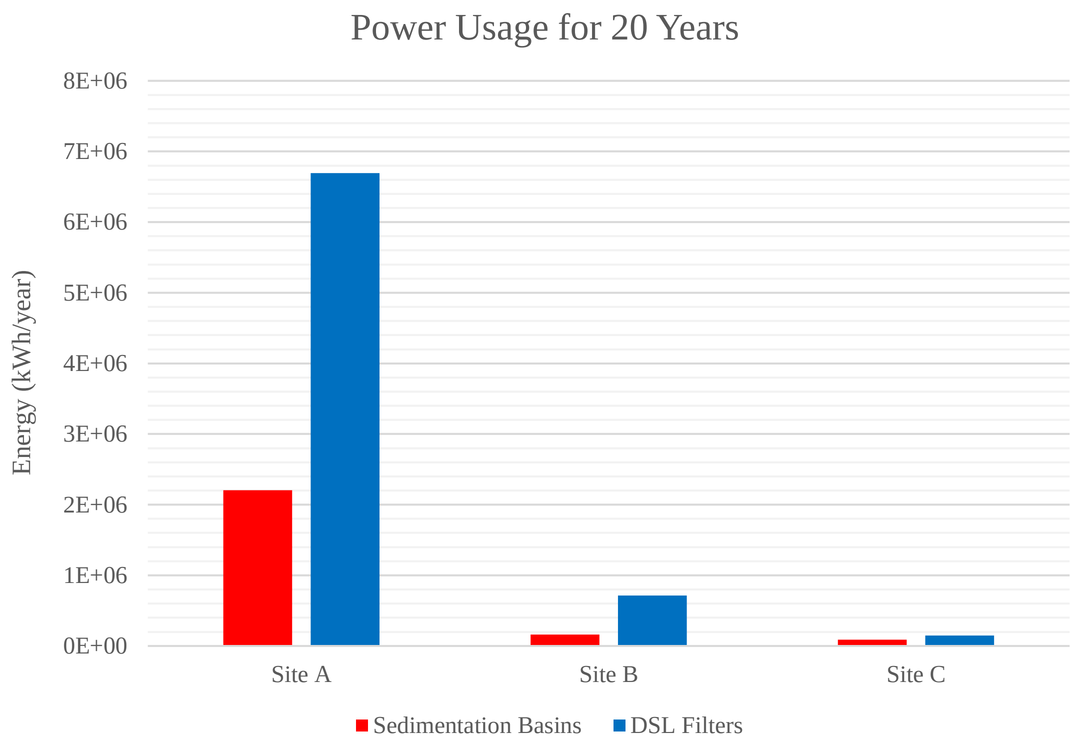


***Figure 17.*** *Energy Usage Comparison*

Two types of materials have been used in both methods. In sedimentation basins the main material is concrete and in case of DSL filters the machines, and the parts are mainly made out of steel. The amount of concrete in two methods have been presented in **Table 16**. The amount of concrete used in DSLs are lower compared to the sedimentation basins, and for Site C since it has been decided to use only one steel case for installing the DSL filter, so there is no concrete material and concrete work for this site. The concrete work has direct effect in the $CO_2$ emission, and the LCA results in this study which will be discussed in related part.

***Table 16.*** *Amount of Concrete Comparison*

| | Concrete ($m^3$) | |
|---|---|---|
| | **Sedimentation Basins** | **DSL Filters** |
| **Site A** | 4064.3 | 337 |
| **Site B** | 223.4 | 80 |
| **Site C** | 50 | - |

Additionally, the amount of steel is used in the two methods are gathered in **Table 17**. The amount of steel used in DSL filters has considerable difference compared to the sedimentation basins. This is since DSL machines are made of steels in almost every part but in case sedimentation tanks only the chain scrapers, drive unite, and the reinforced steel in the concrete are considered to be the steel part of the whole system.

*Table 17. Amount of steel comparison*

| | Steel (kg) | |
|---|---|---|
| | **Sedimentation Basins** | **DSL Filters** |
| **Site A** | 7571 | 135000 |
| **Site B** | 365 | 19500 |
| **Site C** | 81 | 1500 |

Installing DSL filters in the steel case tanks can provide better and easier maintenance regarding the change of malfunctioning parts and easy access to replace the broken parts with new ones. On the other hand, the use of concrete channels is mainly built in sites where a lot of DSL machines have been designed to install. It will involve concrete and concrete work into the project and requires bigger surface area to be built, but it is better in term of wastewater flow division into the filters. In Site B even though the number of filters were two, it has been decided to go with the concrete channels to push the DSL filters into limitation and compare the results in the maximum use with the sedimentation method.

It is important to note that for the LCA, the drives of the machines, which is the drive for the drum filter in the DSL system and the drive for the chain scrapers for the sedimentation basins respectively, were excluded from the emissions caused by the systems. Using a general-purpose life cycle inventory like ecoinvent can make it hard to assess correct numbers for units such as a drive, and since both systems need drives, they were excluded, since the comparisons between the systems was the aim of the study rather than absolute numbers.

The choice to use the ecoinvent database only and only working its “market for…” providers for every material included makes the study more easily reproducible but can lower the resolution of the total emissions if the absolute numbers were of interest. For this study and its purpose though, consequently using the “market for…” providers make it an even more fair comparison between how these systems compare in a general use case, that is more geographically broad then calculating specific transport distances for specific materials would be.

Looking at only the IPCC 2013 impact categories is deemed to be good enough for the purpose of this study, but in another study, it could be interesting to look at more impact categories such as eutrophication, acidification, and harmful/toxic emissions. Whereas the concrete may be worse in a climate change perspective, there could be other considerations missed between the two options that could be important to investigate.

## 6.1 Further Investigation

Primary sedimentations can remove around 50% of suspended solids from the influent of wastewater treatment plants and in case of using DSL filters as an alternative the removing range will 60% to 70%. In that case in order to have a fair comparison it is needed to increase the dimensions of the sedimentation basins to reach the 70% range of suspended solid removals in more detail (*Removal of Suspended Solids,* n.d.). Primary sedimentations can remove around 50% of suspended solids from the influent of wastewater and in case of using DSL filters as an alternative, the removal range will 60% to 70%. In that case in order to have a fair comparison, it is needed to increase the dimensions of the sedimentation basins to reach the 70% range of suspended solid removals in more detail (*Removal of Suspended Solids,* n.d.). Consequently, the amount of electricity consumption in the next steps like aeration can be varied and is worth further investigations and studies to find the comparisons.

The size of DSL filter can affect the different parts of this study. The capacity of larger filters on removing the suspended solids can be increased. On the other hand, the carbon emission, and the electricity consumption of in other sizes of filters can be varied which can be a subject for further studies.

It should be mentioned that the characteristics of the sludge in these two methods can be different. Due to retention time in sedimentation basins, the sludge remains in the tanks for a while and exposed to the air for a while and in the DSL filters the sludge is washed from the mesh and transferred to be processed and dewatered in other steps of treatment which can be investigated in future studies.

Another thing that is interesting to look at, and that will have an important role to play when municipalities decide upon what technologies to go for, is the costs related to the two different technologies. When investigating the costs, it is important to also apply the life cycle perspective: the initial investment is only part of the whole story. Differences in electricity consumption can lead to very different running costs. Also, the suspended solids removal rate and how the two different technologies affect the wastewater chemistry, can lead to very varying running costs in further steps of treatment.

## 6.2 Limitations

The study was limited to the primary treatment part of wastewater treatment plant and the comparisons had been made in the primary stage of treatment. Also, another limitation that should be mentioned in this report is the cost comparison because in order to have a very accurate and useful cost comparison, prices and cost should be gathered in a detailed way and need to be in touched with the providers and producers of the technology. This will also pose price difference in between companies because not all companies offer the same price for their product. Furthermore, possible variations in types of soil which could lead to different amounts of foundational work having to be carried out, was not investigated in this study.

For the life cycle assessment, the geographic locations of the sites, which would affect the transportation length and regional electricity mix which both affect the emissions, were chosen to not be more precise than using the average Swedish electricity mix. The study should be more applicable to the whole of Sweden, and also use the typical emissions linked to the production of the raw materials regardless from where they are sourced.

# 7 Conclusion

This study has conducted a comprehensive comparison between conventional sedimentation and DSL filters, focusing on surface area requirements, energy usage, and climate footprints. The findings suggest that the choice between the two methods should be based on the specific project requirements and challenges.

DSL filters demonstrated superior performance in terms of energy efficiency, although it is important to note that a more rigorous comparison should be conducted, accounting for site-specific factors and considering a more equal removal rate when designing the basins for Site A. Additionally, DSL filters require significantly less surface area compared to sedimentation basins, even when considering the installation of concrete channels for the filters. Also, DSL filters have an option to be installed in steel case or if they are going to be used as an alternative for a treatment that already had some sedimentation tanks, it is possible to consider the fact that they can be built on top of each other and reduce the surface area requirements even more. This is particularly advantageous in projects where the treatment plant needs to be built in mountains, as excavating and transporting materials for sedimentation basins can be highly challenging.

Furthermore, the comparison of material usage between the two methods revealed that sedimentation basins, predominantly composed of concrete, require a substantially larger quantity of materials compared to DSL filters. This disparity has implications for $CO_2$ emissions and overall environmental impact, with DSL filters exhibiting a lower concrete usage and consequently fewer negative environmental effects.

Considering the Life Cycle Assessment results, DSL filters offer a more environmentally friendly alternative, considering their lower concrete requirement and reduced negative environmental impacts.

Based on the findings of this study, DSL filters present a promising option for wastewater treatment, particularly in scenarios where energy efficiency, surface area utilization, and environmental sustainability are of paramount importance. Further research and site-specific investigations are recommended to refine the comparisons and fully assess the suitability of DSL filters in different contexts.

# 8 References


- Andersen, R., & Negendahl, K. (2023). Lifespan prediction of existing building typologies. *Journal of Building Engineering*, *65*. https://doi.org/10.1016/j.jobe.2022.105696
- Arafah, A. (2000). Reliability-based Criterion for Maximum Reinforcement Ratio of Reinforced Concrete Beam Sections. In *J. King Saud Univ* (Vol. 12, Issue 2).
- Chen, Y., Zhang, H., Yin, Y., Zeng, F., & Cui, Z. (2022). Smart energy savings for aeration control in wastewater treatment. *Energy Reports*, *8*, 1711–1721. https://doi.org/10.1016/j.egyr.2022.02.038
- Civil Today. (n.d.). *CivilToday*. Retrieved June 2, 2023, from https://civiltoday.com/civil-engineering-materials/cement/108-what-is-cement-clinker-clinker-definition-composition-types-uses
- Costa, F. N., & Ribeiro, D. V. (2020). Reduction in CO2 emissions during production of cement, with partial replacement of traditional raw materials by civil construction waste (CCW). *Journal of Cleaner Production*, *276*. https://doi.org/10.1016/j.jclepro.2020.123302
- Finnchain. (n.d.). *Scraper Systems for Rectangular tanks*.
- HUBER Company. (n.d.). *HUBER*. Retrieved June 2, 2023, from https://www.huber.de/solutions/energy-efficiency/wastewater-collection-and-treatment/mechanical-treatment.html
- *HUBER Drum Screen LIQUID*. (n.d.). www.huber.de

- Ideker, J. H., Scrivener, K. L., Fryda, H., & Touzo, B. (2019). Calcium aluminate cements. In *Lea's Chemistry of Cement and Concrete* (pp. 537–584). Elsevier. https://doi.org/10.1016/B978-0-08-100773-0.00012-5
- International Energy Agency. (2022, February). *Methane and climate change*. https://www.iea.org/reports/global-methane-tracker-2022/methane-and-climate-change
- IPCC. (2014). Anthropogenic and Natural Radiative Forcing. In *Climate Change 2013 – The Physical Science Basis* (pp. 659–740). Cambridge University Press. https://doi.org/10.1017/CBO9781107415324.018
- Klein, N., Gómez, E. D., Duffó, G. S., & Farina, S. B. (2022). Effect of sulphate on the corrosion of reinforcing steel in concrete. *Construction and Building Materials*, *354*. https://doi.org/10.1016/j.conbuildmat.2022.129214
- Kungsbacka Kommun. (n.d.). *Miljörapport 2020 Hammargårds reningsverk Kungsbacka kommun Förvaltningen för Teknik Kungsbacka kommun Kungsbacka 2021*.
- Metcalf & Eddy. (2014). *Wastewater engineering : treatment and resource recovery* (Fifth edition).
- Miljödepartementet. (2022). *Ett reviderat avloppsdirektiv*. https://data.riksdagen.se/fil/F52E3161-E509-43B7-A2BC-BAAD73561BFD
- Nie, S., Zhou, J., Yang, F., Lan, M., Li, J., Zhang, Z., Chen, Z., Xu, M., Li, H., & Sanjayan, J. G. (2022). Analysis of theoretical carbon dioxide emissions from cement production: Methodology and application. *Journal of Cleaner Production*, *334*. https://doi.org/10.1016/j.jclepro.2021.130270

- Pistocchi, A., Dorati, C., Grizzetti, B., & Udias, A. (2019). *Water quality in Europe: effects of the Urban Wastewater Treatment Directive A retrospective and scenario analysis of Dir. 91/271/EEC*. https://doi.org/10.2760/303163
- *PROBIG*. (n.d.). www.probig.com
- *Removal of Suspended Solids*. (n.d.).
- Shao, Y., Lu, X., Li, Q., Dong, Y., Zhang, L., Jiang, C., Du, P., & Cheng, X. (2022). Study on the preparation and sulfate resistance of Portland cement clinker with the high Fe/Al ratio of ferrite phase. *Cement and Concrete Composites*, *134*. https://doi.org/10.1016/j.cemconcomp.2022.104699
- Sonander, & Tord. (n.d.). *Miljörapport för Hästveda avloppsreningsverk*.
- Swedish Standards Institute. (2006a). *SS-EN ISO 14040:2006*. www.sis.se
- Swedish Standards Institute. (2006b). *SS-EN ISO 14044:2006*. www.sis.se
- Videbris, K.-E. (2021). *Miljörapport Ryaverket 2020*.