Efficient Coagulant Dosing for Sustainable Water Treatment.

An Empirical Study on Reducing Chemical Consumption in Swedish Drinking Water Treatment Plants.

Master's thesis in Materials Chemistry

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Abstract

This abstract summarizes a research project focused on reducing chemical consumption in Swedish drinking water treatment plants (WTPs) by optimizing coagulant dosage and pH conditions. The project addresses societal, ethical, and ecological concerns associated with coagulant usage. The aim is to identify opportunities for reducing coagulant dose through real-time monitoring of current water conditions, and if opportunities exist, to further identify what barriers are currently preventing them from being realised.

The study compares the current dosage used in WTPs with the optimum dosage determined through experiments. The focus is on achieving efficient removal of Dissolved Organic Carbon (DOC) and Absorbance (ABS) while minimizing chemical consumption. The results show that in 9 out of 11 WTPs studied, the optimum dosage was lower than the current dosage, indicating potential for reducing chemical consumption and achieving cost savings.

The study emphasizes that optimizing dosages does not compromise treatment efficiency; instead, it highlights the potential for sustainable and resource-efficient water treatment practices. However, the specific characteristics of each WTP need to be considered, and further research is necessary to ensure applicability on a broader scale.

The research suggests that changing the coagulant itself could further improve the coagulation process. By evaluating and adopting more efficient coagulants, WTPs can potentially achieve higher removal efficiencies and reduce chemical dosage. However, careful evaluation, pilot-scale testing, and cost-benefit analysis are required for selecting suitable coagulants.

Overall, the research contributes to the goal of providing cleaner and safer drinking water by reducing chemical consumption, improving treatment efficiency, and promoting sustainability in water treatment processes. Further research opportunities exist to enhance monitoring systems and continue improving the effectiveness of water treatment practices.

Keywords: Absorbance, Coagulation, DOC, Dosage, Drinking water pH, TOC, WTP

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Jacob Andréasson, Gothenburg, June 2023

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

ABS	Absorbance
CDOM	Colored Dissolved Organic Matter
DBPs	Disinfection By-Products
DOC	Dissolved Organic Carbon
DOM	Dissolved Organic Matter
FDOM	Fluorescent Dissolved Organic Matter
NOM	Natural Organic Matter
OM	Organic Matter
PAC	Polyaluminum Chloride
SUVA	Specific Ultraviolet Absorbance
TOC	Total Organic Carbon
UV-VIS	Ultraviolet-Visible
UVA254	Ultraviolet Absorbance at 254 nanometer
WTP	Water Treatment Plant

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Introduction

Drinking water treatment is a crucial process in ensuring the safety and quality of the water we consume. The World Health Organization (WHO) recognizes access to safe drinking water as a basic human need and a fundamental human right (WHO, 2017). However, drinking water can become contaminated with a variety of pathogens, chemicals, and other impurities that can cause serious health problems. To prevent these contaminants from reaching our taps, water treatment is necessary to remove or kill them.

Water treatment is a complex process that involves multiple steps to ensure the safety and quality of the water we consume. One of the key steps in the treatment of drinking water is the addition of coagulants, which help to remove suspended particles and contaminants, also colloids and some particles that would be classed as dissolved based on size. Coagulation is an essential process in the treatment of water and its optimization can have a significant impact on the efficiency and effectiveness of the treatment process. The dosing of coagulants is a critical aspect of this process also due to that an incorrect dose can lead to inefficiencies in the treatment process and even result in harm to the environment. In Sweden, some advanced drinking water treatment plants use control systems that automatically adjust the chemical dose based on the quantity of quantity of CDOM (chromophoric or coloured DOM), as measured by the absorbance of light with 254 nm wavelength. However, the quality of the CDOM also plays a crucial role in determining the effectiveness of coagulation.

In this project, we aim to investigate the current dosing practices of coagulants at Swedish drinking water treatment plants. This empirical study will examine the relationship between the quantity and quality of NOM in the incoming water and the chemical dose used in coagulation. Our goal is to determine if there are opportunities to reduce chemical consumption in the treatment process and what impact this could have on the environment and cost savings.

To achieve this, we will gather data from multiple drinking water treatment plants in Sweden and analyze the chemical dosing practices currently in use. We will also collect samples of the incoming water and measure its NOM quantity and quality.

The results of this study will provide valuable insights into the coagulant dosing practices of Swedish drinking water treatment plants and the potential for reducing chemical consumption. If the findings indicate that there are opportunities for reducing chemical consumption, it could lead to cost savings, a lower carbon footprint, and a more sustainable water treatment process.

It is important to note that the quality of NOM can vary greatly with the changing seasons and heavy rainfall. Therefore, incorporating NOM quality as a predictor for chemical dose in the treatment process is crucial for ensuring the efficiency and effectiveness of coagulation.

In conclusion, access to safe drinking water is a fundamental human right and the treatment of drinking water is an essential step in ensuring that it is free from harmful contaminants. This project aims to contribute to the improvement of the drinking water treatment process. The findings of this study could have a significant impact on the efficiency, effectiveness, and sustainability of drinking water treatment in Sweden.

2

Goal and project boundaries

The dosing of coagulants at Swedish drinking water treatment plants is a crucial step in ensuring that the water supplied to the public is safe to drink. However, the use of these chemicals can raise several societal, ethical, and ecological concerns.

From a societal perspective, there is concern about the potential health effects of the chemicals used in the coagulation process. These chemicals, such as aluminum sulfate and ferric chloride, can have negative impacts on human health if consumed in large quantities over prolonged periods. Therefore, it is important to ensure that the levels of these chemicals in the treated water are within safe limits.

The economical aspects would likely involve evaluating the cost-effectiveness of different coagulant types and dosing strategies. This could include analyzing factors such as the cost of the chemicals, the capital cost for control systems, the energy required to operate the treatment equipment, and the overall cost of producing clean drinking water. Additionally, an empirical study on opportunities for reducing chemical consumption could involve collecting data on the current usage of chemicals at different plants, identifying areas where consumption could be reduced, and testing different methods for achieving those reductions.

From an ethical standpoint, there are concerns about the environmental impact of producing and disposing of the chemicals used in water treatment. The production of coagulants can be energy-intensive and can lead to the release of greenhouse gases and other pollutants. Additionally, disposing of the chemicals can also be challenging, and proper disposal is needed to avoid contamination of water bodies and soil.

Looking on it from an ecological perspective, the use of coagulants can have a negative impact on aquatic life. Coagulants can disrupt the delicate ecosystem of rivers and lakes, by altering the pH levels. Therefore, it is crucial to minimize the environmental impact of coagulants as much as possible.

An empirical study on opportunities for reducing chemical consumption in Swedish water treatment plants could help to identify ways to mitigate these concerns while still producing safe and high-quality drinking water.

This could include evaluating alternative coagulant materials, optimizing dosing strategies, and incorporating other treatment technologies. It could also include studying the impact of different water sources on the chemical consumption and finding ways to reduce it. Such research can lead to the development of more sustainable and eco-friendly water treatment practices.

In this project, we propose to investigate how coagulant dose is determined at WTPs in the wider Gothenburg region and perform experiments to validate their dosing protocols via jar tests. The aim is to identify opportunities for reducing coagulant dose through real-time monitoring of current water conditions, and if opportunities exist, to further identify what barriers are currently preventing them from being realised.

3

Background and Theory

3.1 The Process of Water treatment

Water in rivers or lakes is rarely clean enough for human consumption if it is not first treated or purified. Groundwater, too, often needs some level of treatment to render it potable. The primary objective of water treatment is to protect the health of the community.

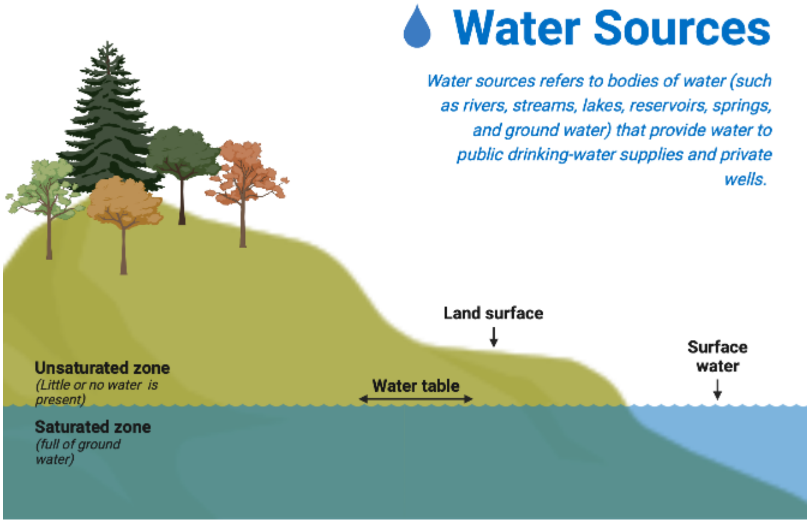

Figure 3.1: Illustration of ground water and surface water (own picture generated by biorender.com).

Groundwater is situated beneath the earth's surface in gaps between rocks and soil. This water source undergoes natural filtration processes that can eliminate certain microorganisms and chemicals based on the depth of the water and the geological characteristics of the surrounding area. When groundwater is accessed via a well, it may be subject to some form of treatment prior to distribution to households for consumption (Stephenson, 1998).

Surface water refers to water that accumulates on the ground or in water bodies such as streams, rivers, lakes, reservoirs, and oceans. It undergoes a constant cycle of evaporation from water bodies, percolation into groundwater supplies, and replenishment through precipitation in the form of rain or snow. When groundwater surfaces and becomes visible, it is known as a spring (Stephenson, 1998).

Public drinking water systems that rely on surface water sources implement treatment processes before distributing water to consumers for consumption. This ensures that the water meets safety standards and is free from harmful contaminants.

Drinking water must, of course, be free of harmful microorganisms and chemicals, but public supplies should also be aesthetically desirable so that consumers will not be tempted to use water from another, more attractive but unprotected source. The water should be crystal clear, with almost no turbidity, and it should be free of objectionable colour, odour, and taste. For domestic supplies, water should not be corrosive, nor should it deposit troublesome amounts of scale and stains on plumbing fixtures. Industrial requirements may be even more stringent; many industries provide special treatment on their own premises (Nathanson, 2020).

The type and extent of treatment required to obtain potable water depends on the quality of the source. The better the quality, the less treatment is needed. Surface water usually needs more extensive treatment than groundwater, because most streams, rivers, and lakes are polluted to some extent. Even in areas remote from human populations, surface water contains suspended silt, organic material, decaying vegetation, and microbes from animal wastes. Groundwater, on the other hand, is usually free of microbes and suspended solids because of natural filtration as the water moves through soil, though it often contains relatively high concentrations of dissolved minerals from its direct contact with soil and rock.

Water is treated in a variety of physical and chemical methods. Treatment of surface water begins with intake screens to prevent fish and debris from entering the plant and damaging pumps and other components. Conventional treatment of water primarily involves clarification and disinfection. Clarification removes most of the turbidity, making the water clear. Disinfection, usually the final step in the treatment of drinking water, destroys pathogenic microbes (LeChevallier et al., 2004). Groundwater does not often need clarification, but it should be disinfected as a precaution to protect public health. In addition to clarification, disinfection, filtration, advanced oxidation and ion-exchange, the processes of softening, aeration and carbon adsorption may be used for certain public water sources.

3.1.1 Coagulation

Coagulation is a chemical process used in water treatment to join small and light particles but also remove colloids and some particles that would class as dissolved based on size, into larger and heavier masses of solids called flocs or agglomerates. The goal of coagulation is to make particles, colloids and dissolved matter settle out more readily in the sedimentation step, which comes after coagulation (Nathanson, 2020).

Coagulation is typically done in two stages: rapid mixing and slow mixing. During rapid mixing, the coagulants are evenly dispersed throughout the water and a complete chemical reaction is ensured. This can be done by adding the chemicals directly before the pumps and relying on the pump impellers for mixing. Alternatively, a small flash-mix tank can be used to provide about one minute of detention time. Slow mixing is a period of gentle agitation that follows rapid mixing. It promotes particle collisions and enhances the growth of agglomerates.

Slow mixing is usually accomplished in a sedimentation tank or a flocculation basin. The length of time required for slow mixing varies depending on the type of coagulant used, the quality of the source water, and other factors. The coagulated water is then ready for sedimentation, where the floc settles to the bottom of the tank, and the clarified water is skimmed off the top.

3.1.2 Flocculation

Flocculation is the process of forming flocs in water treatment. The goal of flocculation is to bring together the flocs formed during coagulation into larger masses that settle more readily in the sedimentation step. Flocculation is accomplished through gentle agitation, which causes the particles in the flocs to collide and stick together, forming larger flocs.

Flocculation is usually accomplished in a flocculation basin, which is a large, shallow tank that provides enough space for the floc to grow and the water to be gently agitated. The length of time required for flocculation varies depending on the type of coagulant used, the quality of the source water, and other factors.

After flocculation, the water is ready for sedimentation. In sedimentation, the agglomerates settles to the bottom of the tank and the clarified water is skimmed off the top. The sediment at the bottom of the tank is called sludge and is pumped out for disposal

3.1.3 Sedimentation

Sedimentation is the process of removing suspended particles from water by relying on gravity. Under still conditions, particles that are denser than water settle to the bottom of a tank. The goal of sedimentation is to remove as much suspended material as possible to improve the clarity of the water (Nathanson, 2020).

Sedimentation tanks are typically rectangular or circular in shape and are about 3 meters deep. Several tanks are usually arranged for parallel (side-by-side) operation. The water is uniformly distributed as it enters the tank and the clarified water is skimmed off the top. The layer of concentrated solids that collects at the bottom of the tank is called sludge. The efficiency of a sedimentation tank for removing suspended solids depends more on its surface area than on its depth or volume. A shallow tank with a large surface area is more effective than a very deep tank with a smaller surface area. Modern sedimentation tanks are equipped with mechanical scrapers that continuously push the sludge toward a collection hopper, where it is pumped out.

3.2 Water Quality Parameters For Treatment Procedure

3.2.1 Naturally Organic Matter

Naturally occurring organic matter (NOM) is an important component in raw water. NOM is formed as a result of interactions between the biosphere and geosphere, as well as the water cycle. The composition of NOM depends on the biochemical cycles in the specific geographical area and is an important factor in water treatment. NOM is characterized in part by the total organic carbon (TOC) content and dissolved organic carbon (DOC) (Sillanpää et al., 2015).

Effective management of water treatment involves controlling and managing the source water, specifically naturally organic matter (NOM). However, the NOM in source water can vary in composition and character, making it difficult to characterise.

To maintain water supply and treatment systems, water treatment companies need better analytical techniques for characterizing NOM. One potential solution is fluorescence spectroscopy which is used to measure dissolved organic matter (DOM (Bridgeman et al., 2011), which offers rapid, sensitive and selective characterisation of DOM with no sample pre-treatment, small sample volume, and the ability for online monitoring. Fluorescence can also provide information on DOM reactivity and sources, but more work is needed on how to collect the data then how to interpret those data in water treatment plants.

3.2.1.1 Fluorescence Spectroscopy

After a sample has absorbed energy from some source, for example electromagnetic radiation in the form of visible light, electrons move from its ground energy level to an excited state.

The excited state lasts for a limited time, usually 1-10 nanoseconds, and the excess energy generated as electrons move down through vibrational energy levels S_1-V_2 och S_1-V_1 in Figure 3.2, is typically converted into thermal energy resulting in a relaxed singlet-excited state, S_1-V_0, from which fluorescence emission arises (Wiederschain, 2014).

3.2.2 Dissolved Organic Carbon

DOC is a subset of what is known as dissolved organic matter (DOM). DOM consists of a mixture of different organic substances with varying complexity. A commonly accepted definition states that DOM is made up of the organic material in a water solution that has passed through a filter with a pore size of 0.45 micrometers in diameter (Frimmel and Abbt-Braun, 2009). CDOM and FDOM are optical mea-

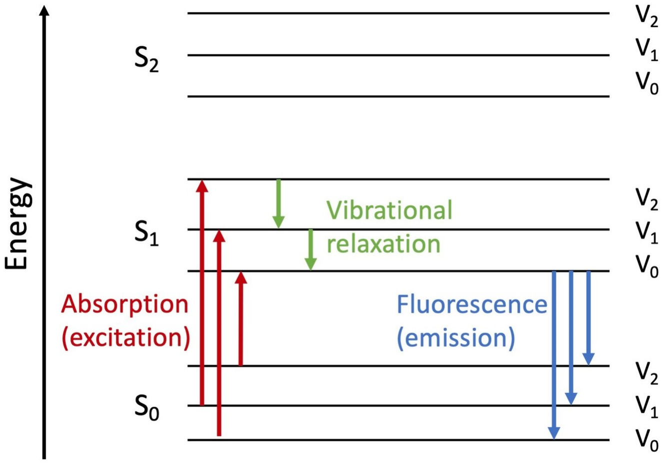

Figure 3.2: Jablonski diagram illustrating the processes involved in creating an excited electronic singlet state through optical absorption and subsequent fluorescence emission. Accessed from 'Jablonski Diagram for EEM' [Image], from AustiaP, 2020, https://commons.wikimedia.org/wiki/File:Jablonski_Diagram_for_EEM.jpg. CC BY-SA 4.0

surement values used to quantify and study the composition of DOM. CDOM is the portion of DOM that absorbs light and FDOM is the portion of CDOM that emits light in the form of fluorescence (Ulliman et al., 2020).

3.2.3 Ultraviolet Absorbance

An alternative way is to measure the aromatic content of dissolved organic carbon in the source water using absorbance spectroscopy by the use of ultraviolet light.

3.2.3.1 Absorbance Spectroscopy

Absorbance spectroscopy has emerged as a valuable tool in the field of water treatment, providing a rapid and reliable method for monitoring and analyzing the quality of water resources. The method is based on electromagnetic radiation passing through a sample. The number of photons passing through the sample decreases as energy is absorbed by the particles in the sample, i.e. the intensity of the radiation decreases. This dampening process is called absorption. If the concentration of a substance is high, the absorption will be greater and therefore weaken the light beam more than if the concentration had been low. The molecule or atom in the sample absorbs the energy of the photons, giving rise to valence electrons being moved to a higher energy level, also known as an excited state. This phenomenon only occurs when the energy of the photons matches the energy difference between the valence electron's ground state and a higher energy state. For each molecule or atom, radiation is absorbed at a specific wavelength. Therefore, a characteristic wavelength can be chosen to examine a specific substance (Harvey, 2016).

An example of absorption spectroscopy that can be used to determine the concentration of a substance is UV/VIS spectroscopy (Harvey, 2016).

3.2.4 Specific Ultraviolet Absorbance and Ultraviolet Absorbance at 254 nm

Specific Ultraviolet Absorbance (SUVA) and UVA254 (Ultraviolet Absorbance at 254 nm) are two parameters used to measure the quantity of dissolved organic matter (DOM) in water (Potter and Wimsatt, 2012).

SUVA is a measure of the specific ultraviolet absorbance of a sample at a particular wavelength (254 nm). It is calculated by dividing the absorbance at 254 nm by the dissolved organic carbon (DOC) concentration of the sample. SUVA is commonly used as a measure of the aromaticity and humification of the DOM in the sample.

UVA254 is simply the absorbance of a sample at 254 nm. It measures the amount of light absorbed by the DOM at this wavelength. It is a direct measure of the concentration of DOM in the sample, and is commonly used as a surrogate for DOC.

Both SUVA and UVA254 are used in water treatment processes to monitor the concentration of DOM in water. High SUVA and UVA254 values indicate a high level of DOM in the water, which can be related to the formation of disinfection byproducts (DBPs) and other water quality issues.

3.3 Treatment with Coagulants

The choice of coagulant depends on several factors, including the nature and concentration of the particles, the pH and alkalinity of the water, and the required level of treatment. Inorganic and organic coagulants are commonly used in drinking water treatment, and each type has its advantages and limitations.

Inorganic coagulants, such as aluminum sulfate (alum) and ferric chloride, have been traditionally used in drinking water treatment due to their high efficiency and low cost. These coagulants work by forming positively charged aluminum or iron hydroxide flocs that attract and trap negatively charged particles, leading to their removal by sedimentation or filtration. Inorganic coagulants are effective in treating a wide range of particles, including turbidity, color, and microorganisms, and can be used over a wide pH range. Moreover, they have a long history of safe use in water treatment, and their treatment performance is well understood (Tetteh and Rathilal, 2019).

The health risks associated with DBPs have led to stricter regulations on the use of inorganic coagulants in drinking water treatment, especially in areas with high levels of natural organic matter.

Organic coagulants, such as cationic polymers and natural coagulants, have emerged as a viable alternative to inorganic coagulants in drinking water treatment. Organic coagulants work by neutralizing the negative charges on suspended particles, leading to their aggregation and settling. They are particularly effective in treating organic and low turbidity waters and can reduce the formation of DBPs. Moreover, organic coagulants are generally biodegradable and have lower toxicity and environmental impact than inorganic coagulants (Tetteh and Rathilal, 2019).

However, organic coagulants have some limitations in drinking water treatment. They may require higher dosages than inorganic coagulants to achieve the same level of treatment, which can result in increased costs. Moreover, some organic coagulants, such as chitosan and starch, may introduce new organic matter into the water, which can lead to increased microbial growth and potential health risks.

In recent years, hybrid coagulation processes that combine inorganic and organic coagulants have gained attention in drinking water treatment. These processes aim to capitalize on the strengths of both types of coagulants while minimizing their drawbacks. For example, alum and polyaluminum chloride (PAC) can be used in combination with cationic polymers to enhance their coagulation performance while reducing the dosage and the formation of DBPs (Nishi et al., 2013).

Overall, the choice of coagulant in drinking water treatment depends on the specific water quality parameters, treatment goals, and regulatory requirements. Inorganic coagulants are still widely used in drinking water treatment due to their efficiency, availability, and low cost, but their potential health risks and environmental impact must be carefully considered. Organic coagulants and hybrid coagulation processes offer promising alternatives that can improve treatment performance while reducing the formation of DBPs and environmental impact.

3.3.1 Characteristics of Destabilization Mechanisms with Coagulants.

Coagulants work by neutralizing the surface charge of the particles, leading to their aggregation and settling. The destabilization mechanisms involved in coagulation can be classified into several categories based on the chemical and physical properties of the coagulants and the particles (Bratby, 2006).

Charge neutralization: Charge neutralization is the primary destabilization mechanism of inorganic coagulants such as aluminum sulfate (alum) and ferric chloride. These coagulants work by reacting with the negatively charged particles in water, neutralizing their surface charge, and forming a precipitate or floc. The neutralization of the charge reduces the repulsive forces between the particles, leading to their aggregation and settling. Charge neutralization is particularly effective in treating negatively charged particles such as colloids, clays, and organic matter (Nath et al., 2021).

Adsorption: Adsorption is the process of attaching coagulant molecules to the surface of the particles, leading to their destabilization. Organic coagulants such as polyacrylamide and chitosan work through adsorption, forming a polymer bridge between the particles and leading to their aggregation and settling. Adsorption is particularly effective in treating low-turbidity waters that contain small particles (Bratby, 2006).

Enmeshment or sweep coagulation: Enmeshment or sweep coagulation occurs when the coagulant molecules surround the particles, forming a larger floc that can settle more easily. Polymers such as polyacrylamide and natural coagulants such as chitosan are effective in enmeshment or sweep coagulation. This mechanism is particularly useful in treating high-molecular-weight organic matter (Lin et al., 2008).

Compression or charge patching: Compression or charge patching is a destabilization mechanism that involves the formation of a patch of opposite charge on the surface of the particles. The coagulant molecules attach to the patch, leading to the formation of a floc. This mechanism is particularly effective in treating organic matter with low charge density.

Bridging: Bridging is a destabilization mechanism that involves the formation of a polymer bridge between particles. The coagulant molecules attach to the surface of two or more particles, forming a bridge that connects them. The bridging mechanism is particularly effective in treating particles with low surface charge and high hydrophobicity.

In conclusion, the destabilization mechanisms involved in coagulation depend on the nature of the coagulant and the particles in water. The choice of coagulant and the mechanism of destabilization can impact the effectiveness and efficiency of coagulation. By understanding the various mechanisms of destabilization, water treatment professionals can select the most appropriate coagulant and treatment strategy to achieve optimal treatment performance. Some of the most commonly used coagulants are PAC (Polyaluminiumchloride), EKOFLOCK 90, PAX 100-XL, and Aluminium Sulfate.

PAC is a widely used coagulant due to its high efficiency in removing various contaminants, including organic matter, turbidity, and certain microorganisms. Its effectiveness in wide-ranging water conditions and its ability to form large and dense flocs make it a preferred choice in many treatment plants (Wei et al., 2015).

EKOFLOCK 90 is another popular coagulant known for its excellent performance in water treatment processes. It is specifically designed to improve floc formation and enhance sedimentation efficiency ("EKOFLOCK 90", n.d.).

PAX 100-XL, also known as polyaluminum chloride, is a coagulant commonly used in water and wastewater treatment. It exhibits good coagulation properties and is effective in removing suspended solids, color, and organic matter. PAX 100-XL is known for its stability and ability to form larger and denser flocs, leading to improved settling and filtration processes (“Inorganic coagulants for water treatment - Kemira”, n.d.).

Aluminium Sulfate, also called alum, is a traditional coagulant widely used in water treatment for many years. It is known for its affordability, ease of use, and reliability in removing turbidity, suspended solids, and certain dissolved organic compounds. Aluminium Sulfate has been extensively studied and applied in various treatment scenarios, making it a trusted option in the industry (Sillanpää and Matilainen, 2015).

These commonly used coagulants have been well-researched and proven effective in water treatment processes. However, it is important for each treatment plant to carefully evaluate their specific water quality parameters, process conditions, and regulatory requirements to determine the most suitable coagulant and optimal dosage for their application.

3.4 Jar Testing

Jar testing is a method of simulating a full-scale water treatment process (Satterfield and Scientist, n.d.). It is used to provide system operators with a reasonable idea of how a treatment chemical will behave and operate with a particular type of raw water. The process mimics full-scale operation, which allows system operators to determine which treatment chemical will work best with their system’s raw water.

This sort of testing entails adjusting the amount of treatment chemicals and the sequence in which they are added to samples of raw water held in jars or beakers. The samples are then stirred, allowing the formation, development, and settlement of floc to be observed, just as it would be in a full-scale treatment plant. Floc is formed when treatment chemicals react with material in the raw water and clump together.

The operator then performs a series of tests to compare the effects of different amounts of flocculation agents at different pH values, to determine the right size floc for a particular plant. The right size of floc depends on the system’s filter dimensions and other constraints.

To summarize the jar testing: For each water sample, a number of beakers (jars) are filled with equal amounts of the water sample. Each beaker is treated with a different dose of the chemical. Other parameters, such as chemical types, mixing rate, aeration level/time, and filtration type, may also be altered. By comparing the final water quality achieved in each beaker, the effect of the different treatment parameters can be determined. Jar testing is normally carried out on several beakers simultaneously, with the results from the first test guiding the choice of parameter amounts in later tests.

4

Methods

There will be three parts, first is basically a survey of the WTP to hear what they do and why, and whether they think there are opportunities to reduce coagulant dose. Then their raw water is tested in the lab with jar tests to determine optimal dose for comparison with theirs. Finally the optimal dose is controlled with the by using fluorescence and absorbance spectroscopy.

4.1 Project description

In this project, research will be made in a state-of-the-art laboratory at WET (Water Environmental Technology) located in ACE (Architecture and Civil Engineering) department. Fluorescence spectroscopy will be used to evaluate the quality of Natural Organic Matter (NOM) and conduct experiments to investigate the relationship between NOM quantity, quality, and the optimal chemical dosage. The laboratory is equipped with eight experimental setups (Jar test), allowing you to run more than 40 experiments at the same time. There will also be access to all necessary equipment for measuring water quality.

Fluorescence and other parameters that are important during the measurements of water has previously been mentioned under the section "Background" but to be able to get results on optimal dosage, jar tests will be performed.

4.2 Survey

Each water treatment plant that was visited and collected samples from also participated in answering a survey. The survey aims to collect information from drinking water treatment plants in Götaland to gain a better understanding of the coagulation process and identify opportunities for improvement. Additional information was gathered on various aspects of the water treatment process, including raw water characteristics, coagulant treatment, coagulant types, and dosages, as well as any alternative methods used to adjust the coagulant dosage, such as jar test or online monitoring. The goal is to identify best practices and to optimize the coagulant dosing to reduce chemical consumption while maintaining the efficiency of the treatment process.

Aspects as the raw water characteristics are important due to they can affect the choice of coagulant, coagulant aids and can have a large impact on the dosage. Understanding the WTPs structures and total treatment was also important due to differences in the treatment after flocculation and sedimentation also can lead to higher or lower dosages.

The survey also investigates the monitoring indicators used to determine dosage and if there were any online indicators used to evaluate the effectiveness of the coagulation step, whether it was turbidity, DOC or UV254, or if they used regular quality control sampling. Monitoring the effectiveness of the coagulation step is essential to ensure that the treated water meets the required quality standards. Any issues experienced during the coagulation process, such as poor performance or excess chemical consumption, were also investigated in the survey to understand how the WTPs find the root cause and potential solutions.

4.3 Experimental procedure

The experimental procedure involved collecting water samples from various sources in Götaland and analyzing them using sophisticated instrumentation. The collected samples were used to conduct jar testing to simulate the coagulation process, The samples were then analyzed using the Aqualog, spectrophotometer, and TOC-analyzer to measure their respective parameters. This section provides a detailed account of the sample collection process, instrumentation used, and the procedures followed in analyzing the water samples.

4.3.1 Collecting samples

The project entailed significant travel to collect samples, with the designated investigation area being Götaland, specifically in relation to various water sources. Sample collection was carried out by car, with a 25 l can and a freeze box containing 2 x 250 ml glass bottles and 2 x 50 ml plastic sample bottles. Raw water from the WTPs was collected in the 25 l can to facilitate later jar testing. In one of the 250 ml glass bottles, raw water was collected, while in the other, water after the coagulation process was obtained. The 250 ml glass bottles were selected to enable measurement of the water in the Aqualog (fluorometer), spectrophotometer, and TOC-analyzer. Plastic bottles were used to obtain the WTP's coagulant to allow for the best simulation of the coagulation process in the jar test.

The function of the freeze box is to keep the water cold and it is important to keep water samples cool during travel to prevent the growth of microorganisms. Additionally, certain chemical reactions can occur more rapidly at higher temperatures, which can also affect the properties of the water sample and skew the results. Keeping water samples cool during travel helps to preserve the integrity of the sample and ensure that accurate and reliable results (for example, affect the TOC and DOC measurements) are obtained.

4.3.2 Jar test

The experimental procedure for jar testing involves several steps to accurately determine the optimal coagulant dosage for water treatment. During the visit to each water treatment plant, information about the amount of dosage being used was gained.
§ To be able to convert the coagulant dosage from weight of coagulant/m^3 to volume of coagulant/l water, the following steps were made:

1. The given dosage of x g/m^3 should be converted to grams per liter by dividing it by 1000. This gives a value of $0,00x\ g/l$.

2. The density of the coagulant should be considered. In this case, the density is given as $y\ kg/m^3$, which is equivalent to $y\ g/l$.

To calculate the coagulant dosage in volume (ex. ml/l water), divide the dosage ($x\ g/l$) by the density ($y\ g/l$). This gives a value of $z\ l/l$ water. To convert this value to ml, multiply by 1000.

One example is when the coagulant EKOFLOCK 90 was used when the dosage from the WTP was 46 g/m^3 To convert the coagulant dosage from g/m^3 to $ml/l\ water$, the following calculation were made:

First, the given dosage of 46 g/m^3 should be converted to grams per liter by dividing it by 1000. This gives a value of 0.046 g/l.

Next, the density of the coagulant should be considered. In this case, the density is given as 1370 kg/m^3, which is equivalent to 1370 g/l.

To calculate the coagulant dosage in volume ($ml/$ö water), divide the dosage (0.046 g/l) by the density (1370 g/l). This gives a value of 0.000034 $l/l\ water$.

To convert this value to ml, multiply by 1000. The coagulant dosage in ml/l water is therefore 0.0336 $ml/l\ water$ or approximately 33.58 $\mu l/l\ water$ which is approximately 30.22 $\mu l/900\ ml\ water$ (33.58 $\mu l/l{*}0.9$).

This enables to get a certain range of dosage. In this case, a range of $10-40\ \mu l/900\ ml\ water$ was chosen to spread out over 7 beakers.

Coagulants PAX 100-XL, EKOFLOCK 90, and PAC, were readily available in a liquid form, and making it convenient for dosing in water treatment plants. However, aluminum sulfate, being in a powdered form, required the preparation of a solution in order to utilize it as a coagulant in liquid form.

To produce the liquid coagulant from aluminum sulfate, it was necessary to dissolve a specific amount of the powder in MilliQ water. For instance, if the desired dosage was 60 g/m^3, a solution at a concentration of 20 g/L (2 g/100 ml) was prepared. To calculate the volume of the solution needed, we divided the dosage by the concentration: $(60g/1000l)/(20g/l) = 0.003l$ of our solution, which is equivalent to 3 ml/l $water$.

To carry out the experimentation, a 900 ml beaker was used, and the optimum dose in volume was calculated as $3\ ml * 0.9 = 2.7\ ml$. Therefore, the dosage range for aluminum sulfate in the experiment was set at $1ml$ to $4ml$. It's worth noting that the dosage measurements for PAX 100-XL, EKOFLOCK 90, and PAC were in the μl range, while for aluminum sulfate, they were in ml.

Figure 4.1: Setup used to measure 900 ml of water in beakers for a jar test. A 25 L can of raw water and a 1000 ml measuring glass are shown in the figure. The setup is simple and efficient, ensuring that the correct volume of water is added to each beaker, which is crucial for accurate test results.

Firstly, 900 ml of raw water is measured and placed in seven large beakers, each with a capacity of 1000 ml. Using a pipette, a coagulant is added to each beaker, as in the examples above regarding EKOFLOCK 90, starting from 10 μl in the first beaker and adding 5 μl to each subsequent beaker. It is important to add the coagulant quickly to ensure that there is no delay in the time that the coagulant has been in each beaker.

The mixing process then begins, with the first step being rapid mixing for 1 minute at 250 rpm. This is followed by mixing for 10 minutes at 100 rpm, during this mixing the pH for each beaker is measured. Then the mixing continues for the next 5 minutes at 60 rpm, 5 minutes at 30 rpm, and finally for 5 minutes at 15 rpm. After mixing, the beakers are left to settle for 15 minutes without any further mixing.

Samples are then extracted from each beaker with the use of a syringe, filtered in a 0,45 μm filter into a cuvette and then measured in the spectrophotometer at the wavelength 254 nm. This gives the possibility to generate a UV254 versus dose curve. By looking at the curve, the optimum dosage can be determined and is done by looking where the decrease in absorbance is lower than 5% percent or in other cases the supervisor was asked for expertise.

After the optimum dosage has been chosen, the next step is to do a so-called pH test. The next step is to use two beakers (900 ml water) to add base in one and acid in one. Add the optimum dose and the pH of the mixture is then adjusted as necessary by adding either 1 M acid/base (HCL or NaOH) or 0.1 M acid/base (HCL or NaOH), and the pH is measured to ensure that it falls within the desired range. Then create a pH vs the number of drops curve for both the base and the acid beaker. Use this to generate a good interval of pH to use for the final jar test (often ranging between 5-7 in pH). This gives the information needed to find the optimum conditions for the optimum dosage.

Figure 4.2: Experimental setup for the Jar Test. Seven large beakers with a capacity of 1000 ml each are arranged in a row on a stirrer.

The procedure is then repeated, 900 *ml* of raw water is measured and placed in seven large beakers, each with a capacity of 1000 *ml*. Using the information from the pH test the number of drops of acid/base needed to adjust the pH is used to add to the 7 different beakers, ranging from 5-7 in *pH* (5, 5.33, 5.66, 6, 6.33, 6.66 and 7, optimum). Using a pipette, the optimum coagulant dose is added to each beaker. Adding the coagulant promptly is crucial to minimize any delay in its presence within each beaker as has previously been mentioned.

Figure 4.3: pH meter being used to measure the pH of water samples during a Jar Test.

The mixing process then begins, with the first step being rapid mixing for 1 minute at 250 *rpm*. This is followed by mixing for 10 minutes at 100 *rpm*, during this mixing the *pH* for each beaker is measured to check if the targeted *pH* is reached. Then the mixing continues for the next 5 minutes at 60 *rpm*, 5 minutes at 30 *rpm*, and finally for 5 minutes at 15 *rpm*. After mixing, the beakers are left to settle for 15 minutes without any further mixing.

Samples are then taken from each beaker, the raw water and the coagulation water from the WTP with a 60 *ml* syringe. One bottle of unfiltered sample from each beaker is filled, as well as one bottle of filtered sample, each with a volume of 40 *ml*. The 40 *ml* bottles are baked in a furnace at 550°C and pre-rinsed 3 times with MilliQ before usage. These samples will be used later to measure total organic carbon (TOC) and dissolved organic carbon (DOC).

After filling the syringe with 40 *ml* of water from the sample the TOC bottle (unfiltered) is filled then the syringe is emptied. Then filling the syringe with 60 *ml* of water from the sample the DOC bottle (filtered) is filled. There often is around 20 *ml* left in the syringe (filter still on) which is used to rinse the cuvette 3 times and to fill the cuvette for measurement in the fluorometer (Aqualog). The same cuvette is then placed in the spectrophotometer to measure the absorbance spectrum. The cuvette is then rinsed 3 times with MilliQ water to be clean for the next sample.

This procedure is then made for all of the 7 beakers and the 2 x 250 *ml* bottles with raw water and water after coagulation from the WTP. The syringe is washed at least 3 times with MilliQ water between each extraction of water from the beaker/bottle to produce a total of 9 samples from each WTP and 18 bottles for the TOC-analyzer (9 DOC and 9 TOC). By following these steps, the jar testing procedure can be performed accurately and efficiently to determine the optimal coagulant dosage for water treatment.

4.3.3 Aqualog

The experimental procedure for utilizing the Aqualog (fluorometer) involves several steps to ensure accurate measurements. To begin the procedure, the first step is to start up the Aqualog and allow it to warm up for approximately one hour. This warming period is necessary to ensure optimal performance and stability of the instrument. Once the machine has reached the desired operating temperature, a lamp check is performed. The detailed method for conducting this check can be found under a certain folder on the computer. This essential step ensures that the instrument's lamp is functioning correctly, guaranteeing accurate fluorescence measurements.

After completing the lamp check, the next step involves measuring the cuvette without any sample inside. This measurement is performed to verify whether the cuvette is clean or dirty. By examining the result, one can determine if the cuvette needs to be cleaned before proceeding with further measurements.

Following the cuvette check, a blank measurement is taken using MilliQ water. The same method employed for measuring samples is used for this blank measurement. This step serves as a baseline measurement, allowing for the removal of any background signals or impurities present in the solvent.

Once the blank measurement is completed, the actual sample measurements can be initiated. It is crucial to follow the designated measurement protocol and accurately record the obtained fluorescence data. During the measurements, it is recommended to maintain a consistent and controlled environment to minimize any external influences on the results.

To ensure proper data management and preservation, it is advised to save the measurements using the HYJ Export function. Additionally, it is recommended to create a dedicated folder with today's date. This organizational step allows for easy retrieval of the collected data and facilitates subsequent analysis and interpretation.

By diligently following these steps, the use of the Aqualog can be effectively integrated into the experimental procedure, ensuring accurate and reliable fluorescence measurements for the intended research or analysis.

4.3.4 Spectrophotometer

The spectrophotometer also involves a series of steps to ensure accurate measurements. To begin, the spectrophotometer is started up, and it is important to allow the machine to warm up for approximately 30 minutes to one hour. This warm-up period is necessary to stabilize the instrument and ensure reliable and consistent measurements throughout the experiment.

Once the spectrophotometer has reached the desired operating temperature, the reference cuvette and the cuvette containing MilliQ water are added to the instrument. The reference cuvette serves as a benchmark for comparison, while the cuvette with MilliQ water provides a baseline measurement to check the instrument's performance.

If a spectrum is required, the next step involves performing a baseline correction on the spectrophotometer. This correction ensures accurate spectral measurements by compensating for any systematic variations or instrumental artifacts that may be present.

However, if only measuring at a single wavelength, an auto-zero procedure can be conducted. This procedure allows the spectrophotometer to establish a reference point for subsequent measurements, compensating for any background signal or noise.

Following the necessary corrections, a measurement is taken using MilliQ water to verify the correctness of the baseline. This step ensures that the instrument is properly calibrated and that any potential interferences or offsets are accounted for before proceeding with the actual sample measurements.

Once the baseline verification is completed, the spectrophotometer is ready to start the measurement process. It is important to accurately record the obtained data for each measurement. To facilitate data management and storage, it is recommended to save each measurement on a USB drive using a short, descriptive name. By diligently following these steps, the use of the spectrophotometer can be effectively integrated into the experimental procedure. This approach ensures accurate and reliable measurements, enabling researchers to gather valuable data for their analysis and research purposes.

4.3.5 TOC

The TOC analyzer is a valuable instrument used for measuring Total Organic Carbon in various samples. To ensure accurate and efficient analysis, a systematic procedure is followed. Begin by starting up the TOC analyzer and the connected computer. This allows the machine and the software to initiate and synchronize, ensuring proper communication between them.

Verify that the container of MillQ-water is full and that the water level in the analyzer is adequate. Additionally, check the pressure of the synthetic gas and ensure it is at the recommended 3 bar. These checks ensure that all necessary components are properly prepared for analysis. The samples that have been previously prepared in the 40 ml vials were collected.

The vials were then arranged in a specific order, starting with the Dissolved Organic Carbon (DOC) vials and followed by the Total Organic Carbon (TOC) vials. To ensure consistency and organization, the tray were started with 3 MilliQ-water then 4 sample vials on the tray and then alternate between placing 2 MillQ-water vials and 4 sample vials repeating this pattern until the tray is filled.

The position or place number of each vial on the tray were recorded. This documentation allows for easy identification of each sample during analysis and subsequent data interpretation.The computer were accesed to assure it was connected to the TOC analyzer and also to verify the settings. Ensure that the software is configured to accommodate 40 ml vials and that it is set to measure multiple samples. Enter the appropriate number of samples and verify that the machine recognizes and aligns with the entered quantity, ensuring accurate measurement of all samples.

The TOC analyzer had to be connected and took around 20 minutes for it to complete the initialization process. This typically involves the machine undergoing self-checks and calibration to ensure accurate analysis. Before initiating the analysis, the settings were checked regarding the machine's behavior after completing the measurement. Depending on the circumstances and whether other users will follow, it was selected whether the machine should turn off or remain on.

Once the analysis is complete, the tray was carefully removed with all the vials from the TOC analyzer which then were transferred to the dishwasher and emptied their contents. The vials were thoroughly cleaned to remove any residue or contaminant, then they were prepared to be baked in a furnace. This baking process ensures proper sterilization and cleanliness, making the vials ready for reuse in subsequent analyses. By following these steps, the TOC analyzer can be effectively utilized to measure Total Organic Carbon, providing valuable information for various research and analysis purposes.

5

Results

5.1 Survey

5.1.1 Capacity

During the survey conducted on various Water Treatment Plants (WTPs) in the Götaland region, it was found that there were significant differences in their capacities. The capacity of a WTP refers to its ability to treat and supply water to the respective areas it serves.

Some WTPs exhibited higher capacities, such high as 180 000 m^3/day, indicating their ability to treat and distribute larger volumes of water. These plants can handle a substantial flow of water per hour, ensuring an adequate water supply for the region they serve.

On the other hand, some WTPs had lower capacities compared to others, as low as around 6 000 m^3/day. While their capacity may be relatively smaller, these plants still play a crucial role in meeting the water demands of their respective areas, although on a smaller scale.

The differences in capacity among the surveyed WTPs highlight the diverse water supply needs and infrastructural variations across the Götaland region. Factors such as population density, industrial activities, and geographical features can contribute to the varying capacities observed.

It is important to recognize that each WTP is designed and operated based on the specific requirements of the area it serves. The capacity of a WTP directly impacts its ability to provide clean and safe water to the population, making it a critical factor in water management and planning.

5.1.2 Selection of Coagulant

Among the 11 surveyed plants, Ekoflock 90 was used by two WTPs, Aluminium sulfate by five WTPs, PAX XL-100 by three WTPs, and PAC (Polyaluminiumchloride) by one WTP. This demonstrates the variation in coagulant choices based on factors such as efficiency, effectiveness, and cost-effectiveness for each plant but also due to differences and raw water characteristics.

The contact times for coagulation varied across the plants. Some plants reported longer contact times, such as 2.5 hours and up to 6 hours, while others had significantly shorter contact times, ranging from 7 seconds to around 22 seconds. These variations highlight the different processes and considerations employed by each plant to achieve optimal coagulation.

The coagulant aids used by the WTPs included lime, carbon dioxide, lye, soda, and water glass. Each plant employed specific coagulant aids to adjust pH levels, increase alkalinity, and enhance sedimentation, depending on their treatment requirements and water characteristics.

The survey results indicate that the WTPs in Göteborg, Götaland employ diverse approaches in terms of capacity, coagulant selection, contact time, and coagulant aids. These variations reflect the unique circumstances and water quality challenges faced by each plant. The findings provide valuable insights into the practices and strategies employed by the different WTPs in the region to ensure efficient and effective water treatment processes.

5.1.3 Factors Influencing Coagulant Dosage

The survey revealed several parameters and factors that determine the dosage of coagulants in water treatment plants:

pH and Turbidity Monitoring: pH meters are used to measure the water's acidity before and after treatment, while turbidity meters measure the clarity of the water after filtration. These measurements help in adjusting the coagulant dosage.

Color and Transmittance: Color and transmittance are indicators of the organic content in the water. Dosage adjustments are made based on different color values and turbidity levels in the raw water.

Microbiological Barrier Analysis: In cases where water sources are exposed to fecal contamination, it is crucial to consider the coagulant's ability to remove disease-causing microorganisms. In some instances, fecal contamination can increase rapidly without a simultaneous increase in water color. In such cases, a constant high dosage of coagulant is used to ensure effective coagulation.

Model-Based Dosage: Water treatment plants use models for dosing polyaluminium chloride due to rapid changes in raw water conditions. Flow rate and weather conditions have a more significant impact on raw water quality than seasonal variations. Dosage adjustments for polyacrylamide may vary during different seasons.

Organic Material Content: Dosage adjustments are made based on the amount of organic material present in the raw water, with a focus on parameters such as COD (Chemical Oxygen Demand), color, and turbidity. During the summer, dosage adjustments are more common due to potential taste and odor issues associated with higher water temperatures.

Real-time Monitoring: Some plants utilize instruments like the i::scan, which measures parameters such as turbidity, UV254, COD, and color in real-time. Although the instrument currently serves as a manual tool for adjusting coagulant dosage, the goal is to incorporate it into a regulation system where it can partially control the dosage based on predefined parameters.

Color-based Dosage Adjustment: Some plants modify their dosage based on color values, increasing the coagulant dosage with higher color values. Online monitoring, particularly using color measurements, helps in monitoring and adjusting the dosage accordingly.

These parameters and monitoring techniques play a crucial role in optimizing coagulant dosage and ensuring effective water treatment.

5.1.4 Frequency of Jar Testing

The survey reveal a diverse range of practices regarding the frequency of jar testing among the surveyed water treatment plants. While some facilities conduct testing infrequently or based on specific needs, others do not perform jar testing at all. This suggests variations in the reliance on other monitoring techniques, operational stability, or the availability of alternative methods for assessing and optimizing coagulation and flocculation processes.

Among the facilities surveyed, as some plants conduct jar tests infrequently, it is often gaps of several years between tests. One plant, for instance, indicated that jar testing occurs only sporadically, perhaps once every other year. This suggests that the plant relies on other monitoring techniques or possesses a high level of confidence in the effectiveness of its existing treatment processes. While this approach may be feasible if alternative methods are employed to ensure optimal performance, it is essential to consider the potential benefits of more regular jar testing in identifying process inefficiencies and improving overall treatment outcomes.

Some plant follows a "need-based" approach to jar testing, indicating that tests are conducted when specific issues arise or when process evaluation is required. This flexible approach suggests that the plant relies on operational experience and other monitoring parameters to guide its treatment processes. However, it is worth noting that considerable periods can pass without conducting jar tests, potentially missing opportunities for proactive optimization and fine-tuning of the process.

Surprisingly, a major part of the plants do not carry out jar testing at all. The reasons behind this decision were not provided in the survey. However, the absence of this testing method raises questions about the plants ability to assess and fine-tune their coagulation and flocculation processes effectively. Jar testing serves as a fundamental tool for evaluating the performance of different coagulants, dosage levels, and process conditions, allowing for informed decision-making and optimization.

In another facility, jar testing is not conducted on an annual basis but rather reserved for significant changes in the treatment process or when switching suppliers. This selective approach suggests a focus on key operational adjustments and supplier performance evaluation. While this may be a practical strategy for managing process changes, it is important to consider the benefits of routine jar testing for continuous process improvement and optimization.

Finally, another plant indicates that jar testing is not performed regularly. While a test was conducted three years ago, there have been no subsequent tests since then. This intermittent testing approach raises concerns about the plant's ability to identify and address any changes or inefficiencies in the coagulation and flocculation processes to ensure optimal treatment outcomes.

5.2 Raw Water Characteristics

The results of analyzing raw water characteristics, including ABS, DOC, TOC, and SUVA, provide valuable information about the organic composition and quality of the water source. These parameters offer insights into the potential challenges and treatment requirements for ensuring the production of safe and clean drinking water.

Absorbance measurements at a specific wavelength, such as 254 nm, indicate the extent to which organic compounds in the water absorb ultraviolet (UV) light. Higher absorbance values suggest a higher concentration of aromatic and conjugated organic compounds. This information is crucial as it highlights the potential for the formation of disinfection by-products during water treatment processes, which may require specific treatment strategies to mitigate their presence.

DOC measurements provide quantitative information about the concentration of dissolved organic compounds in the raw water. This includes various organic molecules originating from natural sources like decaying vegetation or anthropogenic activities. Understanding the DOC levels helps water treatment facilities assess the overall organic load and design appropriate treatment processes to effectively remove or reduce these compounds.

TOC measurements provide a comprehensive assessment of both dissolved and particulate organic carbon in the water. This parameter accounts for the total amount of organic material, including both easily and more resistant-to-degradation compounds. By quantifying TOC, water treatment plants can better understand the organic content and devise suitable treatment strategies to meet regulatory requirements and maintain water quality.

SUVA (Specific Ultraviolet Absorbance) is a ratio calculated by dividing the absorbance at 254 nm by the concentration of dissolved organic carbon (DOC). It is a useful parameter that can provide insights into the organic composition and reactivity of the organic matter in the water. Higher SUVA values suggest a higher proportion of aromatic and humic substances, which could impact the treatment process and influence the formation of disinfection by-products.

By analyzing these raw water characteristics, water treatment professionals can gain a deeper understanding of the organic content and potential challenges associated with the water source. This knowledge enables them to tailor treatment processes, optimize coagulant selection, adjust dosages, and employ appropriate disinfection methods to ensure the effective removal of organic compounds and the production of safe and high-quality drinking water.

Table 5.1: Characteristics for Raw Water From The WTPs.

WTP	1	2	3	4	5	6	7	8	9	10	11
$ABS\ [abs\ m^{-1}]$	0,1331	0,3156	0,3447	0,4289	0,1258	0,1896	0,382	0,2611	0,2051	0,1666	0,1923
$DOC\ [mg\ L^{-1}]$	5,304	9,1	10,54	12,68	5,36	10,14	11,26	7,954	6,929	5,775	6,444
$TOC\ [mg\ L^{-1}]$	5,445	9,071	10,75	12,68	5,287	6,871	11,06	7,946	6,672	5,605	6,657
$SUVA\ [L\ mg^{-1}\ m^{-1}]$	2,5	3,5	3,3	3,4	2,3	1,9	3,4	3,3	3,0	2,9	3,0

Table 5.1 provides an overview of the raw water characteristics for Water Treatment Plants (WTP) 1 to 11. The table includes parameters such as absorbance (ABS), dissolved organic carbon (DOC), total organic carbon (TOC), and specific ultraviolet absorbance (SUVA).

The ABS column represents the absorbance at a specific wavelength (254 nm) and serves as an indicator of the concentration of organic compounds in the water. As previously mentioned, higher ABS values suggest a greater presence of organic matter.

The DOC column denotes the concentration of dissolved organic carbon in milligrams per liter (mg/l). It quantifies the amount of organic compounds present in the water, which plays a crucial role in treatment processes and the potential formation of disinfection by-products.

TOC, also measured in mg/l, represents the total organic carbon, including both dissolved and particulate organic matter. It provides a comprehensive assessment of the overall organic content in the raw water.

SUVA, is expressed as liter per miligram per meter (l/mg/m), the reason behind the unit of this value is due to that it calculated by dividing absorbance with the DOC concentration.

By examining these raw water characteristics for each water treatment plant, a better understanding can be gained regarding the organic composition and potential treatment challenges associated with each water source. These values plays a crucial role in designing effective treatment strategies tailored to address the specific organic content of the raw water at each plant.

5.3 Analysis

Table 5.2 and Table 5.3 shows that no water treatment plant employs the same coagulant while utilizing the exact same raw water source. This lack of consistency makes it challenging to directly compare the treatment processes and dosages among different water treatment plants.

Table 5.2: Raw Water Sources for Water Treatment Plants.

Raw Water Source	Göta Älv	Rådasjön	Öresjö	Köperödssjöarna	Vänern	Finnsjön	Lilla Dalevatten	Färgen	Stora Hällungen	Delsjön
WTP	1, 10	2	3	4	5	6	7	8	9	11

The absence of the same use coagulants and raw water sources highlights the unique circumstances faced by each water treatment facility. Factors such as geographical location, source water quality and infrastructure capabilities all contribute to the individualized approach taken by each plant.

Table 5.3: Used Coagulants at Various Water Treatment Plants.

Coagulant	PAC	PAX 100-XL	EKOFLOCK 90	ALUMINIUM SULFATE
WTP	1	2, 3, 4	5, 6	7, 8, 9, 10, 11

As a result, it becomes difficult to establish a direct comparison between the treatment processes and dosages utilized by different water treatment plants and therefore needs to be a case-by-case study.

It is important to recognize that the selection of coagulants and dosages is highly dependent on the specific water quality challenges faced by each water treatment plant. Different coagulants may be chosen to target specific contaminants, and dosages may vary based on the concentration of impurities in the raw water.

Although direct comparisons may be challenging due to the lack of uniformity, studying the treatment processes and dosages employed by individual water treatment plants can still provide valuable insights into best practices and effective strategies for water treatment.

Table 5.4 compares the coagulant dosage used in various WTPs with the experimental optimum dosage. The trend observed in the table suggests a mixed pattern in terms of how closely the WTP dosages align with the experimental optimum dosages.

Table 5.4: Comparison of Coagulant Dosage Between Water Treatment Plants and Experimental Optimum Dosage.

WTP	1	2	3	4	5	6	7	8	9	10	11
WTP Dosage	-	28,4 µl	47,9 µl	56,6 µl	30,2 µl	24,3 µl	2,7 ml	1,8 ml	1,43 ml	1,53 ml	1,58 ml
Optimum Dosage	350 µl	25 µl	35 µl	35 µl	30 µl	20 µl	2,5 ml	1,5 ml	1 ml	1,5 ml	2 ml
WTP Dose µl/L per mg/L DOC	-	3,47	5,05	4,96	6,26	2,66	266	251	229	294	272
Optimum Dose µl/L per mg/L DOC	73,3	3,05	3,69	3,07	6,22	2,19	247	210	160	289	345

Analyzing the data, we can see that some of the WTP dosages are significantly higher or lower than the corresponding optimum dosages. For instance, in WTP 1, no specific dosage is provided, which makes it difficult to determine its alignment. However, in WTP 2, the dosage of 28.4 μl is relatively close to the optimum dosage of 25 μl. On the other hand, in WTP 3 and 4, the dosages are considerably higher than the respective optimum dosages. Although considering WTP 3, information was gained when visiting the WTP that they are overdosing due to their raw water source by purpose.

Moving further, WTP 5 shows a dosage of 30.2 μl, which is close to the optimum dosage of 30 μl. WTP 6 also exhibits a dosage of 24.3 μl, which is relatively close to the optimum dosage of 20 µl. These instances indicate that some water treatment plants are utilizing dosages that are near the experimental optimum.

However, the trend changes when examining the dosages of WTP 7 to WTP 11, which all of them use Alumininum Sulfate as their coagulant. In these cases, the dosages used in the water treatment plants have a higher diversity from the optimum dosages. For instance, in WTP 9, the dosage of 1,43 ml is higher than the optimum dosage of 1 ml. In general, the optimum dose is lower then the current dose at the WTP considering Aluminium Sulfate. Although in WTP 11, their dosage is giving better results than the experimental optimum. This can be due to certain coagulant aids that are used in their process but not used when conducting the experiment.

Overall, based on the information in the table, it can be concluded that the alignment between the coagulant dosages used in the water treatment plants and the experimental optimum dosages is varied. Some plants show a closer resemblance to the optimum dosage, while others deviate. This suggests that there may be a lack of standardization or optimization in coagulant dosage practices among different water treatment plants.

Further analysis of Table 5.4, in the "WTP Dose (μl/L per mg/L DOC)" row, the values represent the coagulant doses used by each WTP, expressed in microliters per liter of water per milligram of DOC per liter water. The doses vary across the WTPs, indicating different treatment practices and levels of coagulant usage. It is worth noting that for WTP 1, the specific dose is not known.

On the other hand, the "Optimum Dose (μl/L per mg/L DOC)" column provides the recommended coagulant doses for achieving efficient removal of DOC at each concentration. These doses have been determined through the study, considering factors such as the specific characteristics of each WTP and the desired treatment objectives. The values indicate the optimized doses that can potentially lead to improved removal efficiency while minimizing the consumption of coagulant.

Comparing the WTP doses with the optimum doses reveals the potential for dose optimization and reduction of coagulant usage in many cases. For instance, WTP 2, WTP 3, WTP 4, and WTP 6 all demonstrate higher doses compared to their respective optimum doses, indicating the possibility of reducing the coagulant dosage while maintaining efficient DOC removal.

In contrast, some WTPs, such as WTP 9 and WTP 11, already utilize doses close to their optimum values. These WTPs demonstrate a good understanding of the required coagulant dosage based on the DOC concentration in the water.

It is important to note that further analysis and evaluation are necessary to assess the feasibility of adopting the optimum doses in each specific WTP. Factors such as variations in source water quality, treatment process configurations, and local conditions should be taken into consideration.
However, the table highlights the potential benefits of adjusting coagulant doses based on the concentration of DOC, leading to more efficient and optimized water treatment processes.

Another consideration about these differences in dosage could be to try to enhance the method that is being used to determine the dosage in the WTPs. An example would be to get a better sensor that is measuring parameters that has a large influence on how much dosage is needed.

5.4 Dissolved Organic Carbon Removal Efficiency

The removal of DOC is a crucial objective in water treatment processes, as DOC can contribute to the formation of disinfection by-products and affect water quality. The efficiency of DOC removal can be influenced by various factors, including the pH of the water and the type of coagulant used. Understanding the relationship between DOC removal percentage and pH is essential for optimizing water treatment processes and selecting appropriate coagulants.

In this result section, the relationship between DOC removal percentage and pH for different WTPs using different coagulants will be examined. By analyzing the data collected from these WTPs, the aim is to gain insights into the effect of pH on DOC removal efficiency and evaluate the performance of various coagulants under different pH conditions.

In the Figure 5.1 shown below illustrates the relationship between the dosage of coagulant PAC and the corresponding DOC removal efficiency at WTP 1. The reason for focusing on the dosage instead of pH is that the optimum pH range for coagulant PAC had already been determined through previous laboratory experiments, having an optimum pH around 5,6.

By examining the graph, it can be observed how different dosages of coagulant PAC impact the removal of dissolved organic carbon. The data points represent the measured DOC removal efficiency at various dosage levels of coagulant PAC. As seen the optimum dosage of the coagulant PAC is marked out at 350 μl due to the highest DOC removal.

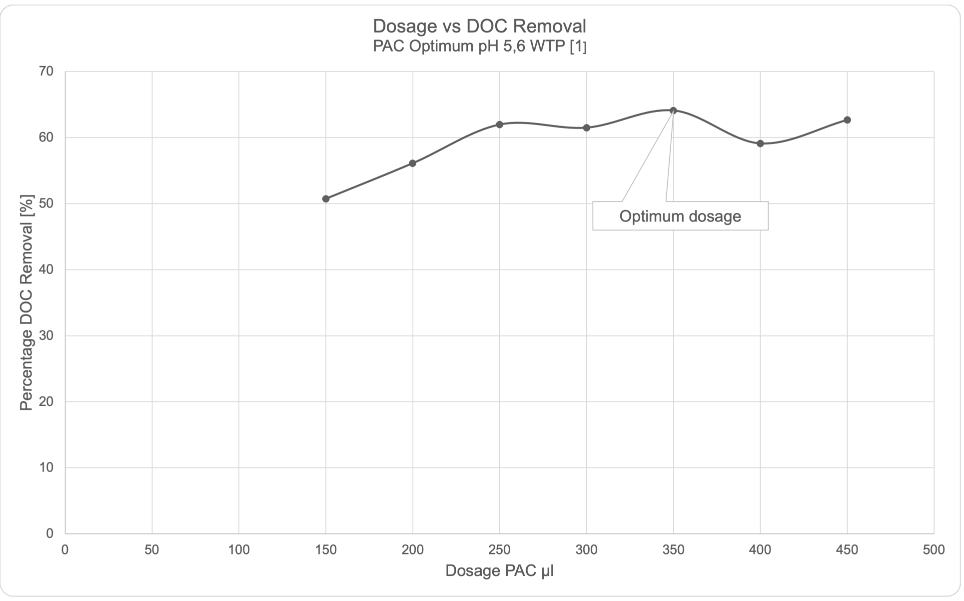

Figure 5.1: Dosage vs. DOC Removal Efficiency for Coagulant PAC

In the subsequent figures presented in this section, the focus shifts back towards examining the relationship between pH and DOC removal percentage. These figures allows to explore the influence of pH on the effectiveness of the water treatment process in removing dissolved organic carbon.

In Figure 5.2, the coagulant in focus is PAX 100-XL which was used by WTP 2, WTP 3, and WTP 4. The figure provides insights into the effectiveness of the coagulant in removing DOC at different pH levels. The experimental optimum dose has been determined for each WTP and is indicated at the bottom of the figure.

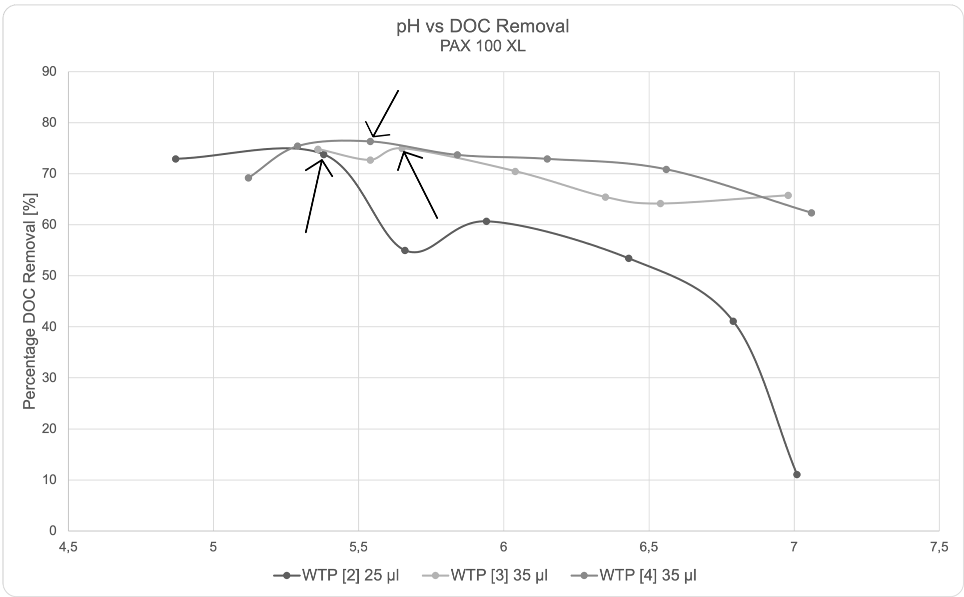

Figure 5.2: pH vs. DOC Removal Efficiency for Coagulant PAX 100-XL

Regarding the information gained from the coagulant PAX 100-XL, it can be seen that the optimum dosage is around 25-35 *µl* and also that the optimum range of pH is quite narrow, varying from around 5,3 to 5,6. In term of DOC removal, PAX 100-XL removes at optimum around 70-80%.

Figure 5.3 shows the relationship between pH and DOC removal for WTP 5 and WTP 6, using the coagulant EKOFLOCK 90. The graph indicates that the optimum dosage of EKOFLOCK 90 differs for the two WTPs. For one of the WTPs, the optimal dose is determined to be 20 *µm*, while for the other WTP, it is 30 *µl*. This suggests that each WTP has unique characteristics and requires a specific coagulant dosage for optimal DOC removal due to its raw water.

Furthermore, the graph reveals that the coagulant's optimal pH range lies between 5.1 and 5.4. Within this pH range, the efficiency of DOC removal is at its highest. This implies that maintaining the pH within this range is crucial for achieving optimal performance of the coagulant.

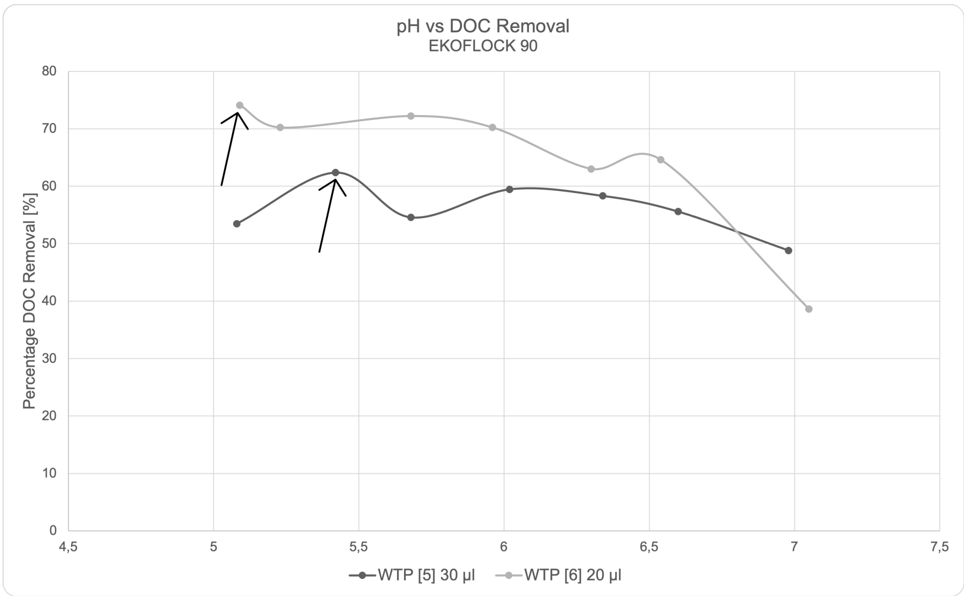

Figure 5.3: pH vs. DOC Removal Efficiency for Coagulant EKOFLOCK 90

The data also demonstrates some variation in the efficiency of DOC removal at the optimum pH range. The efficiency for EKOFLOCK 90 at optimum lies in the region of 60% for WTP 5 which water source is the lake Vänern. For WTP 6 the efficiency is around 70% with its water from Finnsjön. This variability suggests that other factors, such as water composition, organic matter characteristics, and operational conditions, may influence the overall effectiveness of the coagulant.

Figure 5.4 showcases the relationship between pH and DOC removal for WTP 7, WTP 8, WTP 9, WTP 10 and WTP 11 using the coagulant Aluminum Sulfate. The graphs indicate that the optimal dosage of Aluminum Sulfate varies across the different WTPs, from 1 ml up to 2,5 ml. This could be due to that neither of these

WTPs have the same raw water source and therefore there is a difference in the dosage that leads to the highest DOC removal.

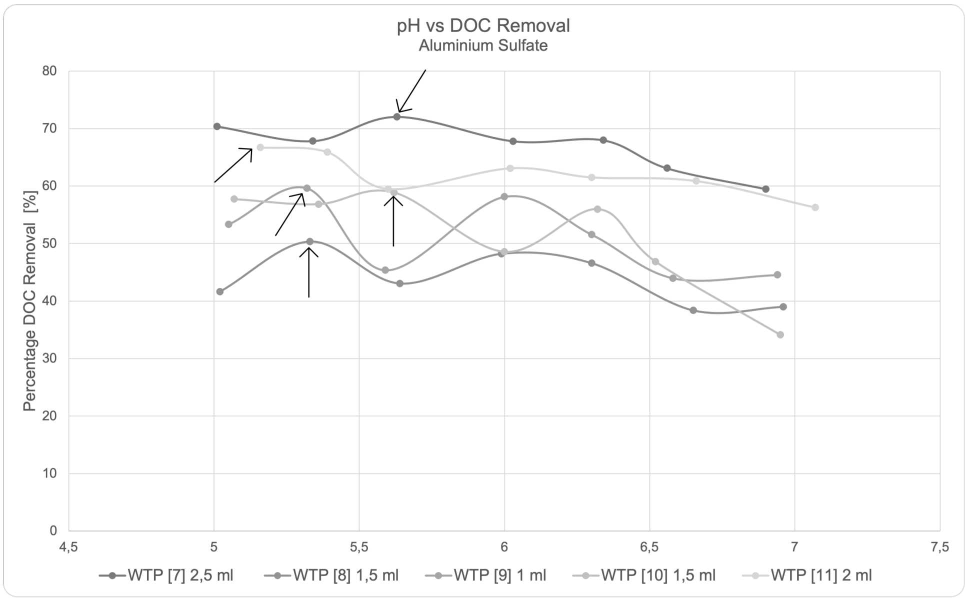

Figure 5.4: pH vs. DOC Removal Efficiency for Coagulant Aluminum Sulfate

Additionally, the graphs reveal that the coagulant's optimal pH range falls between approximately 5.15 and 5.6. Within this pH range, the efficiency of DOC removal is at its highest. It is crucial to maintain the pH within this range to ensure optimal performance of Aluminum Sulfate as a coagulant.

The data presented in the graph also demonstrates variation in the efficiency of DOC removal at the optimum pH range. The efficiency ranges between 50% and 70% across the five WTPs using Aluminium Sulfate. As earlier mentioned for previous figures, the reason that the experimental dosage for each WTP doesn´t lead to the same amount DOC removal in percentage is that each plant has different designs regarding their process and that the raw water source differs.

To summarize regarding the DOC removal, the coagulant PAC has an optimum pH around 5,6 and the highest DOC removal were 64%. PAX 100-XL had an optimum pH range around 5,3-5,6 and had around 70-80% in DOC removal, EKOFLOCK 90 had an optimum pH in the range of 5,1-5,4 and reached as high 60-70% in DOC removal. Lastly, Aluminium Sulfate had a broader pH range, 5,15-5,6 and has a higher variety in its optimum DOC removal from 50-70%.

5.5 Absorbance Removal Efficiency

Besides only looking on the efficiency regarding DOC, there were also measurements made considering the absorbance at the experimental optimum dose in a variety of different pH.

In Figure 5.5 displayed below, the correlation between the coagulant PAC dosage and the corresponding removal efficiency of absorbance (ABS) at WTP 1 is presented. The choice to investigate the dosage instead of pH is exaclty the same as in the previous section regarding the coagulant PAC.

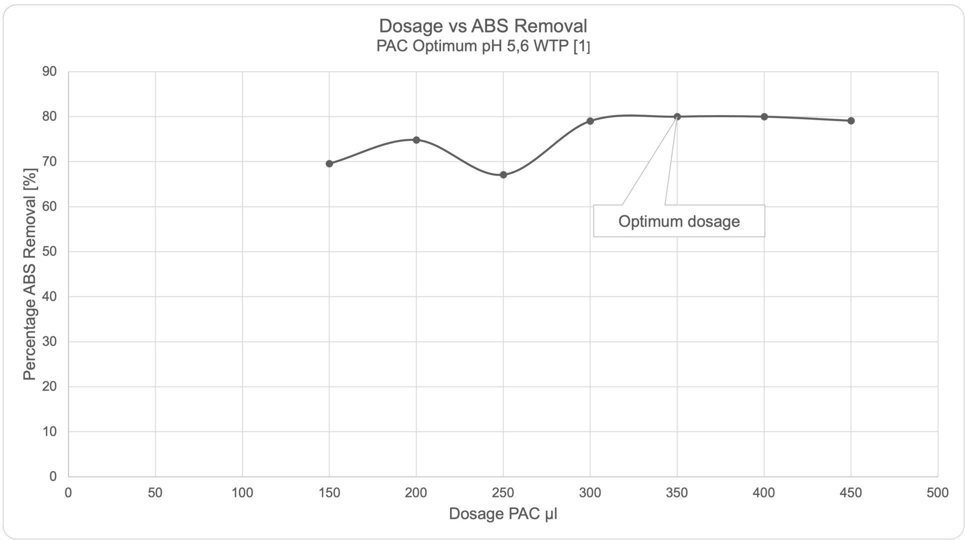

Figure 5.5: pH vs. ABS Removal Efficiency for Coagulant PAC

Due to the prior laboratory experiments that have already determined the optimal pH range for coagulant PAC, which was found to be approximately 5.6. By focusing on the dosage, we can further understand the impact of coagulant PAC on ABS removal efficiency at the determined optimum pH level.

In the case of ABS removal, it can be seen that the dosage 350 μl is the optimum dosage, just the same as DOC removal. When locking at the result of total absorbance removal, from around 300 μl dosage and higher, there is as high as 80% absorbance removal.

In the following figures presented within this section, the attention is redirected towards investigating the correlation between pH and the percentage of ABS removal. These figures enables to explore the impact of pH on the efficiency of the water treatment process in reducing the absorbance from the treated water.

The experimental optimum dose has been determined for each WTP and is indicated at the bottom of each figure. The optimum dose for each WTP and coagulant is the same as in the figures presented in the previous section and therefore the differences in dosages is most likely due to differences in the raw water characteristics which can be found in Table 5.1.

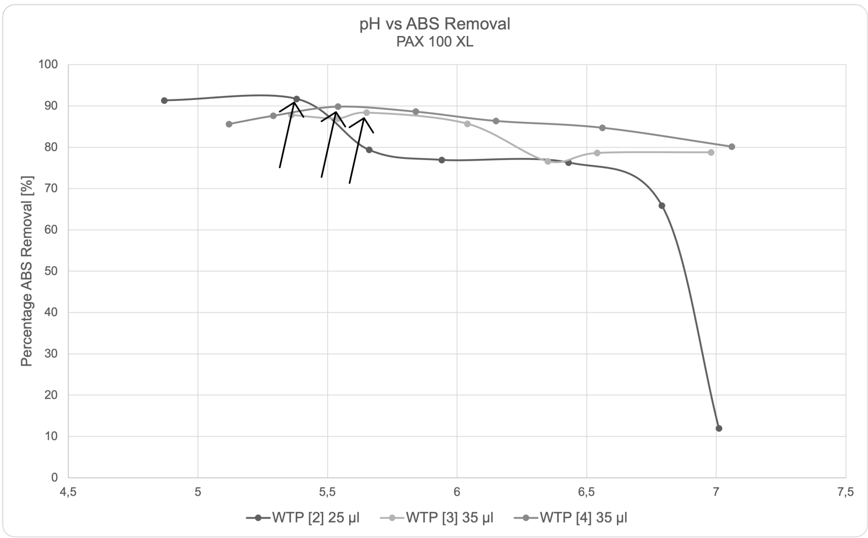

Figure 5.6: pH vs. ABS Removal Efficiency for Coagulant PAX 100-XL

In Figure 5.6, the coagulant in focus is PAX 100-XL which was used by WTP 2, WTP 3, and WTP 4. The figure provides insights into the effectiveness of the coagulant in removing ABS at different pH levels. By examining the graphs, the range of optimum absorbance removal in terms of pH is very narrow for PAX 100-XL, varying between around 5,4-5,6. It can also be seen that the effectiveness is very high in terms of absorbance removal when in optimum pH, as high as 90% although the raw water source differs for the different WTPs.

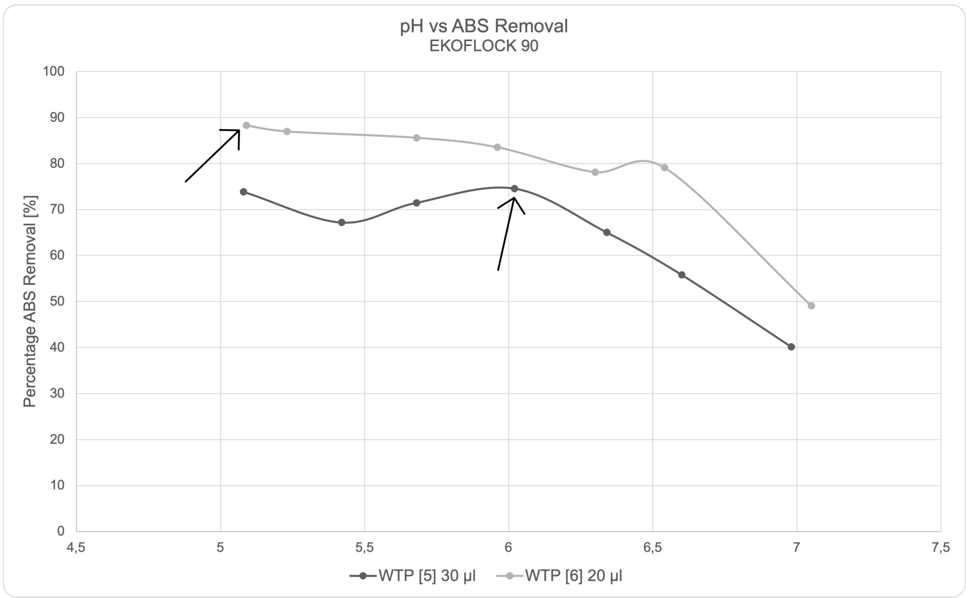

Figure 5.7: pH vs. ABS Removal Efficiency for Coagulant EKOFLOCK 90

Figure 5.7 shows the relationship between pH and ABS removal for WTP 5 and WTP 6, using the coagulant EKOFLOCK 90. The graphs reveals that the coagulant's optimal pH range lies at 6 for WTP 5 and at 5.1 for WTP 6. Although looking more precise on the data it can be seen that the difference between the highest and second highest ABS removal for WTP 5 is less than 1 unit (73,8% at pH 5,1 and 74,6% at pH 6).

This suggests that the optimum pH for EKOFLOCK 90 in terms of ABS removal is 5,1 (almost the same as for DOC removal, 5,1-5,4 in pH). This implies that maintaining the pH within this range is crucial for achieving optimal performance of the coagulant.

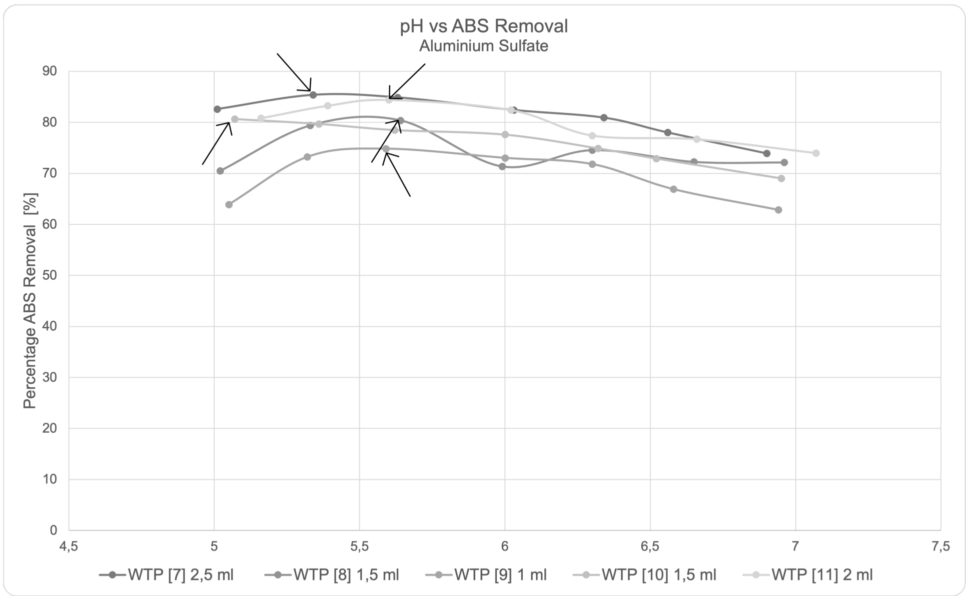

Figure 5.8: pH vs. ABS Removal Efficiency for Coagulant Aluminium Sulfate

Figure 5.8 shows the relationship between pH and ABS removal for WTP 7, WTP 8, WTP 9, WTP 10 and WTP 11 using the coagulant Aluminum Sulfate. The figure provides valuable insights into the efficiency of ABS removal at different pH levels, following the determination of the experimental dose. The optimum dosage for each WTP is indicated at the bottom of the figure.

By looking at the results, Figure 5.8 revealed that the optimum pH range for these WTPs using Aluminum Sulfate as the coagulant was between 5.1 and 5.6. These findings underscore the significance of pH control and the choice of coagulant in achieving efficient absorbance removal. By operating within the optimal pH range and utilizing Aluminum Sulfate as the coagulant, WTPs 7, 8, 9, 10, and 11 demonstrated considerable success in removing absorbance, with removal percentages ranging between 75% and 95%.

5.6 Coagulant Efficiency

Of all the Water Treatment Plants (WTPs) that were visited during the study, it is worth noting that only two of them, namely WTP 1 and WTP 10, shared the same raw water source: the river Göta Älv. This shared water source allowed for a more direct comparison of coagulant efficiency between these two plants.

Given the identical raw water source, the coagulant efficiency in WTP 1 and WTP 10 could be evaluated with fewer variables at play, as the water quality characteristics originating from Göta Älv were relatively consistent, which can be seen in Table 5.1. This provided an opportunity to assess the influence of coagulant choice on treatment performance more accurately.

WTP 1 employed PAC as the coagulant, where the optimum pH range had already been determined through previous laboratory experience. Hence, the dosage of PAC was tested to identify the optimum levels for efficient removal of Dissolved Organic Carbon (DOC) and Absorbance. In this case, the focus was primarily on dosage optimization rather than pH. In contrast, WTP 10 utilized Aluminum Sulfate as the coagulant. Unlike WTP 1, the optimum dosage and pH range was not known beforehand. Therefore, a comparison was made between pH levels and the removal efficiency of both DOC and Absorbance after the optimum dosage was determined. This analysis aimed to investigate the relationship between pH and the effectiveness of coagulation in WTP 10.

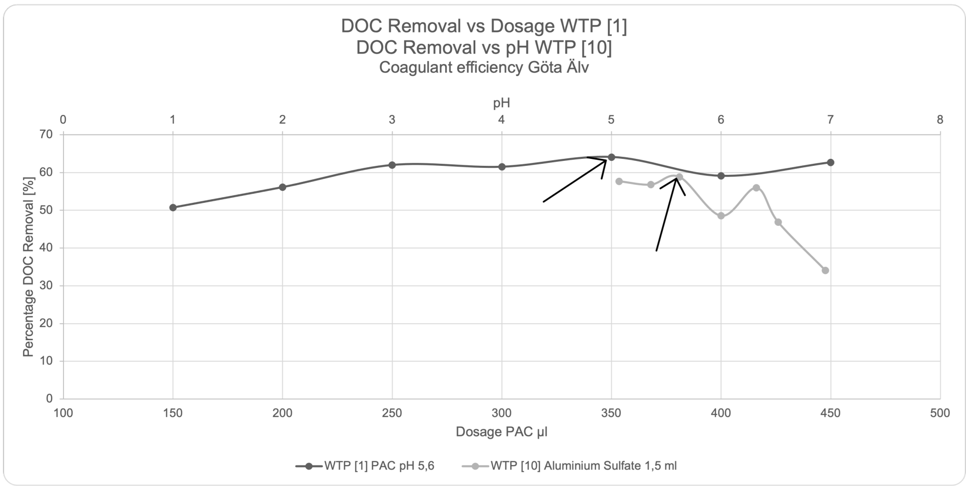

Figure 5.9: DOC Removal Efficiency for Coagulant in Göta Älv PAC vs Aluminum Sulfate

In Figure 5.9 information about the two graphs can be seen at the bottom where the graph from WTP 1 has an optimum pH and the graph from WTP 10 has an optimum dosage. The most important parameter is at the y-axis which is the percentage removal of DOC but the x-axis on the bottom is for WTP 1 (Dosage) and the one on the top is for WTP 10 (pH).

Even if the changing parameters are different for the two graphs, the optimum conditions can be determined for the coagulants when having the same raw water source. For PAC it can be noticed that the optimum DOC removal is as high as 64 % when pH is held at around 5,6 and the dosage is 350 μl. In the case of Aluminium Sulfate as the coagulant when the raw water came from Göta Älv we can see that the optimum dosage is 1,5 *ml* and that the pH should be held at around 5,6.

The dosage of PAC at 350 μl and Aluminum sulfate at 1.5 ml can be in accordance with the preparation methods and concentration differences between the two coagulants. In the case of Aluminum sulfate, it is available in a powdered form. To utilize it as a coagulant in the Water Treatment Plant (WTP), a specific concentration is required. In the laboratory setting, a solution was prepared by dissolving the powder in MilliQ water. This laboratory-prepared solution may have a lower concentration compared to the concentration that is used in the WTP.

On the other hand, PAC is typically supplied in liquid form, already prepared at a specific concentration suitable for water treatment. The recommended dosage of 350 μl is considered the optimum dosage of PAC to achieve the highest percentage removal of DOC.

It is important to consider that if the same amount of Aluminum sulfate powder as used in the WTP was dissolved in the laboratory, the resulting solution would likely have a higher concentration. In such a scenario, the dosage required for Aluminum sulfate would potentially be in the same dosage range as PAC. These differences in dosage can be attributed to the variations in the preparation methods and concentrations of the coagulants, highlighting the importance of accurately preparing and utilizing coagulants to ensure effective water treatment processes.

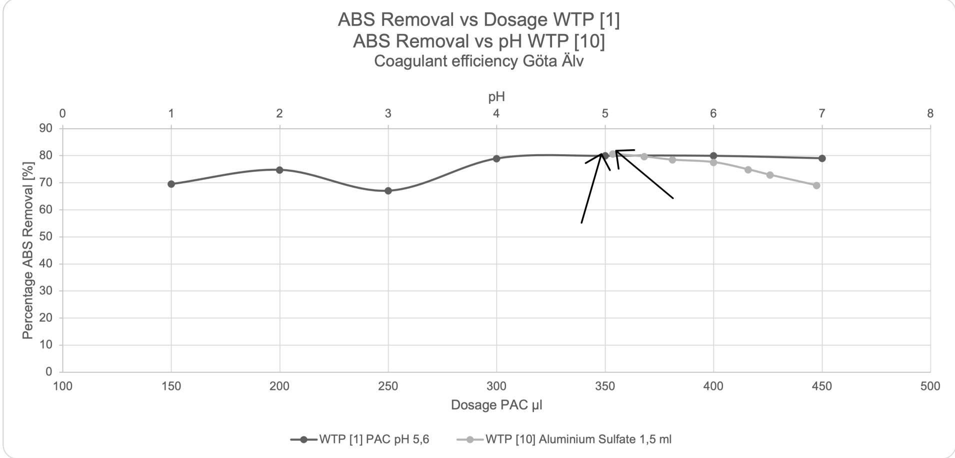

Figure 5.10: ABS Removal Efficiency for Coagulant in Göta Älv PAC vs Aluminum Sulfate

When comparing the relationship between pH and absorbance removal in WTP 10, where Aluminum sulfate was used as the coagulant, with the dosage and absorbance removal in WTP 1 using PAC, in Figure 5.10 differences in both the optimum pH and dosage were observed. As explained above, there is a reason why there is a major difference in the dosage.

It is noteworthy that the optimum pH for WTP 1 was around 5.6, while the optimum pH for WTP 10 was around 5.1 which differs from the optimum pH for WTP 10 regarding DOC removal. This discrepancy indicates that the coagulant type and its chemical properties play a significant role in determining the ideal pH range for achieving optimal absorbance removal.

These findings highlight the importance of considering the specific coagulant, dosage, and pH range when aiming to optimize absorbance removal in water treatment processes. Understanding the variation in optimum pH and dosage for different coagulants provides valuable insights for effective coagulant selection and operational adjustments, ensuring the highest quality of treated water.

5.7 Discussion of Sensitivity, Replication and Potential Error Sources in the Experimental Methods

In the context of water treatment experiments, sensitivity, replication, and potential error sources are critical factors that significantly impact the reliability and accuracy of the obtained results. These considerations play a cruical role in ensuring the validity of the experimental findings. Highly sensitive analytical instruments, including the Aqualog fluorometer, spectrophotometer, and TOC analyzer, are instrumental in detecting and quantifying the parameters of interest.

Each instrument offers exceptional sensitivity in measuring specific aspects of water samples. The Aqualog excels in capturing fluorescence signals emitted by organic compounds, while the spectrophotometer enables precise measurement of absorbance values at targeted wavelengths or spectrum. The TOC analyzer, on the other hand, provides sensitive detection and quantification of organic carbon concentrations in water. These instruments allow researchers to accurately assess the characteristics and composition of the samples under investigation.

When attempting to replicate the coagulation process of Water Treatment Plants (WTPs) using a jar test, it is important to recognize that there are certain limitations and factors that may impact the accuracy of the results obtained. While the jar test can provide valuable insights and help determine appropriate coagulant dosages, it may not fully represent the actual coagulation process employed in WTPs.

One significant factor to consider is the difference in contact time between the water sample and the coagulant. In WTPs, the coagulation process occurs within a specific time frame, influenced by the flow rates and design of the coagulation chambers. In a jar test, the contact time may vary from the actual process, leading to potential variations in coagulation efficiency.

Stirring is another critical aspect that can differ between the jar test and WTPs. The intensity and duration of stirring in WTPs may not be accurately replicated in a jar test, affecting the formation of flocs and sedimentation. Variations in stirring can impact the coagulation process and subsequent removal of impurities.

The temperature of the raw water used in the jar test is also an important consideration. In WTPs, the raw water temperature can fluctuate depending on seasonal changes and environmental factors. However, during laboratory tests, it is common to use room temperature water, which may not accurately reflect the conditions experienced in WTPs. Temperature variations can influence the rate of chemical reactions and affect the performance of the coagulant.

Other factors, such as variations in pH, alkalinity, turbidity, and the presence of specific water constituents, can also impact the coagulation process. WTPs often encounter different water sources with varying characteristics, and these variations may not be adequately replicated in a jar test.

Despite these limitations, the jar test can still generate useful results, particularly when it comes to determining the correct coagulant dosages. By accurately calculating the dosages based on the jar test results, WTPs can achieve effective coagulation and removal of impurities.

Estimating the differences in results due to variations between the jar test and the actual coagulation process in Water Treatment Plants (WTPs) is challenging. Factors such as contact time, stirring, temperature, and other variables can impact the outcomes. The jar test provides an approximation but may not fully represent the dynamic nature of the WTP environment. Variations depend on operational practices, water quality, and accuracy of dosage calculations. Thorough evaluations, pilot-scale studies, and on-site trials can help estimate discrepancies and guide improvements. Bridging the gap between laboratory testing and real-world application is crucial.

The sensitivity of the experimental procedures employed in the jar test and analysis is crucial for accurate measurements. Several aspects of the methods exemplify their sensitivity. For instance, the gradual addition of coagulant in incremental volumes and the meticulous adjustment of pH in small increments allows for precise determination of the optimum dosage and conditions. These careful adjustments ensure that the experimental conditions are finely tuned, enabling researchers to observe even subtle changes or differences in the measured parameters.

However, despite the rigorous efforts to ensure accuracy, potential sources of error still exist. Measurement errors can occur during the use of pipettes and syringes, leading to inaccuracies in coagulant dosage or sample extraction. Inconsistent mixing speed and duration can introduce discrepancies in the experimental outcomes. Instrument errors may arise if the spectrophotometer, fluorometer, or TOC analyzer are not adequately calibrated or maintained. Furthermore, human errors, including the critical cleaning process, can also influence the results obtained from the experiments.

The cleaning process for syringes, beakers, bottles, and the cuvette is a crucial step that requires meticulous attention to detail. Inadequate cleaning of syringes can result in cross-contamination or even malfunctioning of the equipment, compromising the accuracy of the measurements. Residues or contaminants from previous experiments left in beakers and bottles can contaminate subsequent samples, leading to erroneous results. Similarly, insufficient cleaning of the cuvette can introduce residues that interfere with absorbance and fluorescence measurements, impacting the overall accuracy of the obtained data.

To mitigate these potential errors, it is imperative to adhere to the strict cleaning protocols. Thorough rinsing with appropriate cleaning agents and multiple rinses should be employed to ensure complete removal of any residues. Regular visual inspections, particularly for the cuvette, are essential to confirm its cleanliness. By following stringent cleaning procedures, the potential errors associated with cross-contamination, residues, or contaminants can be minimized which ultimately leads to enhancing the accuracy and reliability of the measurements obtained in water treatment experiments.

Additionally, an often-overlooked factor that can impact the accuracy of pH measurements during the jar test is the time pressure to adhere to the mixing procedure. The jar test involves a specific sequence of mixing steps with designated durations to allow for proper coagulation and floc formation. However, in situations where time constraints or a sense of urgency exist, there may be a tendency to rush through the process, compromising the accuracy of pH measurements.

6

Conclusion

The study aimed to compare the optimum dosage of coagulant with the dosage of coagulant currently used in the water treatment plants (WTPs) in order to determine if the consumption of chemicals could be reduced without compromising the removal efficiency. Through our investigation, we sought to identify the optimum conditions in terms of pH for each WTP, with the objective of achieving the highest removal of Dissolved Organic Carbon (DOC) and Absorbance.

Furthermore, the impact of pH on the removal of DOC and Absorbance were investigated, recognizing its importance in the treatment process. By identifying the optimum pH conditions for each WTP, it is possible to enhance the removal efficiency of these parameters, which in turn could lead to improved water quality.

6.1 Conclusion from results

After conducting a thorough analysis of 11 different water treatment plants (WTPs), it became evident that there is significant potential to reduce the amount of coagulant used in the treatment process. Out of the 11 WTPs studied, 9 of them demonstrated that the optimum dosage for achieving efficient removal of dissolved organic carbon (DOC) and absorbance was actually lower than the dosages currently employed at the time of sample collection. This finding suggests the possibility of reducing chemical consumption and achieving cost savings in WTP operations.

On average, the reduction in dosage between the current practices in WTPs and the determined optimum dosage was approximately 12.5%. This substantial reduction indicates that the current dosages used in WTPs may be excessive, leading to unnecessary chemical expenditures and potentially affecting treatment efficiency. By adopting the recommended optimum dosages, WTPs can not only maintain or improve treatment performance but also realize cost savings.

It is crucial to emphasize that the observed trend of lower optimum dosages does not compromise the efficiency of the treatment process. On the contrary, the study demonstrated that by optimizing the dosage, WTPs can achieve comparable or enhanced removal efficiency of DOC and absorbance while operating with reduced chemical dosages. This finding highlights the potential for implementing sustainable and resource-efficient water treatment practices.

The findings of this study offer valuable insights for water treatment plant operators and emphasize the feasibility and benefits of adopting optimized dosages. However, it is essential to consider the specific characteristics of each WTP and conduct further research to ensure the effective application of these results on a broader scale. Factors such as variations in source water quality, treatment process configurations, and specific local conditions may influence the applicability of the determined optimum dosages.

This study presents a promising approach to reduce chemical consumption in water treatment plants by optimizing coagulant dosage. The significant average reduction of approximately 12.5% in dosage indicates the potential for substantial cost savings without compromising treatment efficiency. By implementing these optimized dosages, WTPs can contribute to sustainability efforts, reduce their environmental impact, and allocate resources more effectively.

While optimizing coagulant dosage offers a straightforward solution, it is important to acknowledge that there is another avenue for improving the coagulation process: exploring the possibility of changing the coagulant itself. By transitioning to more efficient coagulants, WTPs can potentially achieve higher removal efficiencies for DOC and absorbance, allowing for a reduction in chemical dosage while maintaining or improving overall treatment performance.

However, changing the coagulant requires careful evaluation, taking into account the specific characteristics of the source water, treatment objectives, and compatibility with existing processes. Comprehensive laboratory testing and pilot-scale studies are necessary to assess the performance of alternative coagulants and ensure their compatibility with the infrastructure.

Moreover, the cost-effectiveness and availability of the selected coagulant should also be considered. While more efficient coagulants may offer improved treatment performance, their procurement and operational costs may vary. A comprehensive cost-benefit analysis should be conducted to determine the economic feasibility of adopting alternative coagulants.

In conclusion, optimizing coagulant dosage and exploring the possibility of changing the coagulant itself represent valuable steps toward reducing chemical consumption in WTPs. A holistic approach that combines optimized dosage and coagulant selection can lead to more sustainable and effective water treatment processes. Further research is needed, including the development and utilization of advanced sensors for real-time, online monitoring of water quality parameters. By implementing an improved sensor system, WTP operators can continuously optimize chemical dosage, ensuring optimal treatment efficiency while minimizing resource consumption.

This research contributes to the ongoing efforts in water treatment by highlighting the potential for reducing chemical consumption in WTPs and optimizing pH conditions for enhanced removal efficiency.

Continued investigation and technological advancements will further improve the sustainability and effectiveness of water treatment processes, ultimately providing cleaner and safer drinking water for communities worldwide.

Bibliography

AustiaP. (2020). *Jablonski Diagram for EEM* [Bild]. Retrieved January 30, 2023, from https://commons.wikimedia.org/wiki/File:Jablonski_Diagram_for_EEM.jpg

Bratby, J. (2006). Treatment with metal coagulants. *Coagulation and flocculation in water and wastewater treatment*, (2016), 149.

Bridgeman, J., Bieroza, M., & Baker, A. (2011). The application of fluorescence spectroscopy to organic matter characterisation in drinking water treatment The application of fluorescence spectroscopy to organic matter characterisation in drinking water treatment. (November 2016). https://doi.org/10.1007/s11157-011-9243-x

Calgary, A. N. E., Hess, A., Green, W., Battery, G. O., Plc, O., & Slc, A. B. (1995). Water Treatment Water Treatment. https://www.cdc.gov/healthywater/drinking/public/water_treatment.html

EKOFLOCK 90. (n.d.). https://feralco.se/en/Products/Ekoflock%2090

Frimmel, F., & Abbt-Braun, G. (2009). Dissolved Organic Matter (DOM) in Natural Environments. In N. Senesi, B. Xing, & P. Huang (Eds.), *Biophysico-chemical processes involving natural nonliving organic matter in environmental systems* (pp. 367–406). John Wiley & Sons. https://doi.org/https://doi.org/10.1002/9780470494950.ch10

Harvey, D. (2016). *Analytical Chemistry* (2.1). https://open.umn.edu/opentextbooks/textbooks/486

Inorganic coagulants for water treatment - Kemira. (n.d.). https://www.kemira.com/products/inorganic-coagulants-for-water-treatment

LeChevallier, M. W., Au, K.-K., World Health Organization. Water, S., & Team, H. (2004). Water treatment and pathogen control : process efficiency in achieving safe drinking water / Mark W. LeChevallier, Kwok-Keung Au.

Lin, J.-L., Huang, C., Chin, C.-J. M., & Pan, J. R. (2008). Coagulation dynamics of fractal flocs induced by enmeshment and electrostatic patch mechanisms. *Water Research*, *42*(17), 4457–4466. https://doi.org/https://doi.org/10.1016/j.watres.2008.07.043

Nath, A., Mishra, A., & Pande, P. P. (2021). A review natural polymeric coagulants in wastewater treatment. *Materials Today: Proceedings*, *46*, 6113–6117. https://doi.org/https://doi.org/10.1016/j.matpr.2020.03.551

Nathanson, J. A. (2020). *Water supply system.* Retrieved February 2, 2023, from https://www.britannica.com/technology/water-supply-system

Nishi, L., Vieira, A. M. S., Guilherme, A. L. F., Bongiovani, M. C., da Silva, G. F., & Bergamasco, R. (2013). Application of Hybrid Process of Coagulation/Flocculation and Membrane Filtration for the Removal of Protozoan Parasites from Water. In W. Elshorbagy & R. K. Chowdhury (Eds.), *Water treatment*. IntechOpen. https://doi.org/10.5772/51287

Potter, B. B., & Wimsatt, J. C. (2012). USEPA method 415.3: Quantifying TOC, DOC, and SUVA. *Journal - American Water Works Association*, *104*(6), 358–369. https://doi.org/10.5942/jawwa.2012.104.0086

Satterfield, B. Z., & Scientist, N. E. (n.d.). Jar Testing. *Tech Brief*. https://www.nesc.wvu.edu/files/d/3cf372e5-ba40-450c-a3ad-cd774f4c3345/jar-testing.pdf

Sillanpää, M., & Matilainen, A. (2015). Chapter 3 - NOM Removal by Coagulation. In M. Sillanpää (Ed.), *Natural organic matter in water* (pp. 55–80). Butterworth-Heinemann. https://doi.org/https://doi.org/10.1016/B978-0-12-801503-2.00003-3

Sillanpää, M., Matilainen, A., & Lahtinen, T. (2015). Chapter 2 - Characterization of NOM. In M. Sillanpää (Ed.), *Natural organic matter in water* (pp. 17–53). Butterworth-Heinemann. https://doi.org/https://doi.org/10.1016/B978-0-12-801503-2.00002-1

Stephenson, D. (1998). Water Sources. In *Centers for disease control and prevention* (pp. 1–19). https://doi.org/10.1007/978-94-011-5131-3{_}1

Tetteh, E. K., & Rathilal, S. (2019). Application of Organic Coagulants in Water and Wastewater Treatment. In A. Sand & E. Zaki (Eds.), *Organic polymers*. IntechOpen. https://doi.org/10.5772/intechopen.84556

Ulliman, S. L., Korak, J. A., Linden, K. G., & Rosario-Ortiz, F. L. (2020). Methodology for selection of optical parameters as wastewater effluent organic matter surrogates. *Water Research*, *170*, 115321. https://doi.org/https://doi.org/10.1016/j.watres.2019.115321

Wei, N., Zhang, Z., Liu, D., Wu, Y., Wang, J., & Wang, Q. (2015). Coagulation behavior of polyaluminum chloride: Effects of pH and coagulant dosage. *Chinese Journal of Chemical Engineering*, *23*(6), 1041–1046. https://doi.org/https://doi.org/10.1016/j.cjche.2015.02.003

WHO. (2017). WHO Guidelines Approved by the Guidelines Review Committee. *In: Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum*, *4th*.

Wiederschain, G. (2014). The Molecular Probes Handbook . A Guide to Fluorescent Probes and Labeling Technologies. (November 2011), 10–11. https://doi.org/10.1134/S0006297911110101

A

Appendix 1

A.1 Survey

It is important to mention that not all water treatment plants (WTPs) participated in the survey, and therefore, the findings and conclusions of this study are based on the responses received. Each WTP is referenced by a unique identification number to maintain anonymity, and the specific names of the WTPs and contact information are not presented in order to ensure confidentiality.

A.1.1 Layout of survey

1. **Namn på vattenverk**
2. **Fullständigt namn**
3. **Yrkestitel**
4. **Telefonnummer**
5. **E-post**
6. **Total kapacitet för anläggningen?**
7. **Vilken/vilka koagulanter använder ni i er behandlingsprocess?**
8. **Optimal dosering av koagulant per enhet vatten?**

Table A.1: Genomsnittsdosering för årstid g/m^3

Årstid	Vår	Sommar	Höst	Vinter
Dosering				

9. **Ändrar ni typ eller dosering av koagulant, och i så fall, vad orsakar förändringen?**
10. **Finns det en specifik metod för att justera koagulantdoseringen? (t.ex. endast jartester, online-övervakning och indikatorer)**
11. **Vad är kontakttiden mellan koagulant och vatten i er process?**
12. **Använder ni några koagulationshjälpmedel i kombination med koagulant? (t.ex. Kalk, koldioxid, syra/bas) Vänligen specificera.**
13. **Hur många gånger per år utförs jartester på WTP?**
14. **När utför ni vanligtvis jartester?**
15. **Tror ni att ni skulle dra nytta av en sensor före behandlingsanläggningen? På vilket sätt? Vad skulle ni vilja mäta?**

A.1.2 Answers from WTP 3

6. Total kapacitet för anläggningen?
30 000 m^3/dygn.

7. Vilken/vilka koagulanter använder ni i er behandlingsprocess?
PAX-XL100

8. Optimal dosering av koagulant per enhet vatten?

Table A.2: Genomsnittsdosering för årstid g/m^3

Årstid	Vår	Sommar	Höst	Vinter
Dosering	7 g Al/m^3	7 g Al/m^3	7 g Al/m^3	7 g Al/m^3

9. Ändrar ni typ eller dosering av koagulant, och i så fall, vad orsakar förändringen?
Mikrobiologisk barriäranalys (MBA) har visat att WTP 3 har lägre mikrobiologisk barriärverkan än vad som rekommenderas. Detta tillsammans med att råvattnet i Öresjö är utsatt för mycket fekal påverkan gör att stor hänsyn måste tas till den kemiska fällningens förmåga att avskilja sjukdomsframkallande mikroorganismer. Flera omständigheter i vattentäkten gör att den fekala påverkan i råvattnet kan öka kraftigt på kort tid. Detta kan ske utan någon samtidig ökning av färgen i råvattnet och det finns ingen onlineövervakning som larmar när det sker. Med dessa förutsättningar har valet blivit att inte styra fällningsdosen efter råvattnets färg, utan i stället använda en konstant hög dos av fällningskemikalie på 7 g Al /m^3.

10. Finns det en specifik metod för att justera koagulantdoseringen? (t.ex. endast jartester, online-övervakning och indikatorer)?
Nej, se fråga 9.

11. Vad är kontakttiden mellan koagulant och vatten i er process?
Cirka 7 sekunder från dosering av koagulant till dosering av soda.

12. Använder ni några koagulationshjälpmedel i kombination med koagulant? (t.ex. Kalk, koldioxid, syra/bas) Vänligen specificera.
Soda för att justera fällnings pH och höja alkaliniteten, vattenglas för att förbättra sedimenteringen.

13. Hur många gånger per år utförs jartester på WTP?
Inga.

14. När utför ni vanligtvis jartester?
Utförs inte.

15. Tror ni att ni skulle dra nytta av en sensor före behandlingsanläggningen? På vilket sätt? Vad skulle ni vilja mäta?

Inte med nuvarande process. Planering finns att förstärka WTP 3 mikrobiologisk barriärverkan med ultrafiltrering samt en kraftigare UV desinfektion som är mindre beroende av den kemiska fällningen. Efter det kan det vara aktuellt att styra koagulantdosen med en sensor för till exempel råvattnets UV transmittans. Då återstår dock frågan hur dricksvattnets alkalinitet ska kunna styras mot ett börvärde på 60 mg HCO_3^-/L.

A.1.3 Answers from WTP 4

6. Total kapacitet för anläggningen?
16800 m^3/dygn.

7. Vilken/vilka koagulanter använder ni i er behandlingsprocess?
Polyaluminiumklorid PAX 100-XL (Kemira)

8. Optimal dosering av koagulant per enhet vatten?

Table A.3: Genomsnittsdosering för årstid g/m^3

Årstid	Vår	Sommar	Höst	Vinter
Dosering	86 g/m^3	75-85 g/m^3	88 g/m^3	90 g/m^3

9. Ändrar ni typ eller dosering av koagulant, och i så fall, vad orsakar förändringen?
Vi använder endast en och samma koagulant året om, justering av dos sker efter halten organiskt material i råvattnet (vi tittar mest på COD, färgtal, turbiditet). Under sommaren kan vi justera rätt mycket upp och ner ifall vi får problem med smak och lukt då råvattnet ligger runt 20 grader vid den perioden.

10. Finns det en specifik metod för att justera koagulantdoseringen? (t.ex. endast jartester, online-övervakning och indikatorer)?
Vi har idag ett i::scan-instrument som mäter turbiditet, UV254, COD och färgtal i råvattnet för att få en bild av råvattenkvalitén i realtid. Den är idag endast ett hjälpmedel för att justera koagulantdosen vilket görs manuellt, men tanken är att den ska ingå i en reglering där den till viss del styr dosen själv efter ett antal parametrar.

11. Vad är kontakttiden mellan koagulant och vatten i er process?
Ca 22 sekunder från doserpunkt till kontaktfilter.

12. Använder ni några koagulationshjälpmedel i kombination med koagulant? (t.ex. Kalk, koldioxid, syra/bas) Vänligen specificera.
Vi justerar pH och höjer alkaliniteten med kalk+koldioxid.

13. Hur många gånger per år utförs jartester på WTP?
Jartester utförs ej i dagsläget.

14. När utför ni vanligtvis jartester?
Jartester utförs ej i dagsläget.

15. Tror ni att ni skulle dra nytta av en sensor före behandlingsanläggningen? På vilket sätt? Vad skulle ni vilja mäta?
Ett i::scan-instrument finns redan installerat idag som mäter på råvattnet, planer finns på att styra doseringen med hjälp av denna.

A.1.4 Answers from WTP 5

6. Total kapacitet för anläggningen?
Max ca 25 000 m^3/dygn (teoretiskt är den 30 000 m^3/dygn men anläggningen kan idag inte utnyttjas fullt).

7. Vilken/vilka koagulanter använder ni i er behandlingsprocess?
Polyaluminiumklorid och polyakrylamid.

8.Optimal dosering av koagulant per enhet vatten?

Table A.4: Genomsnittsdosering för årstid g/m^3

Å*rstid*	Vår	Sommar	Höst	Vinter
Dosering	36 g/m^3	34,5 g/m^3	36 g/m^3	37 g/m^3

9. Ändrar ni typ eller dosering av koagulant, och i så fall, vad orsakar förändringen?
Vi använder en modell för dosering av polyaluminiumklorid, detta då det är en del snabba förändringar i råvattnet. Råvattnet påverkas mer av flöde och väder än årstidvariationer. Däremot är doseringen av polyakrylamid lägre sommartid (om alls) och något högre vintertid.

10. Finns det en specifik metod för att justera koagulantdoseringen? (t.ex. endast jartester, online-övervakning och indikatorer)?
Onlineövervakning ihop med modell.

11. Vad är kontakttiden mellan koagulant och vatten i er process?
Menar du innan flockningsbassänger eller i flockningsbassäng? Innan vet ej riktigt men max någon minut till några minuter. I flockningsbassängerna ca 2 timmar med medelflöde.

12. Använder ni några koagulationshjälpmedel i kombination med koagulant? (t.ex. Kalk, koldioxid, syra/bas) Vänligen specificera.
Kalk och kolsyra.

13. Hur många gånger per år utförs jartester på WTP?
Görs inte årligen, utan framförallt vid större förändringar eller byte av leverantör.

14. När utför ni vanligtvis jartester?
Görs inte årligen, utan framförallt vid större förändringar eller byte av leverantör.

15. Tror ni att ni skulle dra nytta av en sensor före behandlingsanläggningen? På vilket sätt? Vad skulle ni vilja mäta?
Använder idag iscan för att styra doseringen så vi ser absolut nytta av sensorer, dels pga snabba förändringar i vår råvattentäkt men också för att optimera kemikalieanvändningen.

A.1.5 Answers from WTP 6

6. Total kapacitet för anläggningen?
Råvatten max 300 m^3/h och då får vi ut c:a 265 m^3/h.

7. Vilken/vilka koagulanter använder ni i er behandlingsprocess?
Ekoflock 90 från Feralco.

8.Optimal dosering av koagulant per enhet vatten?

Table A.5: Genomsnittsdosering för årstid g/m^3

$Årstid$	Vår	Sommar	Höst	Vinter
	38 g/m^3	38 g/m^3	38 g/m^3	38 g/m^3

9. Ändrar ni typ eller dosering av koagulant, och i så fall, vad orsakar förändringen?
Byter vi har nog någon annan vunnit upphandlingen. Om vi skulle öka doseringen så kör vi nog verket på max när vattnet är som kallast. Ibland har vi ökat på hösten när sjön vänder men resultatet blir sämre.

10. Finns det en specifik metod för att justera koagulantdoseringen? (t.ex. endast jartester, online-övervakning och indikatorer)
Vi har ph-mätare före och efter + turbmätare.

11. Vad är kontakttiden mellan koagulant och vatten i er process?
Vi har snabbsandfilter/dynasand så det blir bara microflockar.

12. Använder ni några koagulationshjälpmedel i kombination med koagulant? (t.ex. Kalk, koldioxid, syra/bas) Vänligen specificera.
Kalk och Koldioxid. Viss del av kalken fungerar även som fällningskemikalie.

13. Hur många gånger per år utförs jartester på WTP?
Sällan kanske vartannat år.

14. När utför ni vanligtvis jartester?
Oftast när vattnet är som kallast.

15. Tror ni att ni skulle dra nytta av en sensor före behandlingsanläggningen? På vilket sätt? Vad skulle ni vilja mäta?
Vet inte om det finns något mer vi behöver mäta.

A.1.6 Answers from WTP 8

6.Total kapacitet för anläggningen?
12000 m^3/dygn.

7.Vilken/vilka koagulanter använder ni i er behandlingsprocess?
Alumninumsulfat

8.Optimal dosering av koagulant per enhet vatten?
Varierar men ca 40 g/m^3
9.Ändrar ni typ eller dosering av koagulant, och i så fall, vad orsakar förändringen?
Vi ändrar dosering vid olika färgvärden och turbiditet på råvattnet.

10.Ändrar ni typ eller dosering av koagulant, och i så fall, vad orsakar förändringen?
Använder alltid samma koagulant nu, har haft hjälpkoagulant för länge sen.

11. Vad är kontakttiden mellan koagulant och vatten i er process?
Ct-tiden för koagulanten är ca 6 tim vid nuvarande flöden men det varierar.

12. Använder ni några koagulationshjälpmedel i kombination med koagulant? (t.ex. Kalk, koldioxid, syra/bas) Vänligen specificera.
Inga.

13. Hur många gånger per år utförs jartester på WTP?
Inga på ett år exempelvis. Ingen kontinuerlig testning.

14. När utför ni vanligtvis jartester?
Har utfört många jartester när vi haft problem med vissa parametrar, men utför inga tester när det funkar så att säga.

15. Tror ni att ni skulle dra nytta av en sensor före behandlingsanläggningen? På vilket sätt? Vad skulle ni vilja mäta?
Inte direkt, vi har en gedigen vattenprovstagning på råvattnet, prover varje dag även lördag och söndag, skickar även många prover till labb.

A.1.7 Answers from WTP 10

6. Total kapacitet för anläggningen?

7. Vilken/vilka koagulanter använder ni i er behandlingsprocess?
Aluminumsulfat

8. Optimal dosering av koagulant per enhet vatten?
(0,7*färgtal) + 15, minst 34 g/m^3
9. Ändrar ni typ eller dosering av koagulant, och i så fall, vad orsakar förändringen?
Ja om färgtal går upp.

10. Finns det en specifik metod för att justera koagulantdoseringen? (t.ex. endast jartester, online-övervakning och indikatorer)
Online och manuella prover till labbet.

11. Vad är kontakttiden mellan koagulant och vatten i er process?
Vid 500 m^3 i koaguleringen ca 2,5 timmar

12. Använder ni några koagulationshjälpmedel i kombination med koagulant? (t.ex. Kalk, koldioxid, syra/bas) Vänligen specificera.
Kalk och lut för att få pH till 6,6.

13. Hur många gånger per år utförs jartester på WTP?
Nej.

14. När utför ni vanligtvis jartester?
Utförs inte.

15. Tror ni att ni skulle dra nytta av en sensor före behandlingsanläggningen? På vilket sätt? Vad skulle ni vilja mäta?

A.1.8 Answers from WTP 11

6. Total kapacitet för anläggningen?
Ca 180 000 m^3/dygn

7. Vilken/vilka koagulanter använder ni i er behandlingsprocess?
Aluminiumsulfat (ALG), fällingskemikalie.

8. Optimal dosering av koagulant per enhet vatten?
Årsgenomsnitt dos ALG g/m3 , varierar under året, huvudsakligen efter färgtal på råvatten, brukar var högst vinter/tidig vår då vi kan gå upp mot 40 g/m3, varier med årets väder samt mängd och fördelning av nederbörd. Optimal dosering kan inte anges som ett genomsnitt.

Table A.6: Genomsnittsdosering för årstid g/m^3

År	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dosering	34,73 g/m^3	31,28 g/m^3	33,39 g/m^3	31,94 g/m^3	32,14 g/m^3	28,90 g/m^3	27,87 g/m^3	32,05 g/m^3	33,70 g/m^3	28,39 g/m^3

9.Ändrar ni typ eller dosering av koagulant, och i så fall, vad orsakar förändringen?
Vi byter inte fällningskemikalie, för dosering se ovan.

10.Finns det en specifik metod för att justera koagulantdoseringen? (t.ex. endast jartester, online-övervakning och indikatorer)
Vi har en del bägarförsök att se på samt lång erfarenhet av olika driftsfall och online övervakning. Vet inte vad som menas med indikatorer i detta fall, färgtal eller extinktion som ett mått på organiskt innehåll?

11. Vad är kontakttiden mellan koagulant och vatten i er process?
Varierar med belastning, 1-2 timmar, ofta ca 1,5 tim.

12. Använder ni några koagulationshjälpmedel i kombination med koagulant? (t.ex. Kalk, koldioxid, syra/bas) Vänligen specificera.
Vi pH justerar med lut eller kalk före tillsats av fällningskemikalie. Vi tillsätter ingen polymer eller annan hjälpkoagulant.

13. Hur många gånger per år utförs jartester på WTP?
Vid behov.

14. När utför ni vanligtvis jartester?
Kan gå många år utan bägarförsök, görs vid behov.

15. Tror ni att ni skulle dra nytta av en sensor före behandlingsanläggningen? På vilket sätt? Vad skulle ni vilja mäta?
Vi drar nytta av det, mäter f-DOM och försök med Extinktion. Använder även labanalyser. Bra att snabbt och säkert kunna mäta organiskt innehåll/färgtal online, bra om inte turbiditet stör. Allmänt intressant med sensorer på råvatten, både för

behandling och för att kunna välja råvatten, men mkt viktigt vad och hur de mäter, samt att de är lätta att sköta och kvalitetssäkrade.

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