Bachelor's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Materials Science and Engineering

Borghild Espejord
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Optimization of Water Treatment Parameters to Improve Precipitation of Heavy Metals in Industrial Wastewater

Optimalisering av vannrensingparametre for å bedre utfelling av tungmetaller i industrielt avløpsvann

Bachelor's thesis in Chemical Engineering
Supervisor: Ina Merete Stuen
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Preface

This bachelor's thesis was written as part of a chemical engineering bachelor's degree at the Department of Material Sciences and Engineering at the Norwegian University of Science and Technology (NTNU). The subject of this thesis was provided by NOAH AS, which is an environmental and resource company that deals with treatment of hazardous waste. At Langøya, Holmestrand, NOAH operates a water treatment plant that treats wastewater received from Norwegian industry. One of the processes conducted at the water treatment plant, is the removal of heavy metals from wastewater. This bachelor's thesis investigates how the heavy metal removal can be optimized in NOAH's water treatment process.

Firstly, we want to thank Haakon Rui for giving us an engaging and important project that supplied us with valuable engineering experience. Moreover, we want to express our thanks for the experience of visiting Langøya where we got to see the water treatment plant and the process of rehabilitating the natural landscape at the island. We also want to express our gratitude to both Haakon Rui and Sverre Koren, who supervised this bachelor's thesis, for the guidance and support we received.

We want to thank our supervisor at NTNU, Ina Merete Stuen, for guidance and advice throughout this project, and for being available to answer our questions. Lastly, we want to thank Hege Sundgård who helped facilitate our work in the laboratory.

Abstract

The release of heavy metals into nature poses a threat to human health and to other living organisms. Many industries may produce wastewater that contain concentrations of heavy metals that are toxic to humans. Thus, such water requires treatment before it can be released into natural waters. NOAH AS receives wastewater from industry and removes heavy metals through chemical precipitation and flocculation. This bachelor's thesis investigates how the removal of heavy metals can be optimized in NOAH's water treatment process.

In order to investigate how heavy metal removal can be optimized through precipitation and flocculation, jar tests were conducted. Jar test involves performing heavy metal removal on a miniature scale. Beakers were filled with wastewater, and different chemicals and conditions were tested on the water. The heavy metal contents were analysed using an ICP-MS. The water was analysed before and after treatment so that the removal of metals could be quantified.

NOAH AS operates with an emission permit drawn up by the Ministry of Climate and Environment, which specifies the concentrations of heavy metals that can be released into natural waters. Metals specified in this permit are, among others, arsenic, cadmium, nickel and lead. These four metals are prioritized in this bachelor's thesis. Cadmium was the only metal that was present in some samples in higher concentration than the limit.

Chemicals were retrieved from Yara and Kemira. Metalsorb HCO and Metalsorb ZT were determined to be the most efficient metal binders combined with the polymer, Flopam EM 240 CT, which are chemicals supplied by Yara. These chemicals were determined to be optimal because they produced more efficient results for cadmium, which were below the emission limit, and they produced high efficiency at lower pH values than other chemical combinations.

Various conditions were tested to find optimal conditions such as stirring speed, duration of stirring, concentration of chemicals, pH and sedimentation. A pH of 9.8-10 was found to produce the most efficient metal removal overall. Lastly, it was found that minimizing physical interferences such as excessive stirring and mechanical means of separation, produced more optimal results.

Sammendrag

Utslipp av tungmetaller til naturen er en trussel til mennesker og andre organismer. Industri kan produsere avløpsvann med høye konsentrasjoner av tungmetaller som er giftig for mennesker. Dermed renses slikt vann før det slippes ut i naturen. NOAH AS mottar avløpsvann fra industri, og fjerner tungmetaller gjennom kjemisk utfelling og flokkulering i sitt vannrenseanlegg. Denne bacheloroppgaven undersøker hvordan fjerningen av tungmetaller i NOAH sitt vannrenseanlegg kan bli optimalisert.

Det ble utført «jar prøver» for å undersøke hvordan fjerningen av tungmetaller kunne bli optimalisert. Dette innebærer å foreta vannrensing på småskala. Begerglass ble fylt med avløpsvann, og forskjellige kjemikalier og betingelser ble testet på vannet. Tungmetallinnholdet i vannet ble analysert med en ICP-MS. Vannet ble analysert både før og etter vannrensingen slik at fjerningen av tungmetaller kunne bli kvantifisert.

NOAH AS foretar rensing av tungmetaller i henhold til en utslippstillatelse fra Miljødirektoratet. Denne tillatelsen angir konsentrasjoner av tungmetaller som kan slippes ut i naturlige vann. Utslippskonsentrasjoner av, blant annet, arsen, kadmium, nikkel og bly er spesifisert. Disse fire metallene er derfor prioritert i denne bacheloroppgaven. Kadmium var det eneste metallet som forekom i konsentrasjoner over utslippstillatelsen.

Kjemikalier ble mottatt av Yara og Kemira. Metalsorb HCO og Metalsorb ZT ble funnet til å være de mest effektive kjemikaliene for kjemisk utfelling kombinert med Flopam EM 240 CT som er flokkuleringsmiddel. Disse kjemikaliene er fra Yara, og ble bestemt til å være optimale fordi de produserte effektive resultater for kadmium som var under utslippsgrensen. Videre produserte disse kjemikaliene høy fjerning ved lavere pH verdier enn andre kjemikaliekombinasjoner.

Flere andre betingelser ble testet for å finne optimale forhold for fjerning av tungmetaller. Betingelser som ble testet var rørehastighet, røringstid, konsentrasjon av kjemikalier, pH og sedimentering. Verdier for pH som produserte høy effektivitet var mellom 9.8-10. Resultatene viste også at det er fordelaktig å minimere fysiske forstyrrelser i prosessen som for mye røring og mekaniske metoder for separering.

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1 Introduction

Industrial waste often contains toxic substances that pose an environmental risk if released into the environment untreated. Industrial wastewater often contain toxic concentrations of heavy metals. Heavy metals are toxic for human beings and other living organisms, and thus technological solutions have been implemented to remove heavy metals from wastewater released into the environment. In Norway, limits have been placed on heavy metal concentrations that can be released into the environment, which is outlined in § 33-5 in the Pollution Control Act. (1)

NOAH AS is a company that specializes in the treatment of hazardous waste from industry. In the near future, some of these waste streams will be recycled and used in new products that are sold back to industry. Thus, NOAH develops solutions that promote a circular economy where materials are reused and recycled. (2) Such solutions are highly necessary as businesses often require environmental solutions that are profitable.

NOAH operates a wastewater treatment plant located at Langøya in Holmestrand. Here, chemical precipitation is used to remove heavy metals from wastewater, which functions as a neutralization/immobilization treatment. Chemical precipitation is a widely used method worldwide because it is a highly developed and available method. Other methods include ion exchange, osmosis and adsorption. (3, 4)

Langøya is more than a landfill; it is a rehabilitation project to reclaim nature after 100 years of limestone quarrying. The heavy metals that are immobilized from the industrial waste are bonded into a gypsum that can be stored in limestone craters at Langøya. Bonding and precipitation of heavy metals into gypsum inhibits the metals from leaching into the environment. When the craters on the island become full, the landfill is capped, and, gradually, the natural landscape is restored. (2)

The purpose of this bachelor thesis is to examine how the heavy metal removal in NOAH's wastewater treatment plant can be optimized. In order to explore ways to increase the efficiency of heavy metal removal, different precipitation agents and polymers were tested. In addition, conditions such as concentrations of chemicals, stirring speed, duration of stirring and pH were tested to provide additional information that can be used in optimizing the process.

2 Theory

2.1 NOAH wastewater treatment plant

In NOAH's current process two principal chemicals are used: Metalsorb HCO (metal binder) and Flopam EM 240 CT (polymer). Metalsorb binds the heavy metals into metal complexes while Flopam is a polymer that binds the metal complexes into larger structures to ensure effective sedimentation. Moreover, a base (sodium hydroxide, NaOH) is added to achieve an optimal pH for precipitation. The pH of cleaned water cannot exceed 10, as this is the limit set by the Ministry of Climate and Environment. (5)

Figure 1 shows the wastewater treatment process at Langøya. Firstly, the wastewater is mixed with metal binder and polymer, which develops red/brown sludge suspended in water. Due to sedimentation, the sludge gradually sinks to the bottom of the pool. A permeable cloth allows water to flow through, leaving behind much of the flocculated particles. As such, a separation happens between the red/brown sludge water and the cleaner water as can be seen in Figure 1. Another separation step in the process includes a wall just below the surface of the water. This wall enables the cleanest water to flow over, while the flocculated particles will sink. Thus, the process involves physical means of separation that promote sedimentation.

Figure 1: The precipitation and sedimentation pool at the wastewater treatment plant at Langøya.

Furthermore, the treated water goes through several sand and coal filters, which removes oil, mercury, and other organic components, before the water is sampled and pumped to sea. In Figure 2, a schematic representation of the process is shown. The figure includes the sedimentation pool and the sand and coal filters. In this bachelor thesis, it is the precipitation/flocculation process in the sedimentation pool that will be examined.

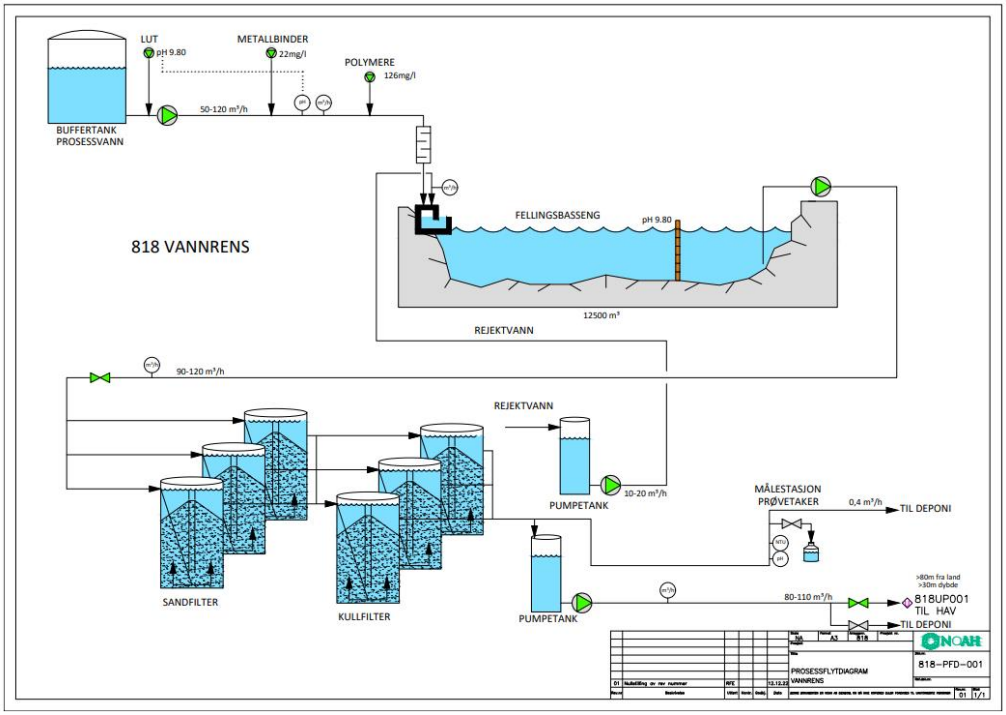

Figure 2: Schematic representation of the wastewater treatment process at Langøya. (6)

NOAH operates with a permit of emissions drawn up by the Ministry of Climate and Environment. This permit specifies the concentrations of certain heavy metals that can be released into natural waters. Among these metals are arsenic, cadmium, nickel and lead as listed below in Table 1.

Table 1: Emission limits of selected metals for NOAHs water treatment plant. From NOAH's emission permit (5)

Metal	Emission limits	
	Concentration limit (daily average)	Mass limit (yearly average)
As	0.03 mg/L	4.0 kg
Cd	0.03 mg/L	5.0 kg
Ni	0.07 mg/L	7.0 kg
Pb	0.03 mg/L	4.0 kg

2.2 Toxicity of heavy metals/environmental concerns

The release of heavy metals into the environment poses serious health risks for humans and other living organisms. Heavy metals do enter water streams and soil from natural sources such as rock and aquifers. However, there is growing concern regarding heavy metals that enter the environment from anthropogenic sources. These sources include mining, industry, sewage, metallurgical industry, thermal power plants and agriculture. (7)

Heavy metals are highly soluble in water; thus, they are easily absorbed by living organisms such as plants, fish and humans thereby entering the food chain. Accumulation of heavy metals in the human body can pose serious health risks, including cancer, organ damage, nervous system damage and autoimmunity. (8) Some heavy metals are important for human health in trace amounts. (7) These include Cu, Co, Zn, Fe, Mn, Mo, etc. (7) However, these metals also become toxic when they exceed concentrations that are healthy for humans. Other heavy metals are nonessential for human health, and pose serious health risks to humans and other organisms. (7) Examples of such toxic heavy metals are As, Pb, Cd and Hg. (7)

2.3 Chemical precipitation

Common precipitation reactions with heavy metals produce compounds with low solubility such as hydroxides, sulphides and carbonates. The pH is adjusted to create optimal conditions to produce such insoluble compounds. Lime ($Ca(OH)_2$), caustic soda (NaOH), soda ash ($NaCO_3$), sodium bicarbonate ($Na(HCO_3)_2$), sodium sulphide (Na_2S) and sodium hydrosulphide (NaHS) are commonly used to treat industrial effluent. (9)

A standard chemical formula for chemical precipitation of metal hydroxides is shown in Equation {1}. (8) An anionic precipitating agent reacts with the cationic heavy metal to produce an insoluble product.

$$M^{2+} + 2(OH)^{-} \leftrightarrow M(OH)_2 \qquad \{1\}$$

Metal hydroxide precipitation and metal sulphide precipitation are two commonly used methods. The process of metal hydroxide precipitation is advantageous due to simple implementation, low cost and low pH. On the other hand, it is difficult to achieve an ideal pH for a wide range of metals simultaneously, which may lead to metal complexes redissolving in solution. Metal sulphide precipitation, on the other hand, produces metal complexes with lower solubility than metal hydroxide precipitation. The use of sulphide precipitants provides more efficient metal removal over a wider pH range. The disadvantages of this method include possible production of hydrogen sulphide gas and the production of colloidal particles that are difficult to separate. Alternative chemicals have been developed to mitigate these problems. (10)

Alternative chemicals used include chelating ligands, dithiocarbamate compounds and compounds containing thiol groups. (10) In NOAH's current process Metalsorb is used, which is a polymeric thiocarbamate that consists of a sulfur derivative combined with an organic molecule. (3, 11) The positively charged metal ions react with the anionic sulfur derivative to form a chelate complex as shown in Figure 3. (11) The chemical is highly soluble and has multiple functional groups that can form complexes, which enables

Metalsorb to remove >99.5% of heavy metals in solution. (3) This removal efficiency is necessary as heavy metals are often present at extremely low concentrations that are toxic.

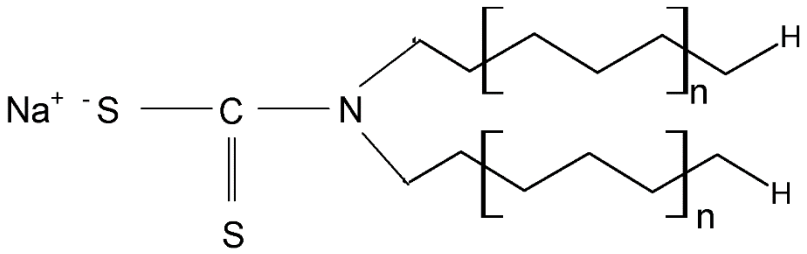

Figure 3: The chemical structure of Metalsorb. (3)

The sulfur based Metalsorb produces metal complexes with lower solubility compared to complexes with carbonate and hydroxide as shown in Table 2. (12) This means that Metalsorb will form metal complexes that will not easily redissolve in solution. Furthermore, its low solubility enables Metalsorb to function effectively over a wide range of pH (3-10). (12)

Table 2: Solubility of heavy metal complexes. (12)

Metal	Carbonate	Hydroxide	Sulphide
Ag	5	16	4×10^{-15}
Hg	10^{-2}	6×10^{-13}	10^{-36}
Ni	2	4×10^{-3}	6×10^{-7}
Pb	6×10^{-6}	3×10^{-7}	8×10^{-13}
Zn	10^{-3}	5×10^{-4}	5×10^{-7}

2.4 Thermodynamics and kinetics of precipitation reactions

A system is in thermodynamic equilibrium when the chemical potential of the liquid phase is equal to the chemical potential of the solid phase as shown in Equation {2}. (13)

$$\mu_{liquid} = \mu_{solid} \quad \{2\}$$

With the addition of a metal binder, a reaction occurs, which alters the equilibrium state for the system. The chemical potential of the product is increased, exceeding the value at equilibrium. This change in chemical potential is the thermodynamic driving force for the

reaction as shown in Equation {3}. The solution becomes supersaturated with respect to the product. (13)

$$\Delta\mu = \mu_{liquid} - \mu_{liquid,eq} = \mu_{liquid} - \mu_{solid} \quad \{3\}$$

The precipitation reaction proceeds according to different mechanisms. The three main mechanisms are nucleation, growth and agglomeration, see Figure 4. The mechanism that takes place is dependent on the kinetics of the reaction. Nucleation is the process whereby a solid phase is formed in solution. Nucleation can occur spontaneously in solution or by induction due to foreign particles or formed crystals present in the solution. Growth is another mechanism where crystals in solution become enlarged. Lastly, agglomeration occurs when solid particles come into contact and stick together. This is a process that can lead to impurities as particles can become trapped inside the solid structure. (13)

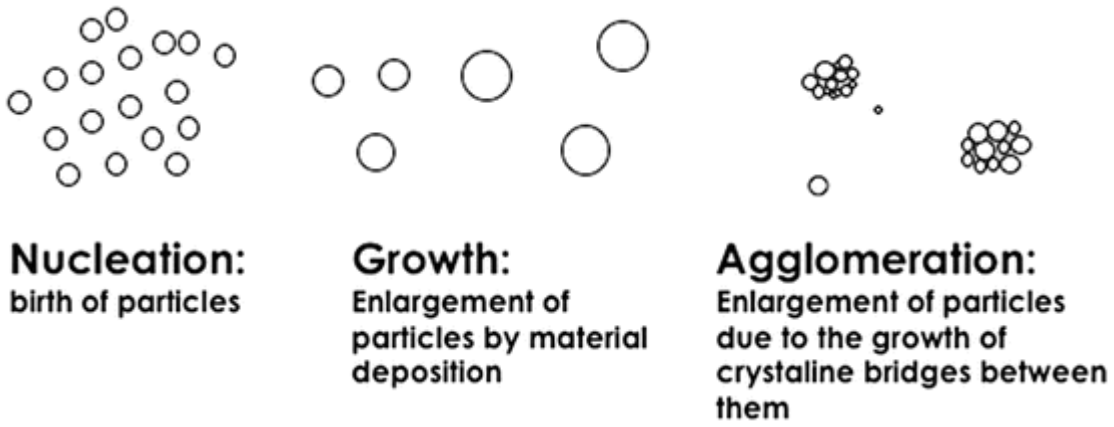

Figure 4: Precipitation mechanisms. (13)

All three mechanisms are dependent on supersaturation levels. Nucleation can take place at high levels of supersaturation while growth can take place at a lower level. If the supersaturation levels are sufficiently high in the solution, then nucleation will be favoured, leading to a suspension of small particles. On the other hand, if the supersaturation levels are lower, larger particles can be formed. Agglomeration is dependent on collisions as well as the supersaturation level. Thus, agglomeration will be favoured when a high number of particles is present in solution. (13)

Figure 5 shows the relationship between the three mechanisms and supersaturation levels. In addition, crystal size is shown in relation to the three mechanisms.

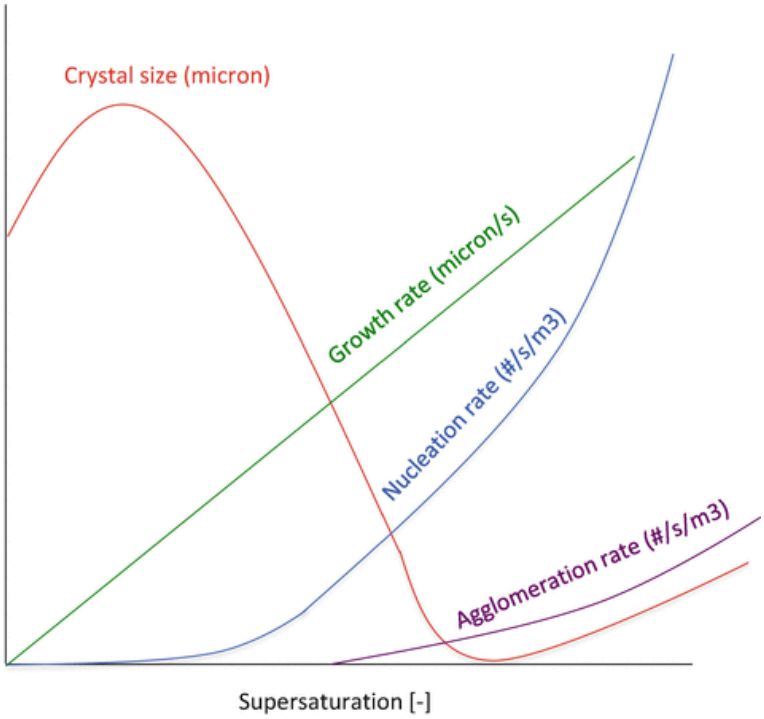

Figure 5: Relationship between supersaturation and mechanisms of product formation. (13)

2.5 Flocculation polymers

Chemical precipitation binds the heavy metals into metal complexes that are insoluble. However, these particles are present in small sizes and may repel due to surface charges, which stabilizes the colloidal suspension and inhibits sedimentation. (14) Therefore, industrial processes often use flocculation chemicals that bind the precipitates into larger solid aggregates that will result in more effective sedimentation.

Synthetic water soluble polymers have become widely used in industry due to cost efficiency and easy handling. (14) Small dosages of polymer flocculant are required to achieve the desired effect. (14) However, it can be challenging to find the optimal polymer dosage. If an insufficient dosage is added, the dewatering process will be ineffective; and if too much polymer is added, it can lead to charge reversal effects that interferes with the process. (15) Other factors that may influence the performance of the flocculant are mixing intensity, water composition, particle size, charge density, molecular weight and the ionic strength and pH of the solution. (14, 15)

Depending on the flocculant used, different mechanisms of flocculation occur, see Figure 6. Three common mechanisms are charge neutralization, polymer bridging and electrostatic patch. Charge neutralization is the mechanism whereby a cationic flocculant destabilizes a suspension of particles with negatively charged surface, which results in agglomeration. The second mechanism involves polymer bridging. Here a long, linear chain of polymer is adsorbed by the contaminant through intra- and intermolecular forces. The long chain of polymer will continue to adsorb onto more particles thereby bridging the colloidal particles suspended in solution. Lastly, electrostatic patch is a mechanism that results from using a

polymer of low molecular weight and high charge density. The charge of the polymer is complementary to the colloidal particles, which promotes adsorption of the polymer onto the contaminant to form flocs. (14)

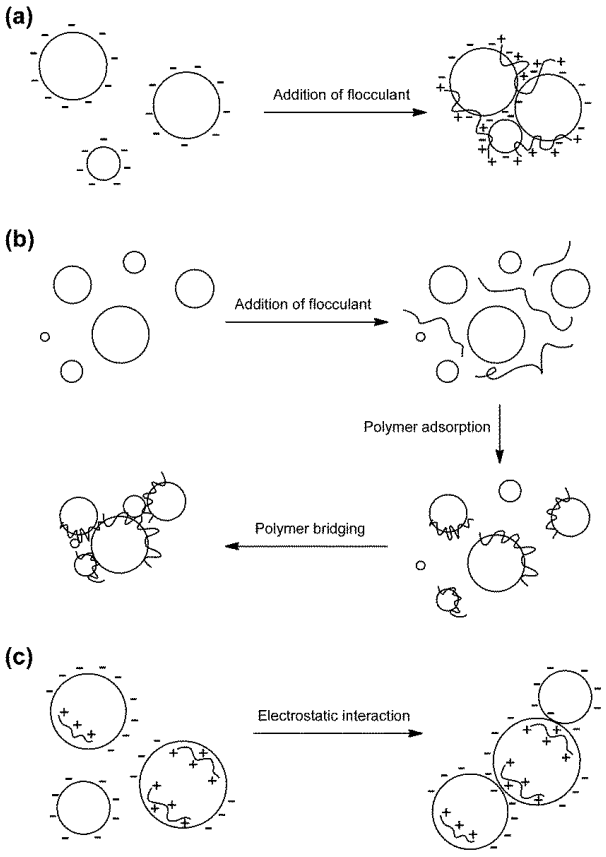

Figure 6: Mechanisms of flocculation by a) charge neutralization, b) polymer adsorption and bridging and c) electrostatic patch. (14)

2.6 Sedimentation and flocculation

Sedimentation is a process whereby particles are removed from suspension due to the force of gravity, which causes the particles to settle. This is a widely used process at wastewater treatment plants. The sedimentation rate is dependent on multiple variables such as the shape, size and specific gravity of the particles. Furthermore, factors such as viscosity, temperature and quiescence of the water are important to consider. (16)

Sedimentation can be performed with or without chemical coagulation. Depending on the particle size, plain sedimentation (sedimentation without use of chemicals) may not be economically feasible. Heavy particles may settle rapidly without the addition of chemicals. However, a suspension of fine particles with a diameter of 10 µm or less and low density, will require the addition of a coagulant. As mentioned above, the coagulant or flocculant will increase the particle size and promote settling. (16)

With the addition of a flocculant, stirring can be applied to ensure efficient flocculation. Stirring ensures that the flocculation polymer comes in contact with the metal complexes,

thus facilitating flocculation. The stirring velocity should not be too high as this may break apart newly formed flocculated particles. A longer duration for the process is often required to compensate for lower stirring speed. (11)

2.7 Jar test

In this bachelor thesis, Jar tests were conducted. Jar test is a systematic approach to test dosages of chemicals and other conditions to find the optimal conditions for a certain water treatment process.

The apparatus used was a multiple stirrer where multiple samples could be tested at a time. Figure 7 shows the set-up of the experiment. Furthermore, the multiple stirrer has lighting that improves observation.

Multiple sources of error can affect the results when conducting jar tests. These interferences can include temperature change, gas release and testing period. If the temperature changes in the room or if there is a heat source close to the samples, thermal or convection currents can occur. This may interfere with sedimentation. Gas release can happen if fast stirring is used or if the chemical reaction produces gas. This can cause flotation of particles that inhibits sedimentation. Lastly, the time between sampling of the wastewater and experimentation will affect the composition of the water, and should thus be minimized. (17)

Figure 7: Jar-test set up in multiple stirrer.

2.8 Triplicate test

Triplicate tests were conducted in this bachelor thesis. This means that the same method and conditions were applied in three samples. Then the average value was calculated from the samples.

2.9 Chemicals used in experimentation

Metalsorb HCO is the metal binder currently used in NOAH's wastewater treatment plant, which is supplied by Yara. Additional metal binder retrieved from Yara for experimentation were Metalsorb PCZ, ZM 3, ZT and HCO. Metalsorb HCO is the same metal binder that Yara supplies to NOAH. Flopam EM 240 CT is the polymer currently used in NOAH's process, which is also supplied by Yara. Flopam EM 240 CT is a linear cationic polyacrylamide of medium molecular weight. (15, 18)

KEMIRA PAX-18, PAX-XL3103G, and PIX-111 are metal binders retrieved from Kemira. PAX-18 and PAX-XL3103G are aluminium based while PIX-311 is iron based. The polymers retrieved from Kemira are the following: SUPERFLOC A-130HMW and A-110HMW, which are anionic polyacrylamides; and C-494HW and C-491HMW, which are cationic polyacrylamide. See Appendix A.

3 Materials and Methods

3.1 Instruments

- pH-meter PHM210 Standard pH meter, MeterLab, Radiometer analytical
- ICP-MS
- Centrifuge Kubota 2010
- Multiple stirrer, Velp Scientifica, JLT6 Flocculation Tester
- Analytical balance
- Precision balance

3.2 Chemicals

- Flopam EM 240 CT, Yara. Retrieved from NOAH AS.
- Metalsorb HCO, Yara. Retrieved from NOAH AS.
- Buffer solution pH = 7.00 ±0.02 (25°C)
- Buffer solution pH = 10.01 ±0.02 (25°C)
- NaOH 1M
- KEMIRA PAX-18, retrieved from Kemira
- KEMIRA PAX-XL3103G, retrieved from Kemira
- KEMIRA PIX-311, retrieved from Kemira
- SUPERFLOC A-130HMW, retrieved from Kemira
- SUPERFLOC A-110HMW, retrieved from Kemira
- SUPERFLOC C-494HMW, retrieved from Kemira
- SUPERFLOC C-491K, retrieved from Kemira
- Metalsorb PCZ, retrieved from Yara
- Metalsorb ZM 3, retrieved from Yara
- Metalsorb ZT, retrieved from Yara
- Metalsorb HCO, retrieved from Yara

3.3 Approach

In order to examine how NOAH's heavy metal removal process can be optimized, jar-tests were conducted. A multiple stirrer was used where 6 samples could be tested at a time; thus 6 samples often constituted one trial. Different chemicals and different conditions such as stirring speed, stirring time, concentration, and pH were tested. Moreover, triplicate tests were performed, and the effect of sedimentation was tested. The set up of the experiment is shown in Figure 7.

The chemicals used in the experiment were retrieved from NOAH, Yara and Kemira. Slightly differing methods were used for some trials depending on the chemicals used. The method used for the chemicals retrieved from NOAH (supplied by Yara) and Yara are based on the wastewater treatment process at Langøya, whereas the method used for chemicals from Kemira was based on recommendations from Kemira. (19) Thus, three slightly differing methods are described in chapter 3.5.

The standard method, expressed in chapter 3.5, is mostly followed with the exception of certain conditions. In chapter 3.6, the method used in each trial is specified.

3.4 Wastewater used in experimentation

The wastewater used in experimentation was sampled by NOAH two times. The first sampled water was used for most of the trials, and the second sampled water was used for the triplicate tests in trials 16-19 and trial 10. Reference concentrations were obtained for the wastewater by analysing untreated wastewater in the IPC-MS. Three such reference analyses were obtained for each sampling of water and the average was calculated of the values. These two averages were used in order to determine the degree of heavy metal removal for the trials conducted in experimentation.

3.5 Preparation and dilution of chemicals

In Table 3, the standard concentrations used in the experimentation are listed. The concentrations of the Metalsorb chemicals and of Flopam EM 240 CT (retrieved from Yara) were prepared according to the dosages used in NOAH's water treatment process. The chemicals from Kemira were prepared according to recommendations from the supplier. (19) Concentrations used in all the samples are listed in Appendix C.

Table 3: Standard concentration of chemicals.

Chemicals	**Concentration in final solution**	**Concentration prepared**	**Amount added**
Metalsorb, Yara	1.9×10^{-3} L/L	0.990 mL/L	10 mL
Flopam EM 240 CT, Yara	1.5×10^{-5} g/L	0.078 g/L	10 mL
KEMIRA PAX and PIX, Kemira	50 µL/L	Pure chemical	50 µL
SUPERFLOC, Kemira	2×10^{-4}g/L	1 g/L	200 µL

All the Metalsorb solutions, retrieved from NOAH and Yara, used in experimentation, were prepared using the same approach. Based on calculations in Appendix B1, it was found that 0.990 mL/L would produce a final concentration of 1.9×10^{-3} L/L, which was the final concentration obtained in NOAH's process when the Metalsorb was mixed with the wastewater in the precipitation pool. Thus, the Metalsorb solutions were prepared by transferring 0.990 mL of Metalsorb, using a 100-1000 µL micropipette, to a 1000 mL volumetric flask. Then the volumetric flask was filled with water to the mark.

Flopam EM 240 CT was prepared by weighing 0.78 g of liquid polymer on a precision balance in a 1000 mL volumetric flask, which was then filled with water to the mark. The solution was stirred on a magnetic stirrer until homogenous. After the solution was properly mixed, 100mL of the solution was transferred to a new 1000mL volumetric flask using a

100mL volumetric pipette. Lastly, the new flask was filled with water to the mark, and the solution was placed on a magnetic stirrer for a minimum of 20 minutes.

The metal binders retrieved from Kemira did not require dilution. The dosages that were recommended by Kemira are listed in Table 3. The polymers retrieved from Kemira were prepared by weighing 1.00 g of powdered polymer on an analytical balance and adding the powder to a 1000 mL volumetric flask. Then the volumetric flask was filled with water to the mark. The polymer solutions were mixed for 1-3 hours.

3.6 Standard method

3.6.1 Preparation of samples and adjustment of pH

For trials where chemicals from NOAH and Yara were used, 1000 mL beakers were filled with 500 mL wastewater. For the trials where chemicals from Kemira were used, 2000 mL beakers were filled with 1000 mL wastewater.

The pH of the wastewater had to be adjusted before the metal binder and polymer could be added. Adjustment of pH was achieved using a pH-meter. Before use, the pH-meter was calibrated using a buffer with a pH of 7.00 and a buffer with a pH of 10.01. A 3 mL pipette was used to transfer sodium hydroxide (1M) into the samples. A standard pH of 9.8 was used for the chemicals retrieved from NOAH and Yara. For the chemicals retrieved from Kemira, a higher pH of 10-10.5 was used as the metal binders were more acidic. The adjusted pH values in all samples are listed in Appendix D.

3.6.2 Addition of chemicals

For trials that used chemicals retrieved from NOAH, 10 mL of metal binder was added to each of the six 1000 mL beakers, followed by 10 mL of polymer. The polymer was quickly added after the metal binder. This was done using a 10mL volumetric pipette and a clean pipette was used for each chemical solution. The beakers were placed into the multiple stirrer and the stirring was started. Initially, the speed of the rotation blades was set to 120 rpm for one minute to ensure effective mixing. (17) Then the speed was lowered to 20 rpm for 20 minutes. (17)

The same method was used for trials that used chemicals retrieved from Yara as the one for NOAH except for one change. The metal binder was added to the samples first and were stirred for 1 minute at 120 rpm. Then the polymer was added, and the samples were stirred for another 20 minutes at 20 rpm.

For trials that used chemicals retrieved from Kemira, the dosages listed in Table 3 were added. 50 µL metal binder was added to all the samples using a 20-200 µL micropipette, and the samples were then stirred in the multiple stirrer. The speed of the rotation blades was set to 120 rpm for 1 minute. Then the speed was lowered to 20 rpm for 4 minutes. Thereafter, the beakers were removed from the multiple stirrer, and 200 µL polymer was added to the

samples using a 100-1000 µL micropipette. The beakers were placed back into the multiple stirrer, and the rotation speed was set to 20 rpm for 10 minutes.

3.6.3 Collection of samples

The time for the first flocculated particles to form was observed. (17) After the stirring was completed, the rotation blades were removed from the beakers, and settling was allowed to occur. For trials 1-7, the period of settling was 15 minutes, whereas for the remaining trials, the period was 1-5 minutes. 40 mL from each beaker was transferred into 50 mL centrifuge tubes. The sample water was collected using a 3 mL pipette that was placed half-way into the beaker to retrieve the water. A clean pipette was used for each transfer.

The centrifuge tubes were placed in a centrifuge that was run for 5 minutes at a speed of 3200 rpm. Four centrifuge tubes could be placed in the centrifuge at one time. Thus, four tubes were centrifuged first followed by the last two tubes. After this step, 30 mL of the centrifuged sample was transferred to 6 new 50 mL centrifuge tubes. These tubes were marked and numbered, and then sent to NOAH's laboratory where the heavy metal contents were analysed using an IPC-MS. All concentrations analysed are in Appendix E.

3.7 Method specified for each trial

In this chapter the conditions that were varied in the trials are specified. One or a few conditions were tested at a time, and a summary of the trials are listed in Table 4, Table 5 and Table 6.

Table 4: Overview of trials 1-15. Conditions that are varied between samples or differs from standard conditions are specified.

Chemicals retrieved from NOAH AS		**Chemicals retrieved from Yara**		**Chemicals retrieved from Kemira**	
Trials		**Trials**		**Trials**	
1	Standard conditions	8	Combinations of chemicals (pH=9.8)	11	Combinations of chemicals
2	Metalsorb HCO concentration	9	Combinations of chemicals (pH=10)	12	Combinations of chemicals
3	Flopam concentration	10	Concentration of Metalsorb ZT	13	Concentration of PAX-18
4	Metalsorb HCO and Flopam concentration			14	Concentration of SUPERFLOC A-130
5	PH (9.2, 9.4, 9.6, 9.8, 10, 10.2)			15	Concentration of PAX-18 and SUPERFLOC A-130
6	Stirring time (5, 10, 15, 39, 40 and 50 minutes)				
7	Stirring speed (10, 15, 25, 39, 35 and 40 rpm)				

Table 5: Overview of triplicate tests, trial 16-19.

Trials	**Supplier**	**Metal binder and polymer**
16	Yara (retrieved from NOAH)	Metalsorb HCO, Flopam EM 240 CT
17	Yara	Metalsorb ZT, Flopam EM 240 CT
18	Kemira (NOAH method)	PAX 18, Flopam EM 240 CT
19	Kemira	PAX 18, SUPERFLOC A-130

Table 6: Overview of pH test and sedimentation/pH test, trial 20-21.

Trials	Test	Chemicals
20	PH (9.6, 9.7, 9.8, 9.9, 10, 10.1)	Metalsorb HCO and Flopam EM 240 CT, retrieved from NOAH
21	Sedimentation/pH test	Metalsorb HCO and Flopam EM 240 CT, retrieved from NOAH

3.7.1 Trials: Chemicals retrieved from NOAH

Trial 1: Standard method

The standard method was conducted in trial 1. One sample was tested under standard conditions.

Trial 2: Concentration of Metalsorb HCO

In trial 2, the concentration of Metalsorb HCO solution was varied. The other variables were kept constant according to the standard method described in chapter 3.5. The standard concentration of Flopam solution was used, which is 0.078 g/L. The concentrations of Metalsorb tested were 0.495 mL/L, 0.740 mL/L, 0.870 mL/L, 1.1 mL/L, 1.2 mL/L, and 1.5 mL/L for samples 1-6 respectively. When transferring the chemicals into the samples, a clean volumetric pipette was used for each transfer.

In Table 7, the concentrations of Metalsorb that were added into the beakers and the final concentrations in the samples are listed. An example of calculation is in Appendix B2.

Table 7: Concentrations of diluted solutions and final concentrations of Metalsorb HCO.

Samples	Fraction of standard Metalsorb HCO concentration	Metalsorb HCO in diluted solution (mL/L)	Concentration of Metalsorb HCO in final solution (mL/L)
1	1/2	0.495	0.00952
2	3/4	0.740	0.0142
3	7/8	0.870	0.0167
4	9/8	1.10	0.0212
5	5/4	1.20	0.0231
6	3/2	1.50	0.0288

Trial 3: Concentration of Flopam EM 240 CT

In trial 3, the concentration of Flopam EM 240 CT was varied, while the other variables were kept constant. The concentration used for Metalsorb HCO was 0.990 mL, which is the standard listed in Table 3. The concentrations of Flopam prepared were 0.039 g/L, 0.059 g/L, 0.068 g/L, 0.088 g/L, 0.098 g/L, 0.117 g/L for samples 1-6 respectively, as shown in Table 8.

1.17g of Flopam was weighed on a precision balance and was transferred to a 1000mL volumetric flask that was diluted to the mark with water. This solution was further diluted to prepare 6 different concentrations of polymer solution. This was done by transferring different volumes from the prepared solution to 6 new 1000mL volumetric flasks. As listed in Table 8, the following volumes were added to new volumetric flasks: 100 mL, 83 mL, 75 mL, 58 mL, 50 mL and 33 mL.

Volumetric pipettes of 100 mL and 50 mL were used for the 100 mL and 50 mL solutions, respectively. A 100 mL measuring cylinder was used for the 83 mL, 75 mL and 58 mL solutions, and a 50 mL measuring cylinder was used for the 33 mL solution. The six new solutions were stirred on a magnetic stirrer for a minimum of 20 minutes.

In Table 8, the concentrations tested are shown. In Appendix B2, there is shown an example for calculating the concentrations.

Table 8: Concentrations of diluted solutions and final concentrations of Flopam EM 240 CT.

Sample	**Fraction of standard polymer concentration**	**Polymer in diluted solution (g/L)**	**Concentration of polymer in final solution (process) (g/L)**	**V diluted polymer added to final volumetric flask (mL)**
1	1/2	0.039	7.50×10^{-4}	33
2	3/4	0.059	1.13×10^{-3}	50
3	7/8	0.068	1.31×10^{-3}	58
4	9/8	0.088	1.69×10^{-3}	75
5	5/4	0.097	1.88×10^{-3}	83
6	3/2	0.117	2.25×10^{-3}	100

Trial 4: Concentration of Metalsorb HCO and Flopam EM 240 CT

In trial 4, the concentrations of Metalsorb and Flopam were varied simultaneously. The concentrations that were tested were the same concentrations that were prepared in trial 2 and 3. The concentrations of Metalsorb and Flopam were added in the same order as in trial 2 and 3 as shown in Table 9.

Table 9: Concentrations of chemicals added in each sample in trial 4.

Samples	Metalsorb HCO added (mL/L)	Metalsorb HCO final conc. (ml/L)	Flopam EM 240 CT added (g/L)	Flopam EM 240 CT final conc. (g/L)
1	0.495	0.00952	0.039	7.50×10^{-4}
2	0.740	0.0142	0.059	1.13×10^{-3}
3	0.870	0.0167	0.068	1.31×10^{-3}
4	1.10	0.0212	0.088	1.69×10^{-3}
5	1.20	0.0231	0.097	1.88×10^{-3}
6	1.50	0.0288	0.117	2.25×10^{-3}

Trial 5: pH test

In trial 5, different pH-values in the wastewater were tested. The pH-values tested were 9.2, 9.4, 9.6, 9.8, 10, and 10.2 for trials 1-6 respectively. The other variables were kept constant according to the standard method described in chapter 3.5.

Trial 6: Stirring duration

In trial 6, different durations of stirring were tested. These durations were 5, 10, 15, 30, 40, and 50 minutes for samples 1-6 respectively. The six beakers were stirred simultaneously. First, stirring was conducted at a speed of 120 rpm for one minute according to the standard procedure. Then the stirring speed was set to 20 rpm. The beakers were removed from the multiple stirrer after 5, 10, 15, 30, 40, and 50 minutes respectively. The other variables were kept constant according to the standard method described in chapter 3.5.

Trial 7: Stirring speed

In trial 7, different stirring speeds were tested. The multiple stirrer could only be run at one speed at a time. Thus, one beaker was tested at a time. The stirring speeds tested were 10, 15, 25, 30, 35 and 40 rpm for samples 1-6 respectively.

3.7.2 Trials: Chemicals retrieved from Yara

Trial 8 and 9: Chemical combinations, Yara

Chemicals from Yara were tested, which were Metalsorb HCO, PCZ, ZT and ZM 3. These were tested for samples 1-4 respectively in each trial. In trial 8, the pH was adjusted to 9.8, whereas in trial 9, the pH was adjusted to 10.

Trial 10: Concentration of Metalsorb ZT

Different concentrations of Metalsorb ZT were tested. This was done by preparing the standard concentration for Metalsorb listed in Table 3. In order to achieve different final concentrations, different volumes of the standard concentration were added to the beakers. The volumes added to samples 1-6 were 4, 6, 8, 12, 14 and 16 mL respectively. These volumes were added using volumetric pipettes of the following volumes, 1, 2, 3, 4, 5, 10 and 15 mL. For certain samples two volumetric pipettes had to be used to achieve a certain volume. The pH was adjusted to 10.

3.7.3 Trials: Chemicals retrieved from Kemira

Trial 11: Chemical combinations, Kemira

In trial 11, combinations of metal binder and polymer were tested as shown in Table 10. Each metal binder was tested with each polymer. The samples were prepared by adjusting the pH to 10.5, which was recommended by Kemira. (19)

Table 10: Combinations of metal binder and polymer tested in trial 11.

Samples	Metal binder	Polymer
1	PAX-18	C-494
2	PAX-XL31036	C-494
3	PIX-311	C-494
4	PAX-18	A-110
5	PAX-XL31036	A-110
6	PIX-311	A-110

Trial 12: Chemical combinations, Kemira

The same method was followed as for trial 11. The combinations of chemicals tested are listed in Table 11.

Table 11: Combinations of metal binder and polymer tested in trial 12.

Samples	Metal binder	Polymer
1	PAX-18	C-491
2	PAX-XL31036	C-491
3	PIX-311	C-491
4	PAX-18	A-130
5	PAX-XL31036	A-130
6	PIX-311	A-130

Trial 13: Concentration of PAX-18

The concentration of the metal binder, PAX-18, was varied. The metal binder was not diluted but varying volumes were added to the sample in increments of 10 µL. The volumes added were 20, 30, 40, 50, 60 and 70 µL for samples 1-6 respectively.

Trial 14: Concentration of SUPERFLOC A-130

The concentration of polymer, SUPERFLOC A-130, was varied. The volume was varied in increments of 20 µL to achieve different final concentrations. The volumes added were 140, 160, 180, 200, 220, 240 µL for samples 1-6 respectively.

Trial 15: Concentration of PAX-18 and SUPERFLOC A-130

The concentration of metal binder, PAX-18, and polymer, SUPERFLOC A-130, were varied simultaneously in the same order as in trial 14 and 15 as shown in Table 12.

Table 12: Trial 15, Volume of PAX-18 and SUPERFLOC A-130.

Samples	**Volume of PAX-18 added (µL)**	**Volume of SUPERFLOC A-130 added (µL)**
1	20	140
2	30	160
3	40	180
4	50	200
5	60	220
6	70	240

3.7.4 Trials: Triplicate tests

Trial 16: Triplicate test using chemicals retrieved from NOAH

A triplicate test (3 samples) was conducted using the chemicals retrieved from NOAH. The standard method was followed with one exception: the concentration of Flopam added was 1.17 g/L.

Trial 17: Triplicate test using chemicals retrieved from Yara

A triplicate test (3 samples) was conducted where Metalsorb ZT, retrieved from Yara, was tested. The standard method was followed with one exception: the concentration of Flopam added was 1.17 g/L.

Trial 18: Triplicate test using chemicals retrieved from Kemira (NOAH method)

A triplicate test (3 samples) was conducted using PAX-18 and Flopam EM 240 CT. The same method was used as for the chemicals retrieved from Yara and NOAH in order to test the metal binder from Kemira under similar conditions as the chemicals from Yara and NOAH.

Trial 19: Triplicate test using chemicals retrieved from Kemira

A triplicate test (3 samples) was conducted using PAX-18 and SUPERFLOC A-130. The standard method for Kemira trials was followed.

3.7.5 Trial: pH test and sedimentation/pH test

Trial 20: pH test

The pH values tested were 9.6, 9.7, 9.8, 9.9, 10 and 10.1 for samples 1-6 respectively. Metalsorb HCO and Flopam EM 240 CT retrieved from NOAH were used. First Metalsorb was added and stirred for 1 minute at 120 rpm. Then the stirring speed was lowered to 20 rpm for 4 minutes. Thereafter, Flopam was added, and the samples were stirred for 15 minutes at 20 rpm.

Trial 21: Sedimentation/pH test

In trial 21, three samples were not centrifuged but were placed on the counter so that sedimentation could occur. The samples stood on the counter for a total of five days. The pH was measured to observe change in pH over time. Samples were also taken from the beakers on the third day. The adjusted pH in samples 1-3 were 9.8, 9.9 and 10 respectively.

The method used for this trial was slightly different from the standard method. Chemicals retrieved from NOAH were used. Metalsorb HCO was added and stirring was conducted for 1 minute at 120 rpm followed by 4 minutes at 20 rpm. Then the polymer was added, and the samples were stirred for 15 minutes at 20 rpm.

4 Results and discussion

In this chapter, the efficiency of heavy metal removal is presented in figures and tables. The figures aim to show the effects of the different chemicals and conditions tested during experimentation. The results are presented in such an order that similar trials can be compared to each other more easily.

A total of 19 heavy metals were analysed by NOAH, using an ICP-MS. 12 of these metals are omitted from the results as these metals had concentrations that stayed mostly constant or were erroneous. In addition, some of these metals are not listed in the emission permit or Norwegian emission laws and are thus not prioritized. The concentrations of all the metals analysed can be found in Appendix E.

The metals prioritized in the results are arsenic, cadmium, nickel, and lead. This is because NOAH operates with a permit outlined by the Ministry of Climate and Environment that specifies the concentrations of these metals that can be released into natural waters. (5) Chromium is also specified in the permit; however, this metal was not present in the wastewater in sufficiently high concentrations to be analysed. Other metals that are analysed in this section are copper and zinc as these metals are specified in Norwegian emission laws. (20)

4.1 Observations

In this sub-chapter, an overview is given for the observations made during experimentation as these observations were often quite similar for many of the trials conducted.

Metalsorb HCO formed brown/white particles. These particles became visible in most of the samples after 1 minute, and the precipitated particles became enlarged with the addition of polymer. After stirring was completed, much of the particles underwent sedimentation while some particles remained suspended in solution for the duration of sedimentation time. In Figure 8, an example is shown of a sample where Metalsorb HCO and Flopam EM 240 CT were added.

In Figure 9, another example is shown of a sample containing chemicals from Yara, which in this sample is Metalsorb ZM 3. Flocculated particles can be seen slightly clustered together and are not evenly mixed in the solution.

In Figure 10, a sample is shown in which chemicals from Kemira were added. In samples where Kemira chemicals were used, precipitated particles were quickly formed after 1 minute and the particles became visibly enlarged after the addition of polymer. These particles have a white or orange colour, depending on the metal binder used, and were evenly mixed in the solution.

In Figure 11, an example is shown of a sample where the wastewater contained precipitation before any reaction had taken place. Some samples contained such discoloration to varying degrees. The wastewater was retrieved from NOAH and were contained in buckets. Precipitated particles were concentrated at the bottom of the buckets, and these particles entered some of the samples.

The pH in the wastewater before the pH was adjusted was around 9. Thus, the water already had high basicity, which may have caused some metals to precipitate before the water treatment reaction had taken place. Such precipitation made observation difficult for some of the samples. Moreover, it can be postulated that the presence of such particles may have affected the results by interfering with the reaction taking place after the addition of chemicals. (10)

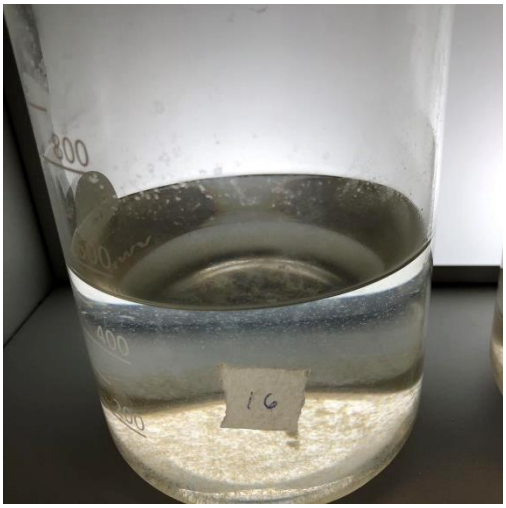

Figure 8: Trial 2, Metalsorb HCO and Flopam

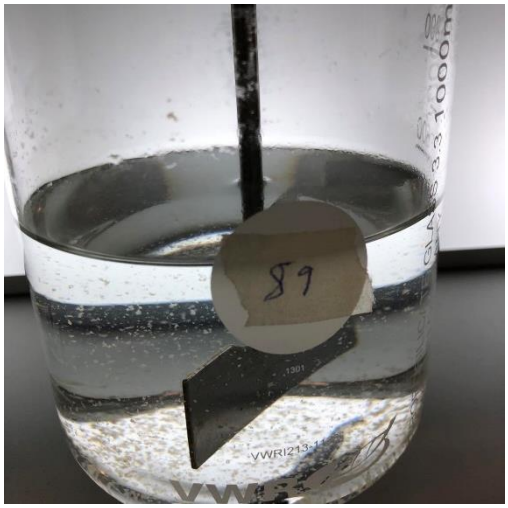

Figure 9: Trial 9, Metalsorb ZT and Flopam

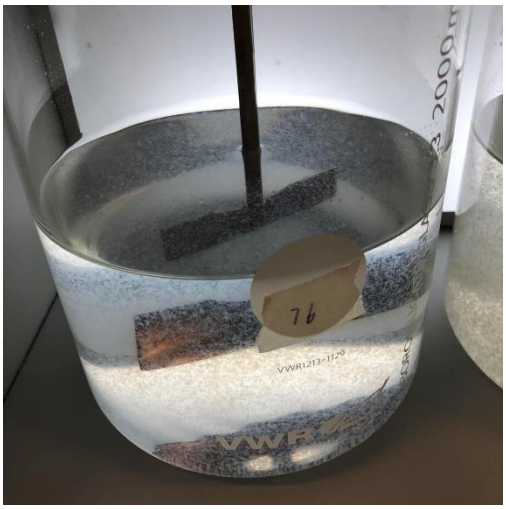

Figure 10: Trial 11, PAX-18 and SUPERFLOC C-494

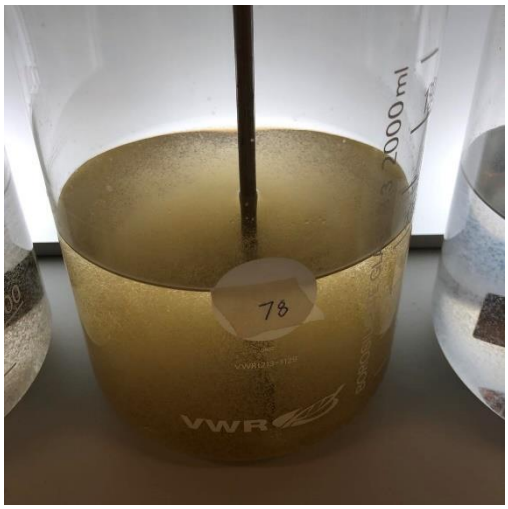

Figure 11: Trial 11, PIX-311 and SUPERFLOC C-494

4.2 Reference values

The wastewater was samples two times as described in chapter 3.4 Wastewater used in experimentation. Three samples were taken from each sampling, and the average value of the

three samples was used as a comparison for the contents of the treated samples. In Table 13, the average concentrations of the metals present in the wastewater before treatment are listed.

Table 13: Average reference concentrations before metal removal.

Metals	Reference average, sampled wastewater 1 (µg/L)	Reference 1, standard deviation	Reference average, sampled wastewater 2 (µg/L)	Reference 2, standard deviation
As	4.77	1.69	6.57	0.83
Cd	66.23	1.31	150.67	1.53
Cu	54.80	6.76	46.93	2.77
Ni	15.07	2.73	19.10	1.80
Pb	9.77	6.81	15.57	2.10
Zn	70.60	48.64	115.33	14.64

4.3 Standard test based on NOAH's current process

4.3.1 Trial 1: Standard test

In trial 1, the standard method was used, which is the method based on NOAH's current process. The chemicals used were Metalsorb HCO and Flopam EM 240 CT, and the pH was adjusted to 9.8.

The percentage removal and concentration after removal for each heavy metal is presented below in Table 14. Calculation example for percent removal can be found in Appendix B3. All percentage removals calculated can be found in Appendix F.

Table 14: Percentage removal of heavy metals in trial 1.

Metals	Percent removal (%)	Concentration after removal (µg/L)
As	60.14	1.90
Cd	84.60	10.20
Cu	84.12	8.70
Ni	61.50	5.80
Pb	96.93	0.30
Zn	95.75	3.00

4. 4 Duration of stirring

4.4.1 Trial 6: Duration of stirring

Metalsorb HCO and Flopam EM 240 CT were used, and the pH was adjusted to 9.8. The stirring durations tested for samples 1-6 were 5, 10, 15, 30, 40 and 50 minutes respectively.

Figure 12 and Figure 13 show the concentration of metals in each of the six samples after treatment.

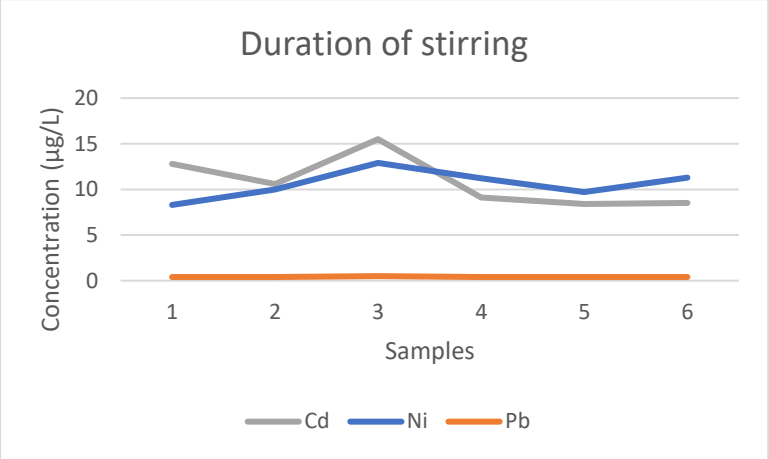

Figure 12: Trial 6, concentration of Cd, Ni and Pb in samples after metal removal.

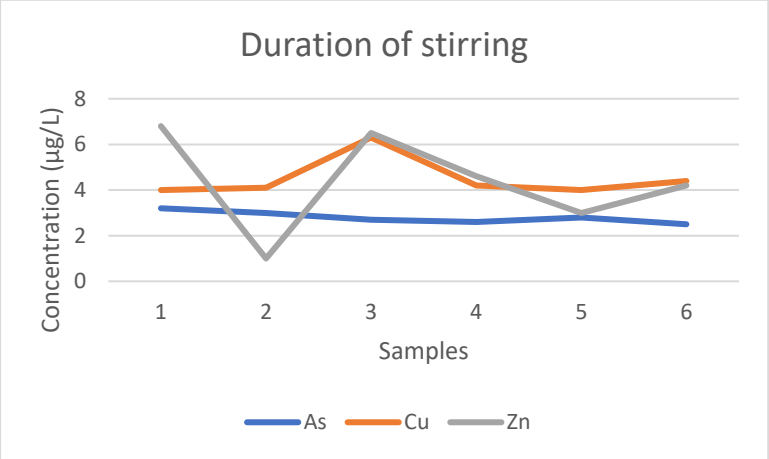

Figure 13: Trial 6, concentration of As, Cu and Zn in samples after metal removal.

The results for trial 6 do not have much variation. In Figure 12 and Figure 13, some variation can be seen for cadmium, copper, nickel and zinc, but these are not significant variations. Zinc, for example, had a percent removal within the range of 90.34%-98.58%. These values can be found in Appendix F. The metal with the most variation in the results is nickel, which has a percent removal within the range of 14.38%-44.91%. A possible cause for this variation in nickel, will be discussed in chapter 4.11 Comparison between trials.

No clear trend can be observed from these results, which might suggest that the duration of stirring does not have a significant impact on the percent removal. There was observed a gradual increase in precipitation from the first to the last sample, which could suggest an increase in efficiency. However, this observation was not confirmed by the results, and could have been impacted by the presence of precipitated particles that were already present in the wastewater in the last two samples.

4.5 Stirring speed

4.5.1 Trial 7: Stirring speed

Metalsorb HCO and Flopam EM 240 CT were used, and the pH was adjusted to 9.8. The stirring speeds tested in trial 6 were 10, 15, 25, 30, 35 and 40 rpm for samples 1-6 respectively.

Figure 14, Figure 15 and Figure 16 show the concentrations of metals for the six samples. Additional information such as percent removal for each metal can be found in Appendix F.

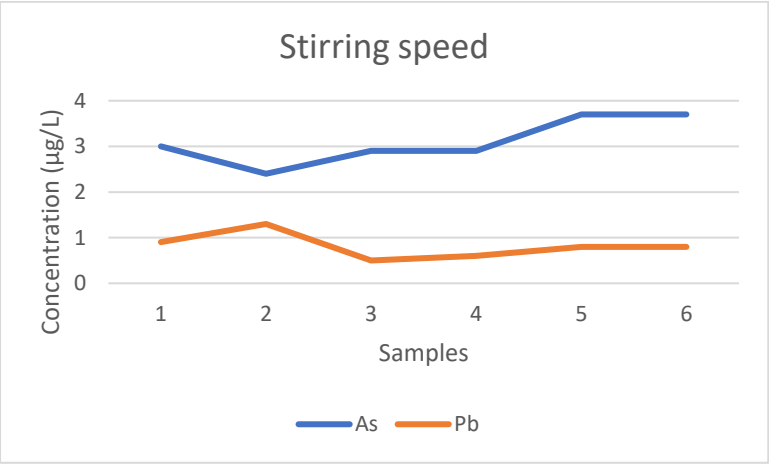

Figure 14: Trial 7, concentration of As and Pb in samples after metal removal.

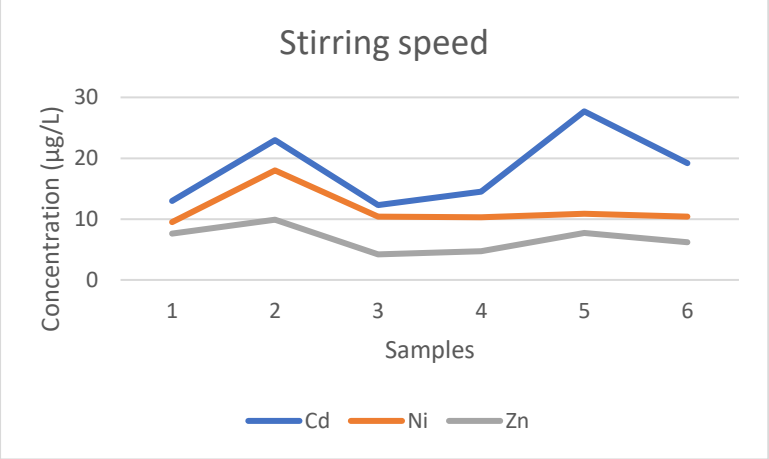

Figure 15: Trial 7, concentration of Cd, Ni and Zn in samples after metal removal.

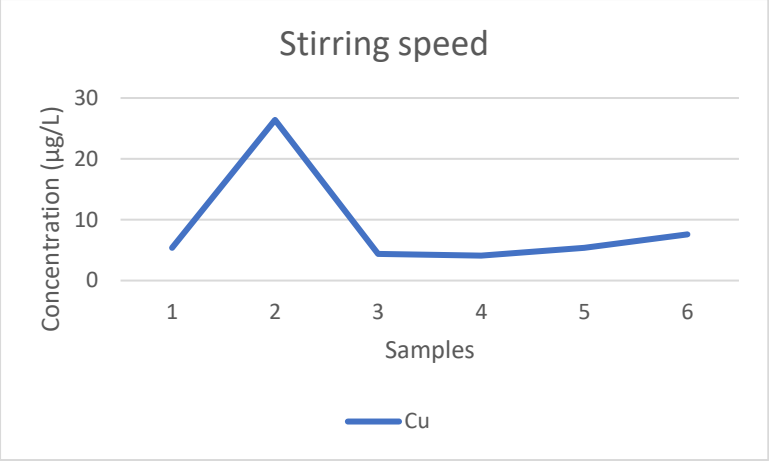

Figure 16: Trial 7, concentration of Cu in samples after metal removal.

In Table 15, total percent removal for each sample is shown. Calculation example is in Appendix B4.

Table 15: Trial 6 and 7, total percent removal of metals.

Trials/Samples (%)	**1**	**2**	**3**	**4**	**5**	**6**
6	83.95	86.85	79.93	85.49	87.21	85.85
7	82.19	63.39	84.32	83.23	74.60	78.35

Trial 7, where stirring speed was tested, showed more variation in the results than trial 6, which can be seen in Figure 14, Figure 15 and Figure 16. The heavy metal removal was slightly lower for this trial than for stirring duration. This can be seen in Table 15 where trial 6 have total percent removals around 80% while trial 7 has percent removals of around 60%, 70% and 80%. This coincides with expectations as too much stirring can break apart formed particles, thereby interfering with flocculation. (11)

4.6 Chemicals retrieved from Yara

4.6.1 Trial 8 and 9: Combinations of chemicals, Yara

Four Metalsorb chemicals were retrieved from Yara. These were added to samples 1-4 in the respective order: Metalsorb HCO, PCZ, ZT and ZM 3. In trial 8 and 9, the pH was 9.8 and 10 respectively.

In Figure 17 and Figure 18, sample 4 in both trials are pictured. This is to show an example of the difference in precipitation formed between the two trials. In Table 16, the total percent removals for trial 8 and 9 are listed.

Figure 17: Reaction with Metalsorb ZM 3 and pH = 9.8.

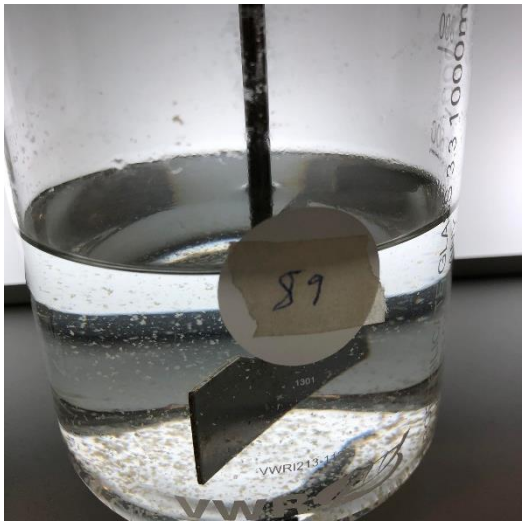

Figure 18: Reaction with Metalsorb ZM 3 and pH = 10.0.

Table 16: Trial 8 and 9, total percent removal of metals.

Trials/samples (%)	HCO	PCZ	ZT	ZM3
8	68.31	71.70	77.99	58.82
9	82.24	82.10	85.58	79.16

In trial 8, where the pH used was 9.8, small, white particles that remained suspended in solution were observed as exemplified in Figure 18. In trial 9, where a pH of 10 was used, larger particles were formed and the particles underwent faster sedimentation, as exemplified in Figure 18. These observations are also confirmed in the results where trial 9 is the more efficient trial. In trial 8, the total percent removal is within a range of 58.82%-77.99, while in trial 9 the range is 79.16%-85.58% as seen in Table 16.

The reason for this significant difference in precipitation is probably due to the difference in pH. This may suggest that a higher pH is necessary to ensure effective heavy metal removal when using Metalsorb HCO, PCZ, ZT and ZM 3. This could be because low dosages of Metalsorb are used, and thus an optimum pH needs to be in place to compensate for the low chemical dosages. (11) Moreover, this may suggest that the efficiency differences between the chemicals becomes less notable when a high pH is used in the water.

Figure 19 and Figure 20 show the removal efficiency for the metals, As, Cd, Ni and Pb, using the four Metalsorb chemicals from Yara.

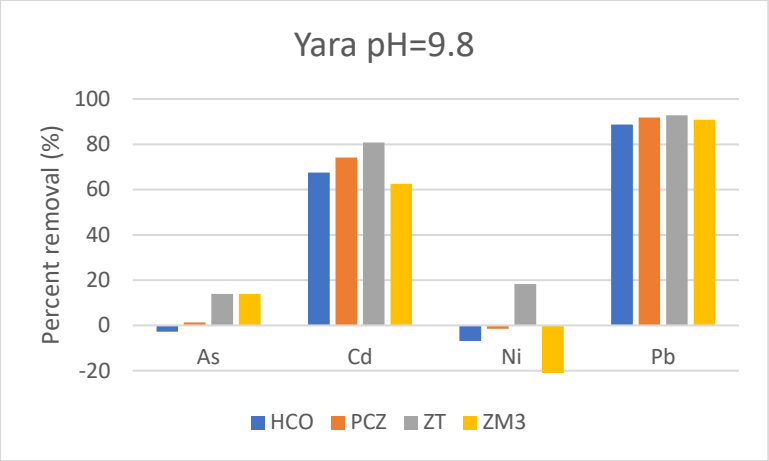

Figure 19: Trial 8, percent removal of arsenic, cadmium nickel and lead using Yara chemicals.

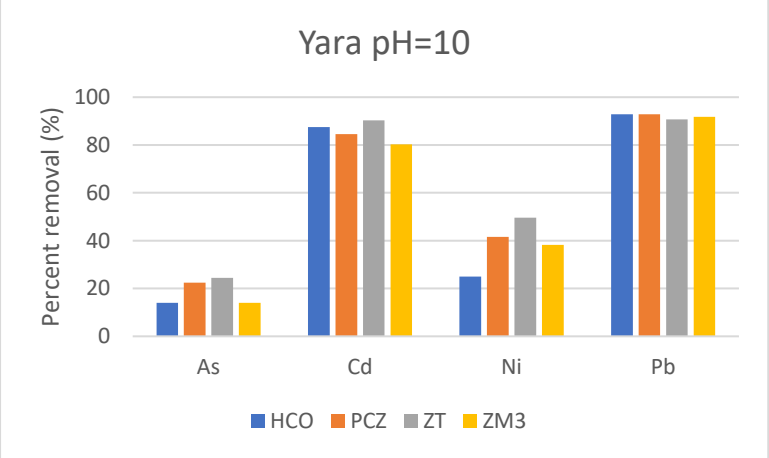

Figure 20: Trial 9, percent removal of arsenic, cadmium, nickel and lead using Yara chemicals.

Among the chemicals received from Yara, which included Metalsorb HCO, PCZ, ZT and ZM 3, Metalsorb ZT was found to be the most efficient. In Figure 19 and Figure 20, it can be seen that Metalsorb ZT is the most efficient chemical for arsenic, cadmium and nickel. Metalsorb ZT is also efficient for lead, which had a constant metal removal of around 90%. All the metal binders were efficient for the removal of zinc, although these results contained more variation.

The findings are summarized in Table 17, which shows the optimal metal binder for each heavy metal analysed.

Table 17: Optimal metal binder among Yara chemicals.

Metals	Metal binder
As	ZT
Cd	ZT
Cu	ZT
Ni	ZT
Pb	All
Zn	All (inconclusive)

4.7 Chemicals retrieved from Kemira

4.7.1 Trial 11 and 12: Combinations of chemicals, Kemira

The 12 different combinations of chemicals received from Kemira were tested, and the pH was adjusted to 10.5.

In Figure 21, Figure 22, Figure 23, and Figure 24, the percent removal of arsenic, cadmium, nickel and lead is plotted against the chemical combinations. The letters, A, B, C and D, are used to denote the polymers, while numbers, 1, 2 and 3, are used to denote the metal binders as listed below in Table 18.

Table 18: Notation used for Kemira chemical combinations.

Metal binder	Polymer
1: PAX-18	A: SUPERFLOC C-494
2: PAX-XL3103G	B: SUPERFLOC A-110
3: PIX-311	C: SUPERFLOC C-491
	D: SUPERFLOC A-130

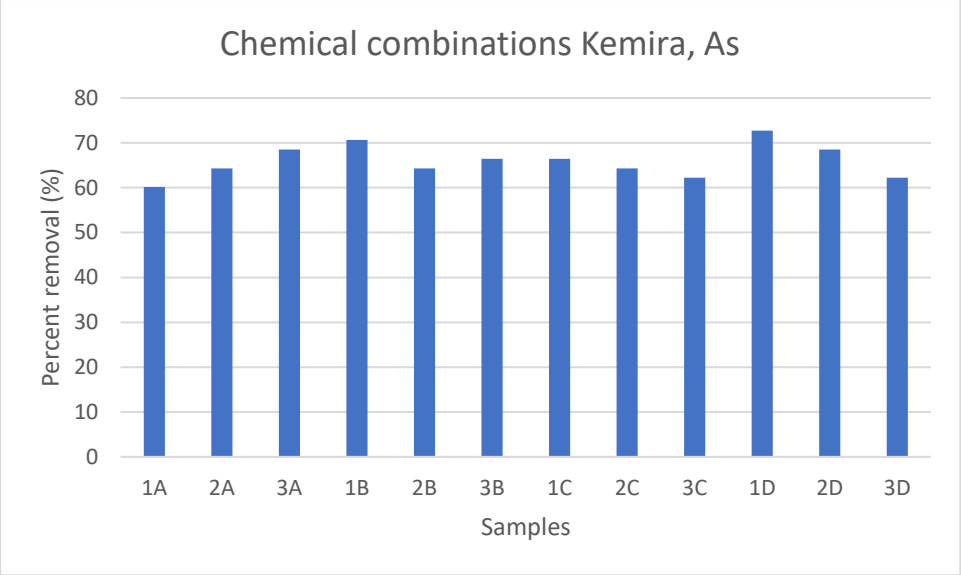

Figure 21: Trials 11 and 12, percent removal of arsenic. Polymer and metal binder combinations in each sample are indicated by numbers and letters as listed in Table 18.

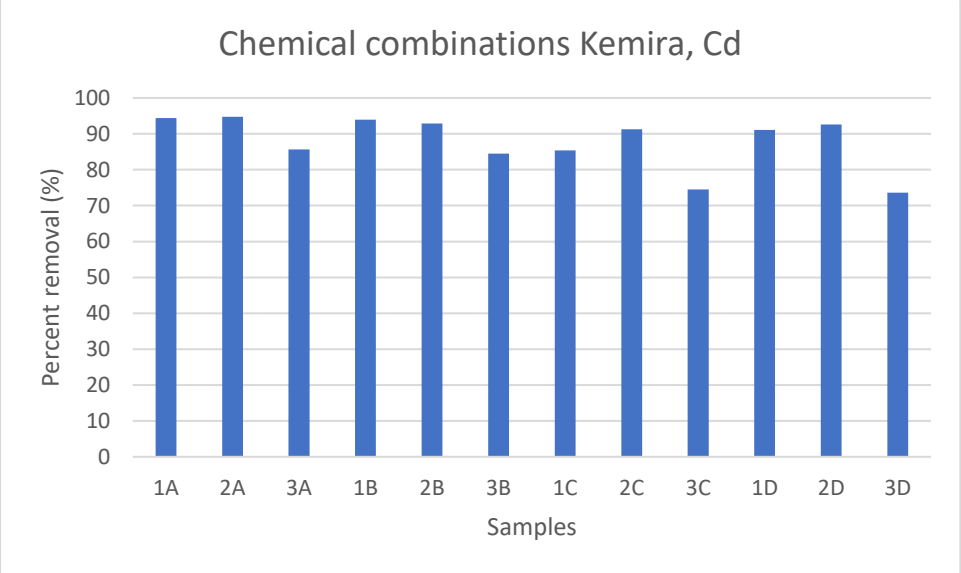

Figure 22: Trials 11 and 12, percent removal of cadmium. Polymer and metal binder combinations in each sample are indicated by numbers and letters as listed in Table 18.

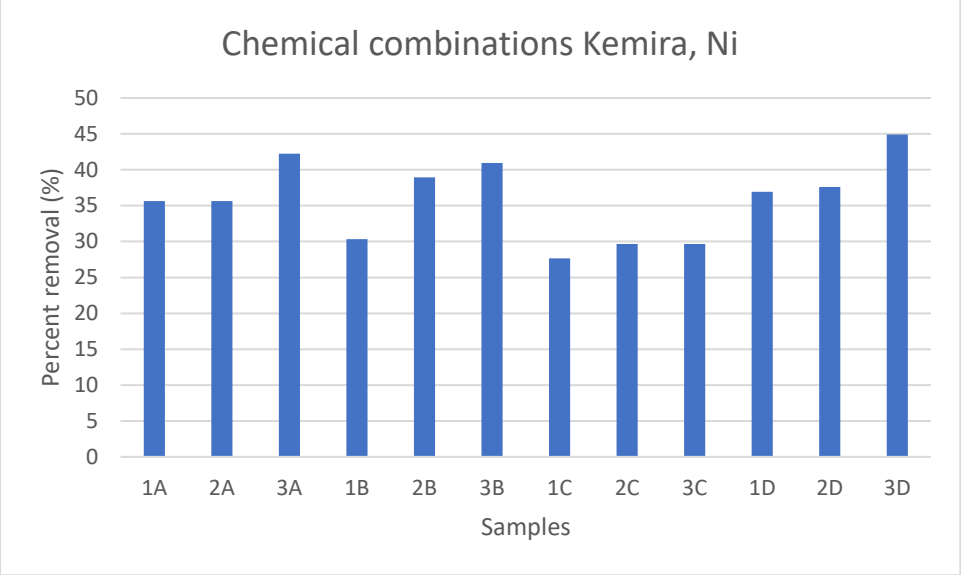

Figure 23: Trials 11 and 12, percent removal of nickel. Polymer and metal binder combinations in each sample are indicated by numbers and letters as listed in Table 18.

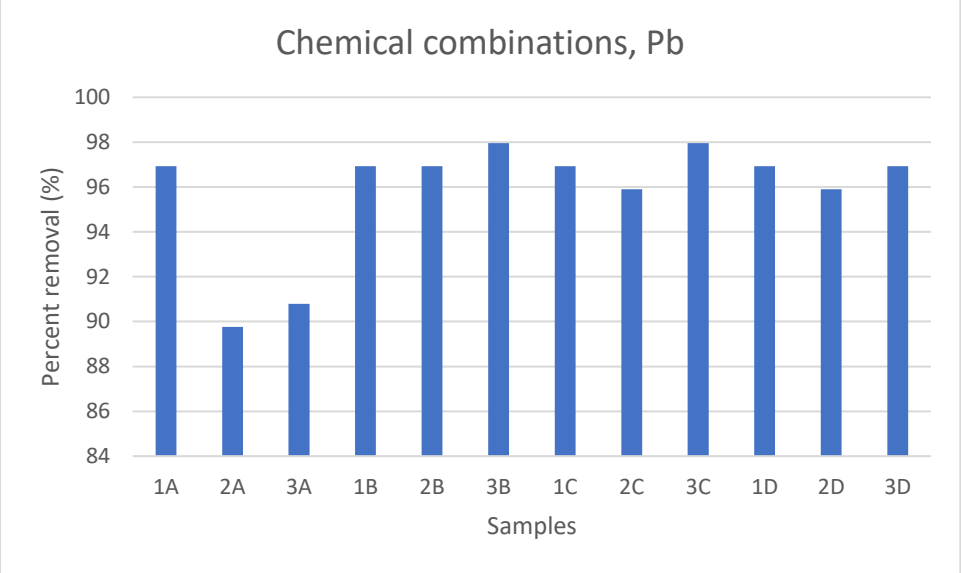

Figure 24: Trials 11 and 12, percent removal of lead. Polymer and metal binder combinations in each sample are indicated by numbers and letters as listed in Table 18.

In Figure 21, it can be seen that 1D produced the highest percent removal for arsenic. 1B is also an efficient chemical combination. The percentage removals produced by 1D and 1B are 72.73% and 70.63% respectively.

The most efficient chemical combination for cadmium was 2A, which produced a percent removal of 94.72% as shown in Figure 22. Other efficient combinations were 1A, 2A, 1B, 2B, 1D and 2D where all the percentage removals surpassed 90%. As can be seen in Figure 22, combinations where PAX-18 and PAX-XL3103G are used, produced the most efficient results.

For nickel, the most efficient chemical combination is 3D, consisting of PIX-311 and SUPERFLOC A-130. This can be seen in Figure 23. This combination produced a percent removal of 44.91%. Other efficient combinations were 3A and 3B. Thus, PIX-311 was the most optimal metal binder for nickel. PAX-18 (1D) also produced slightly less efficient results with a percent removal of 36.95%. Combinations where PAX-18 is used produced higher metal removal than combinations with PAX-XL3103G.

In Figure 24, the most efficient chemical combinations can be observed for lead, which are 3B and 3C. However, all the chemical combinations produce a percent removal above 95% apart from 2A and 3A, which produced percent removals of 89.76% and 90.78% respectively.

The optimal combination was chosen to be 1D, consisting of PAX-18 and SUPERFLOC A-130. This is because it was the most optimal combination for arsenic and among the most optimal combinations for cadmium. For nickel the most optimal metal binder was PIX-311, however, this metal binder is closely followed by PAX-18 in efficiency. Lastly, most combinations were efficient for lead.

The optimal metal binder and polymer among Kemira chemicals for each heavy metal is presented in Table 19.

Table 19: Optimal metal binder and polymer among Kemira chemicals.

Metals	Metal binder	Polymer
As	PAX-18	A-130
Cd	PAX XL3103G (PAX-18)	All
Cu	All	C-491
Ni	PIX-311 (PAX-18)	A-130
Pb	All	All
Zn	All	All

4.8 Concentration of chemicals

4.8.1 Trial 2, 3 and 4: Concentrations of Metalsorb HCO and Flopam EM 240 CT

Concentrations of chemicals retrieved from NOAH were tested in trials 2, 3, and 4. The concentrations of Metalsorb HCO tested in trial 2 were 0.495 mL/L, 0.740 mL/L, 0.870 mL/L, 1.10 mL/L, 1.20 mL/L and 1.50 mL/L for samples 1-6 respectively. The concentrations of Flopam EM 240 CT tested in trial 2 were 0.039 g/L, 0.059g/L, 0.068 g/L, 0.088 g/L, 0.097 g/L, 0.117 g/L for samples 1.6 respectively. The same order of concentrations of both Metalsorb HCO and Flopam EM 240 CT were tested in trial 4. The adjusted pH was 9.8.

In Table 20, the total percentage removal is shown for the metals analysed.

Table 20: Total percentage removal of metals for trial 2, 3 and 4.

Trials/samples (%)	1	2	3	4	5	6
2	70.03	84.59	83.64	69.62	78.71	87.30
3	93.31	84.81	84.54	89.60	80.61	82.64
4	89.83	92.00	92.72	89.65	86.58	63.88

From Table 20 it can be observed that the percent removal is higher overall in trial 3 and 4 than in trial 2. An observation made when the experiment was conducted was that larger particles were formed in trial 3 than in 2. Using a higher concentration of polymer may contribute to more precipitation as the metal complexes are bound into larger flocculated particles that become easier to separate.

The concentrations of metals after metal removal are shown in Figure 25 and Figure 26 for when the concentration of Metalsorb HCO was varied.

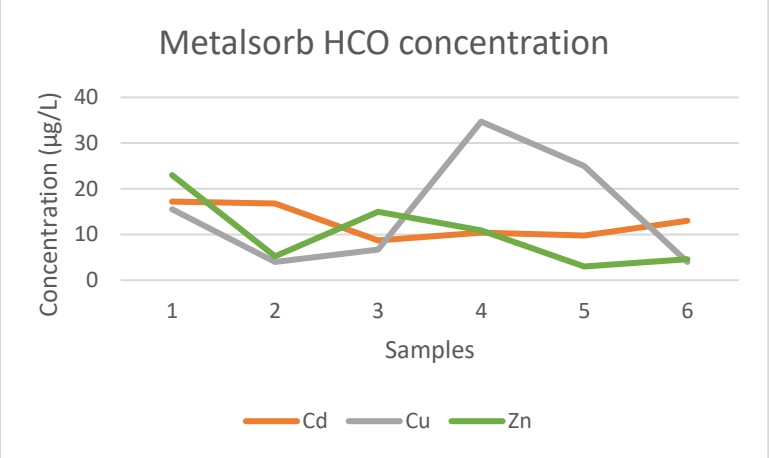

Figure 25: Trial 2, Concentration of metals Cd, Cu and Zn after metal removal. Concentration of Metalsorb HCO increases from sample 1-6.

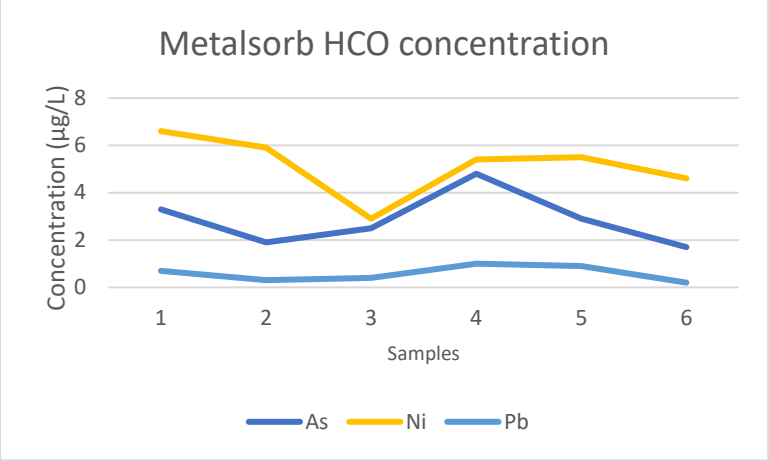

Figure 26: Trial 2, concentration of metals As, Ni and Pb after metal removal. Concentration of Metalsorb HCO increases from sample 1-6.

The concentrations of metals after heavy metal removal are shown in Figure 27 and Figure 28 for when the concentration of Flopam EM 240 CT was varied.

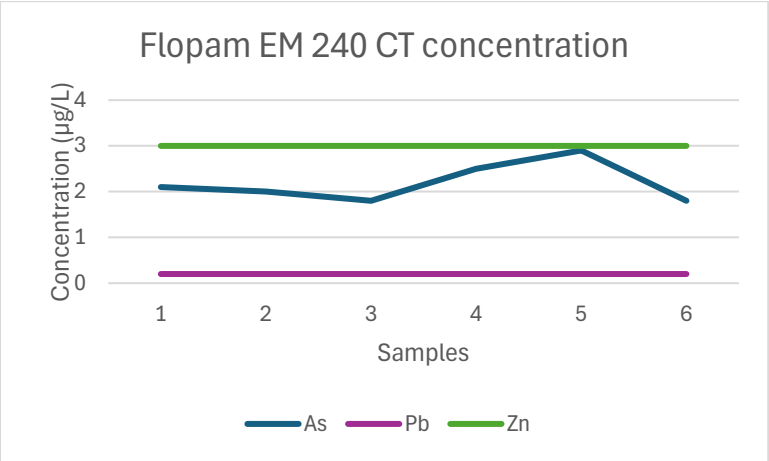

Figure 27: Trial 3, concentration of metals As, Pb and Zn after metal removal. Concentration of Flopam EM 240 CT increases from sample 1-6.

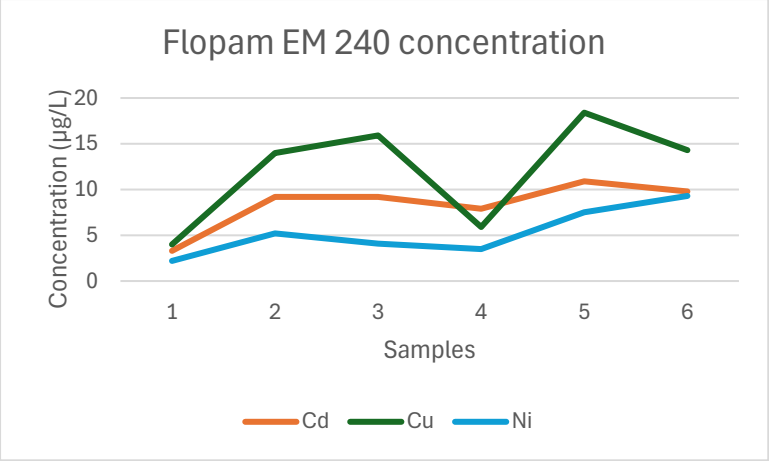

Figure 28: Trial 3, concentration of metals Cd, Cu and Ni after metal removal. Concentration of Flopam EM 240 CT increases from sample 1-6.

The concentrations of metals after heavy metal removal are shown in Figure 29 and Figure 30 for when the concentration of both Metalsorb HCO and Flopam EM 240 CT was varied.

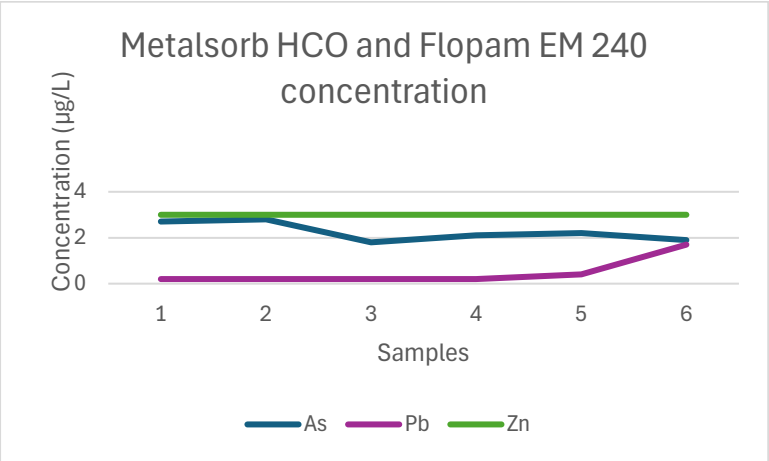

Figure 29: Trial 4, concentration of metals As, Pb and Zn after metal removal. Concentration of Metalsorb HCO and Flopam EM 240 CT increases from sample 1-6.

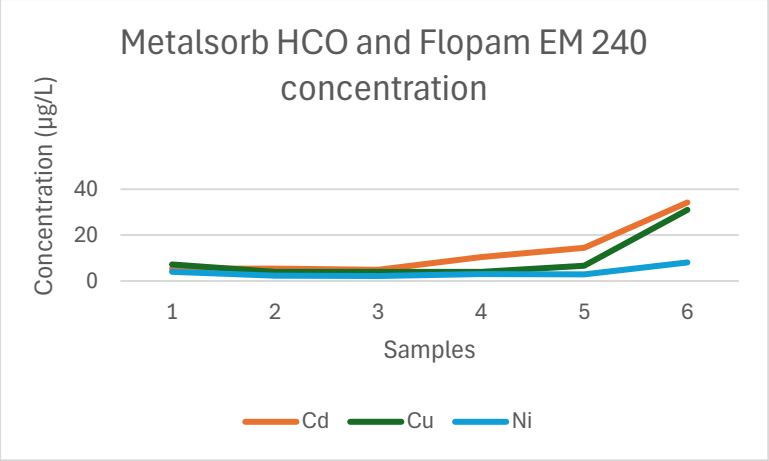

Figure 30: Trial 4, concentration of metals Cd, Cu and Ni after metal removal. Concentration of Metalsorb HCO and Flopam EM 240 CT increases from sample 1-6.

In Figure 25 to Figure 30, it can be observed that there is more variation in the results for trial 2 than for trial 3 and 4. Trial 2 and 3 have more stable results than trial 2. This could be an indication that the precipitation/flocculation reaction is more sensitive to the metal binder dosage than to the polymer dosage.

There was precipitation present in the wastewater before treatment in some of the samples. In trial 2, there was precipitation already present in samples 4, 5 and 6. Trial 3 had little or no precipitation already present, while trial 3 had some precipitation already present. This could be the cause for some of the variation observed in the results between the trials as this precipitation could have interfered with the precipitation/flocculation reaction after the addition of chemicals. (10)

4.8.2 Trial 10: Concentrations of Metalsorb ZT

In trial 10, concentrations of Metalsorb ZT were tested, and Flopam EM 240 CT was used as polymer. The volumes added were 4, 6, 8, 12, 14 and 16 mL of Metalsorb ZT for samples 1-6 respectively. The pH was adjusted to 10.

In Table 21, the total percentage removals of metals are shown for the samples. In Figure 31 and Figure 32, the concentration of arsenic, copper, zinc, lead, nickel and cadmium are shown for all six samples.

Table 21: Trial 10, total percent removal of metals.

Trials/Samples (%)	1 (4 mL)	2 (6 mL)	3 (8 mL)	4 (12 mL)	5 (14 mL)	6 (16 mL)
10	90.81	81.00	89.41	90.66	84.83	89.68

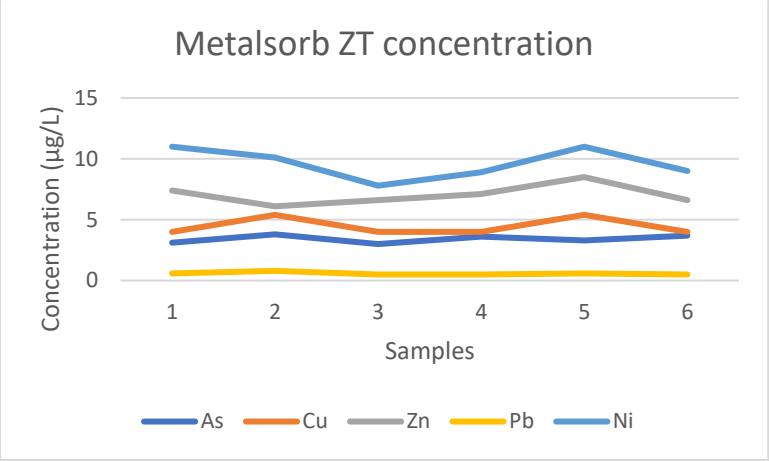

Figure 31: Trial 10, Concentration of metals after reaction. The concentration of Metalsorb ZT increasing from sample 1-6.

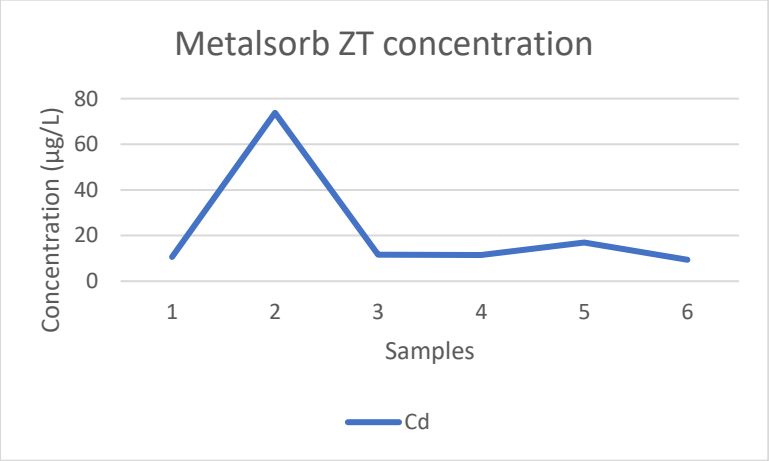

Figure 32: Trial 10, Concentration of Cd after reaction. The concentration of metalsorb ZT increased from sample 1-6.

Trial 10, where the concentration of Metalsorb ZT was varied, showed significantly less variation on the results than trial 2, where the concentration of Metalsorb HCO was varied. In Table 21 it can be seen that the total percentage removal ranges from 81.00%-90.81%, which is a smaller range than 69.62%-87.30% in trial 2 as shown in Table 20. Moreover, it can be seen in Figure 31 that the gradient is closer to 1 than for trial 2. These results also coincide with observations made during experimentation where a similar amount of white precipitation/flocculation was observed in all the samples. There is one metal that shows significant variation in this trial, which is cadmium as shown in Figure 32.

The results from this trial might suggest that the precipitation/flocculation reaction is less sensitive to the dosage of metal binder than was conjectured for trial 2. The cause could thus be the precipitation already present in the wastewater. Trial 10 had no precipitation already present while trial 2 has a significant amount. Moreover, trial 10 had a pH of 10 while trial 2 had a pH of 9.8. Therefore, a higher pH could be a factor that compensates for other mechanisms that can interfere with the reaction. As was mentioned earlier, a higher pH can compensate for low metal binder dosages. (11) Thus, it can be postulated that an optimal pH could compensate for other factors as well.

4.8.3 Trial 13, 14, and 15: Concentration of chemicals from Kemira

In trial 13, 14 and 15, the concentration of PAX-18, SUPERFLOC A-130 and both were varied respectively. In trial 13, the volumes added of PAX-18 were 20, 30, 40, 50, 60 and 70 µL from the first to the last sample. The volumes of SUPERFLOC A-130 added to samples 1-6 were 140, 160, 180, 200, 220, 240 µL respectively. The pH was adjusted to 10.

Figure 33 and Figure 34 show the concentration of the metals after metal removal when the concentration of PAX-18 was varied.

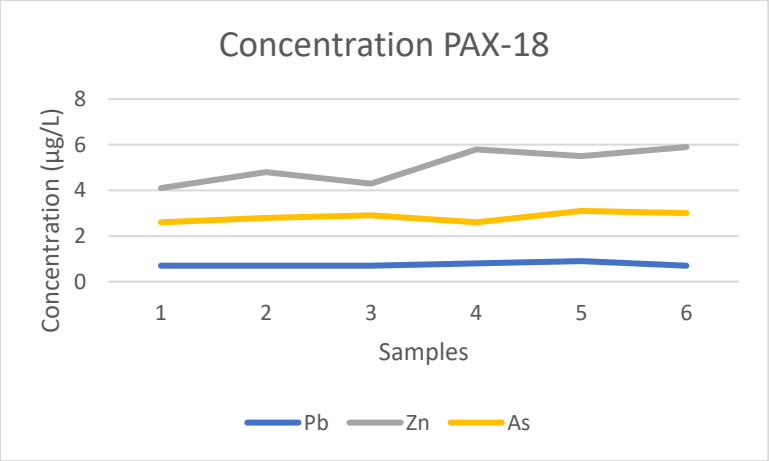

Figure 33: Trial 13, concentration of lead, zinc, and arsenics after metal removal. The concentration of metal binder PAX-18 was increased from sample 1-6.

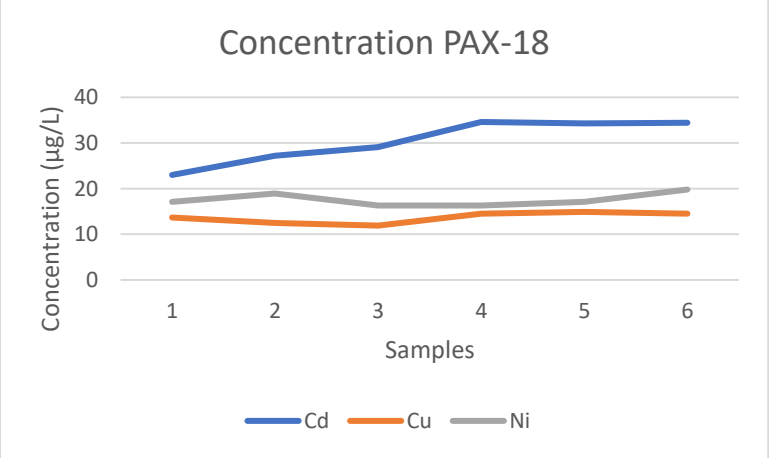

Figure 34: Trial 13, concentration of cadmium, copper, and nickel after metal removal. The concentration of metal binder PAX-18 was increased from sample 1-6.

In Figure 33 and Figure 34, the overall trend shows an increase in concentration of Pb, Zn, As, Cd, Cu and Ni. This means that the metal removal decreases as the metal binder is increased. This was contradictory to the observations made during experimentation where precipitation increased as the concentration of PAX-18 was increased. However, this gradual

increase in precipitation could have been due to precipitation already present in the wastewater, which might have exaggerated the appearance of precipitation.

In Figure 35 and Figure 36, the concentrations of metals are shown as the concentration of SUPERFLOC A-130 was varied in trial 14.

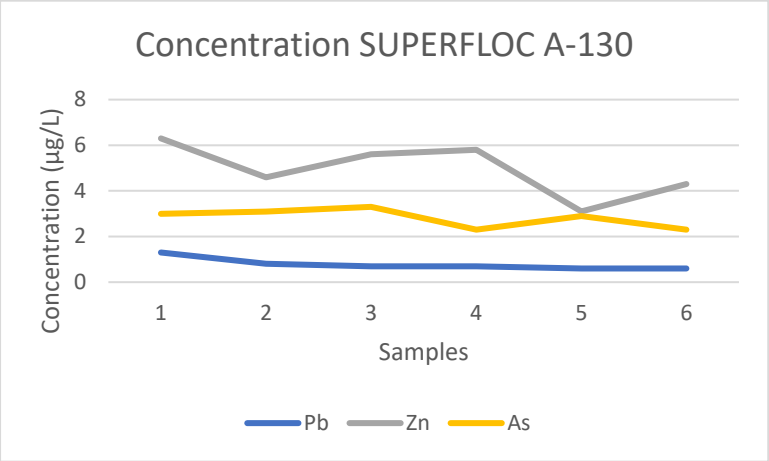

Figure 35: Trial 14, concentration of lead, zinc, and arsenic after metal removal. The concentration of polymer SUPERFLOC A-130 was increased from sample 1-6.

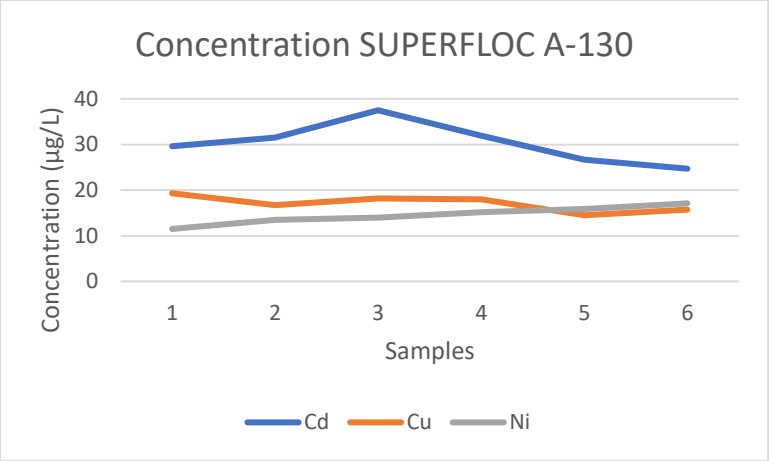

Figure 36: Trial 14, concentration of cadmium, copper, and nickel after metal removal. The concentration of polymer SUPERFLOC A-130 was increased from sample 1-6.

For the metals, As, Cd, Cu and Pb, the overall trend shows an increase in heavy metal removal as the concentration of polymer is increased. In Figure 36, the concentration of nickel increases, which means that the metal removal decreases for this metal. Zinc does not have a clear trend, which can be seen in Figure 35.

In Figure 37 and Figure 38 the concentration of metals are shown as the concentration of PAX-18 and SUPERFLOC A-130 were varied simultaneously.

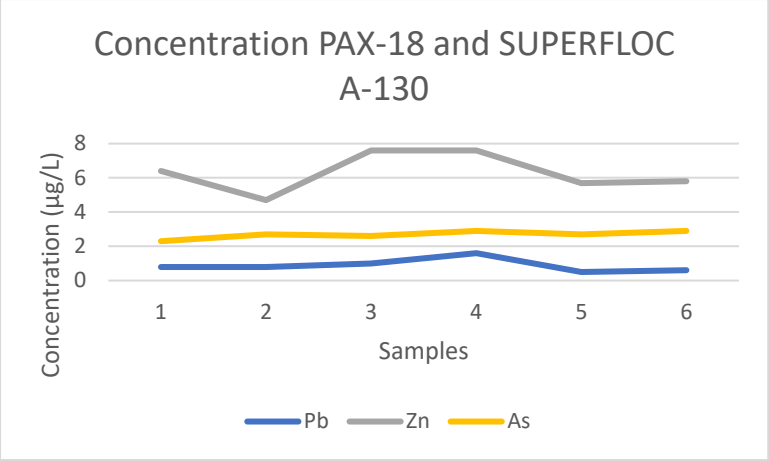

Figure 37: Trial 15, concentration of lead, zinc, and arsenic after metal removal. The concentration of metal binder PAX-18 and polymer SUPERFLOC A-130 was increased from sample 1-6.

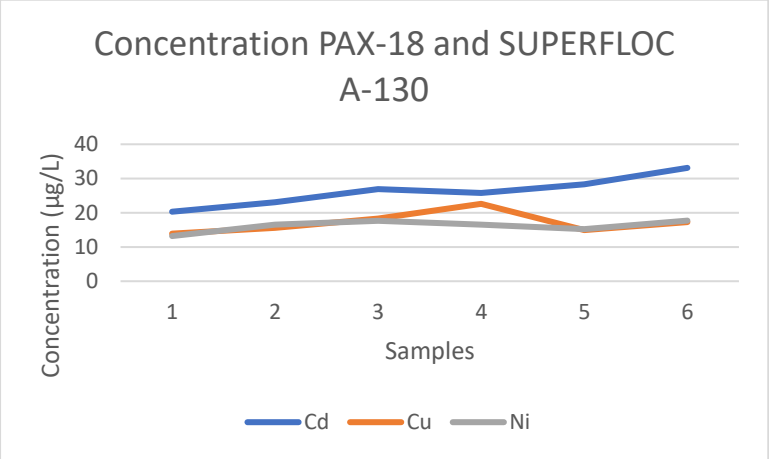

Figure 38: Trial 15, concentration of cadmium, copper and nickel after metal removal. The concentration of metal binder PAX-18 and polymer SUPERFLOC A-130 was increased from sample 1-6.

In trial 15, the overall trend is a slight decrease in metal removal as the concentrations of PAX-18 and SUPERFLOC A-130 are increased which can be seen in Figure 37 and Figure 38.

4.8.4 Summary for concentration of chemicals

In summary, it seems that increasing the dosage of polymer may increase the efficiency of metal removal, while increasing the dosage of metal binder seems to produce more variating results overall. This could be because polymer ensures that metal complexes do not break apart or redissolve. It could be that formed particles can break apart when a sample is run in the centrifuge. (21) Increased concentration of polymer may decrease such an effect. Moreover, the metal binder might have been added in a sufficient dosage for the reaction, and it could be postulated that increasing the dosage may create interferences to the precipitation/flocculation reaction.

Finding the optimal dosage can be difficult as the mechanism is dependent on multiple variables. (14, 16) However, the results indicate that a higher concentration of polymer will increase the percent removal. Thus, a higher concentration of polymer can be considered.

4.9 Variation in pH

In trial 1-7, a human error was conducted when measuring the pH. The error was determined to contribute to an extra +0.03 to the pH measurements. This difference is too small to have a significant impact on the results.

4.9.1 Trial 5: Variation in pH

In trial 5, the pH was tested, and Metalsorb HCO and Flopam EM 240 CT were used. Samples 1-6 were tested with pH values, 9.2, 9.4, 9.6, 9.8, 10, and 10.2 respectively.

In Figure 39 to Figure 42, bar charts are made to show the removal efficiency for different metals. And in Figure 43, a line diagram is made to show the percent removal for copper and zinc.

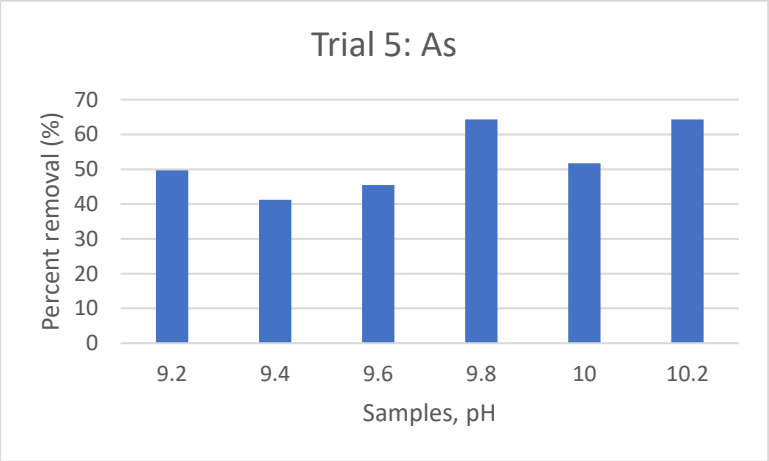

Figure 39: Trial 5, percent removal of arsenic.

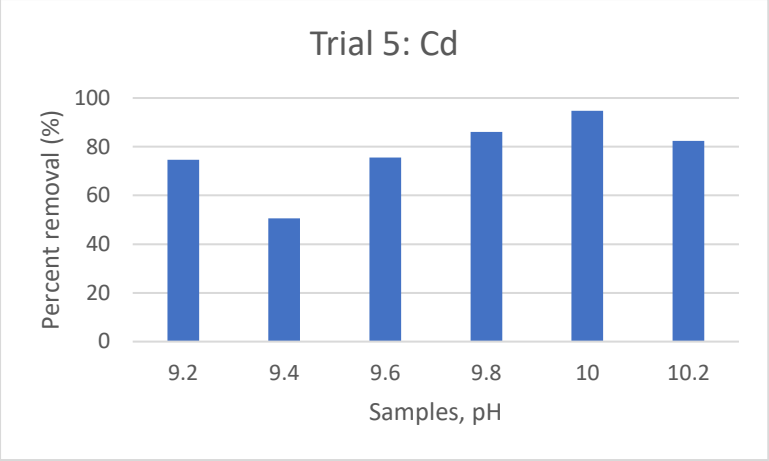

Figure 40: Trial 5, percent removal of cadmium.

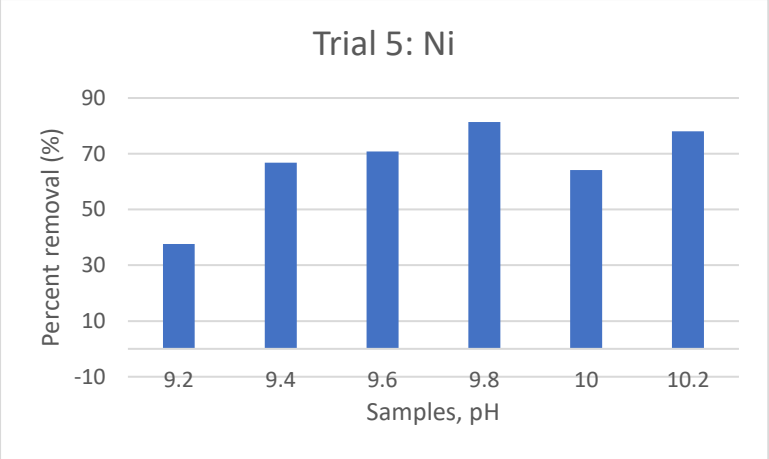

Figure 41: Trial 5, percent removal of nickel.

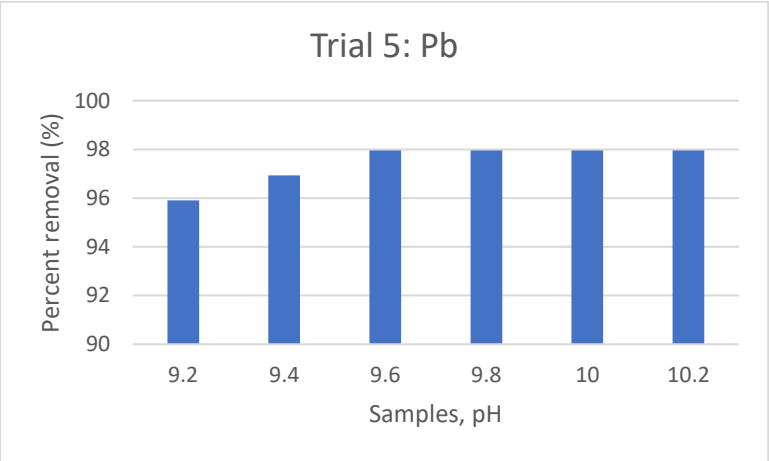

Figure 42: Trial 5, percent removal of lead.

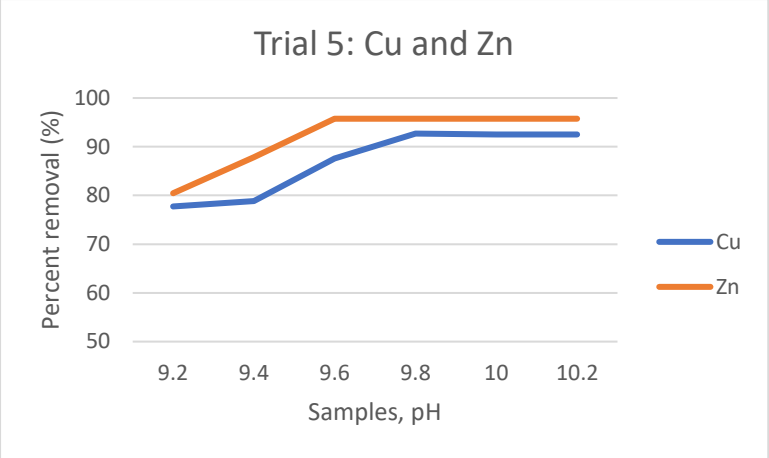

Figure 43: Trial 5, percent removal of Cu and Zn.

In Figure 39 to Figure 43, it can be observed that higher percent removals are accomplished at higher pH values. In Figure 39, a notable increase in percent removal is seen between pH values, 9.6 and 9.8. This coincides with observations made during experimentation where there was noticeably more precipitation in the sample with pH 9.8 than for the sample with pH 9.6. In Figure 42, a gradual increase in percent removal is observed for copper and zinc as the pH is increased. The gradient also becomes close to one when the pH surpasses 9.8, which means that the chemicals will not become significantly more efficient above a pH of 9.8.

There is some variation in trend in Figure 39, Figure 40 and Figure 41 as there is not a gradually increasing trend as the pH is increased. In Figure 39 for arsenic, the percentage removal is high for samples with pH 9.8 and 10.2, but lower for sample with pH 10. A similar trend is seen in Figure 41 for nickel. In Figure 40, a higher value is observed for pH 10 and lower for 9.8 and 10.2. In Figure 42, there is a gradually increasing and stable trend.

4.9.2 Trial 20: Variation in pH

Metalsorb HCO and Flopam EM 240 CT were used. Samples 1-6 were tested with pH values 9.6, 9.7, 9.8, 9.9, 10, and 10.1 respectively.

A line diagram, in Figure 44, was made to show the removal efficiency for arsenic, cadmium, nickel, and lead. In Figure 45, a line diagram is made to show a trend in percentage removal for copper and zinc.

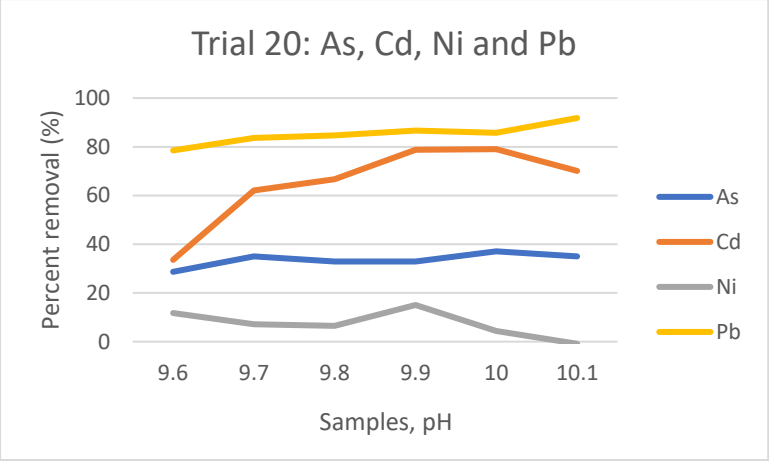

Figure 44: Trial 20, percent removal of As, Cd, Ni, and Pb.

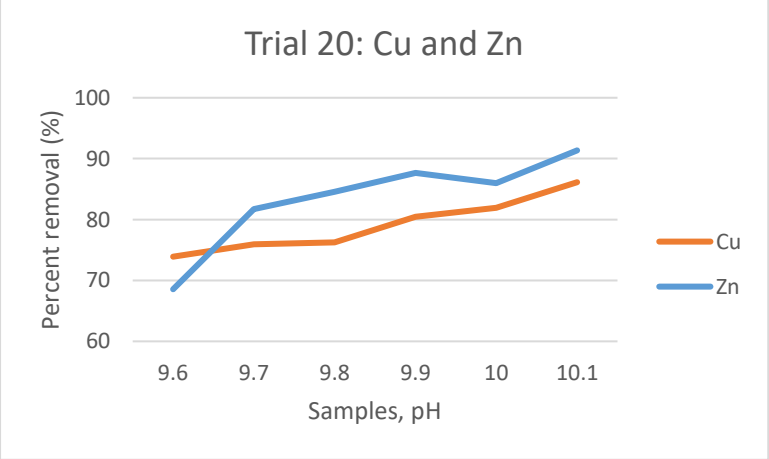

Figure 45: Trial 20, percent removals of Cu and Zn.

In trial 20, similar trends are observed as for trial 5. In Figure 44, arsenic and cadmium have the highest removal at a pH of 10. Nickel has a high removal at 9.9, and there is much variation for nickel. Lead generally has quite constant results, however, there is more variation in this trial, and the best result is for pH of 10.1. Copper and zinc have a gradual increase in percent removal as pH is increased as seen in Figure 45. There was precipitation present in the wastewater in these samples before treatment. Thus, this may have influenced the results.

4.9.3 pH change for Yara and Kemira chemicals

The pH in the samples was reduced after the metal binder was added due to the acidity of the chemicals. The pH change was measured for several trials. In Table 22, the changes in pH after the addition of chemicals are shown for trial 8, 9, 11, 16, 17, 18, and 19. The pH values used to find the pH changes are listed in Appendix D.

Table 22: Decrease in pH after addition of chemicals.

Trials/Samples	**1**	**2**	**3**	**4**	**5**	**6**
8	0.09	0.09	0.09	0.08		
9	0.07	0.07	0.07	0.07		
11	0.52	0.51	0.48	0.55	0.49	0.43
16	0.07	0.08	0.10			
17	0.08	0.08	0.10			
18	0.21	0.21	0.21			
19	0.27	0.26	0.27			

For trials 8 and 9, when chemicals from Yara were tested, the pH decreased in all the samples with the values 0.07, 0.08 and 0.09, which can be seen in Table 22. Such a decrease will not have a significant effect on the results. In trial 16 and 17, triplicate tests were conducted using chemicals from NOAH and Yara respectively. The pH in these samples decreased with the values 0.07, 0.08 and 0.10. Thus, a decrease in pH of 0.10 was the highest value observed for these chemicals.

The metal binders from Kemira are acidic. The decrease in pH after the addition of the metal binder was within the range of 0.43-0.55 in trial 11. The decrease in pH in the triplicate test, when Kemira chemicals were used, was 0.21 in trial 18 and 0.26 and 0.27 in trial 19.

The chemicals from Kemira have a more significant impact on the pH in the samples due to greater acidity. See product information in Appendix A. Such a reduction in pH is not desirable as this may increase the mobility of the metals, causing the metal complexes to redissolve. (11) The highest pH change observed in trial 10 and 11, was 0.55 in trial 11. For the triplicate tests, trial 18 and 19, the highest value observed was 0.27 in trial 19. Kemira chemicals thus cause a more significant reduction in pH than Yara chemicals. Therefore, a slightly higher pH should be used for Kemira chemicals to maintain the efficiency of precipitation. However, the pH should not be too high as the emission permit specifies a pH limit of 10. (5)

4.9.4 Summary pH

Based on the results, it can be concluded that a pH above 9.8 should be implemented to optimize the metal removal. Due to the emission permit, the water that is released cannot exceed a pH of 10. If the pH is adjusted to 10 in NOAH's process, it would be expected that this pH would decrease due to the metal binder that is added, which is slightly acidic, and due to exposure to open air, where CO2 will dissolve into the water and decrease the pH.

4.10 Triplicate tests

4.10.1 Trial 16, 17, 18 and 19: Triplicate tests

In trial 16, Metalsorb HCO and Flopam EM 240 CT were used; in trial 17, Metalsorb ZT and Flopam EM 240 CT were used; and in trial 18, PAX-18 and Flopam EM 240 CT were used. The concentrations of metal binder and polymer were 0.990 mL/L and 1.17 g/L respectively. For trial 19, the chemicals were added according to recommendations from Kemira, which were 50 µL/L of PAX-18 and 2×10^{-4} g/L SUPERFLOC A-130. The pH was adjusted to 10 in these four trials.

Figure 46-Figure 49 shows the percentage removal for arsenic, cadmium, nickel and lead for the triplicate tests.

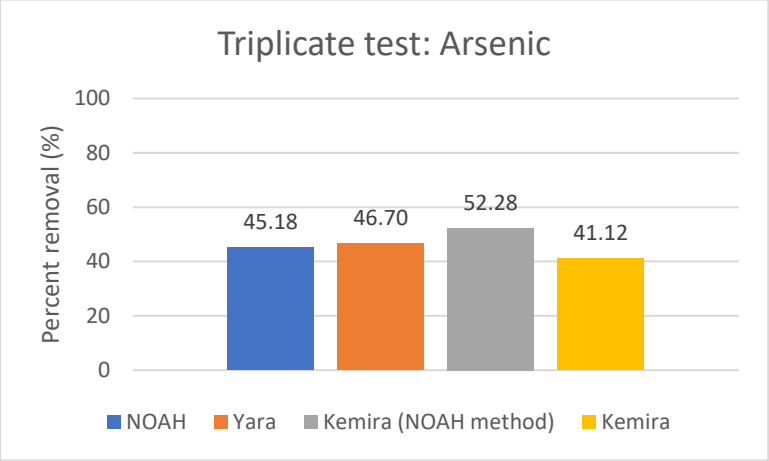

Figure 46: Trial 16-19 triplicate test. Percent removal of arsenic.

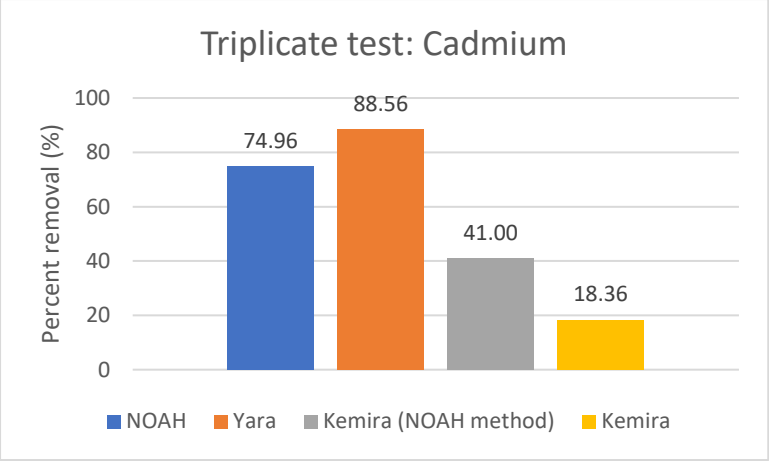

Figure 47: Trial 16-19 triplicate test. Percent removal of cadmium.

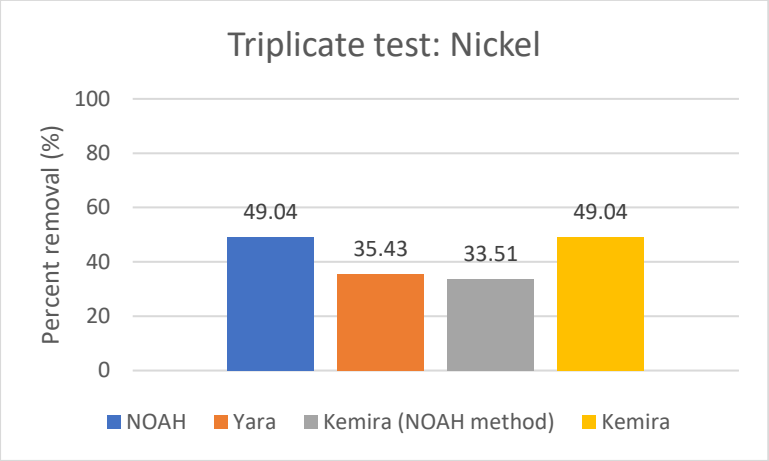

Figure 48: Trial 16-19 triplicate test. Percent removal of nickel.

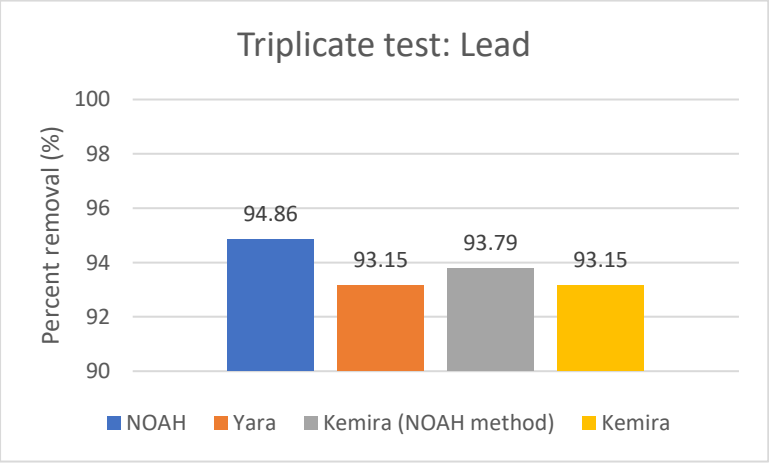

Figure 49: Trial 16-19 triplicate test. Percent removal of lead.

The percent removal is the average value of the three samples in each triplicate test. The average percent removals are listed in Table 23 and Table 24.

Table 23: Percent removal of metals in triplicate tests, trials 16 and 17. Standard deviations are listed in parenthesis.

Metals/Trials	Trial 16: Metalsorb HCO, NOAH (%)	Trial 16: Standard deviation	Trial 17: Metalsorb ZT, Yara (%)	Trial 17: Standard deviation
As	45.18	7.61	46.70	8.06
Cd	74.96	1.16	88.56	2.75
Cu	91.48	0.00	90.27	1.42
Ni	49.04	11.23	35.43	3.96
Pb	94.86	0.64	93.15	1.34
Zn	92.31	0.13	93.35	0.66

Table 24: Percent removal of metals in triplicate tests, trials 18 and 19. Standard deviations are listed in parenthesis.

Metals/Trials	Trial 18: PAX-18, Kemira (NOAH method) (%)	Trial 18: Standard deviation	Trial 19: PAX, 18, Kemira (%)	Trial 19: Standard deviation
As	52.28	3.52	41.12	8.39
Cd	41.00	1.60	18.36	4.65
Cu	82.03	2.66	83.38	1.82
Ni	33.51	4.29	49.04	12.62
Pb	93.79	0.37	93.15	0.98
Zn	95.32	1.05	95.23	0.63

From Table 23 and Table 24, it can be seen that Metalsorb HCO retrieved from NOAH and Metalsorb ZT from Yara accomplish a higher percent removal than Kemira for the metals, cadmium and copper. Cadmium shows the most significant difference where the removal for NOAH and Yara are 74.96% and 88.56% respectively, while the removal for Kemira is 41% in trial 18 and 18.36% in trial 19. This can be seen in Figure 47. For the metals, arsenic, nickel, lead and zinc, the percentage removals for the four trials are very similar.

These results are different from previous trials. Trials 11 and 12, where combinations of Kemira chemicals were tested, have high percent removals compared to the triplicate tests, trials 18 and 19. A reason for this difference could be the adjusted pH. In trials 11 and 12, the pH was adjusted to 10.5, whereas the pH was adjusted to 10.00 in trials 18 and 19. Thus, this could indicate that the chemicals from Kemira are more efficient when the wastewater has a pH higher than 10. This comparison can be seen in Table 25.

Table 25: Percent removal of metals, comparing results of tests of chemicals from Kemira.

Metals/Trials	Trial 11: PAX-18 and SUPERFLOC A-130 (%)	Trial 13: PAX-18 and SUPERFLOC A-130 standard conc. (%)	Trial 18: Kemira (NOAH methos) triplicate test average (%)	Trial 19: Kemira triplicate test average (%)
As	72.73	39.16	52.28	41.12
Cd	91.09	56.06	41.00	18.36
Cu	87.41	78.28	82.03	83.38
Ni	36.95	-8.19	33.51	49.04
Pb	96.93	92.83	93.79	93.15
Zn	95.75	93.91	95.32	95.23

When comparing the percent removal of trial 16 and 17, the trials conducted for NOAH and Yara respectively, trial 17 is slightly more effective than 16 except for nickel. In trial 16 and 17, the percent removal for nickel is 49.04% and 35.43% respectively, which can be seen in Figure 48. However, nickel does show much variation in the results, which means that the lower percentage removal for nickel in trial 17 may not be an indication that Metalsorb ZT is less effective for this metal than Metalsorb HCO.

4.11 Comparison between trials

In, the percentage removal in trial 1, 8, 16, and 21 are listed. Trials 1, 8 and 21 were conducted using Metalsorb HCO and had a pH of 9.8. Metalsorb HCO was also used in trial 16 with a pH of 10. The efficiency of trial 1 is much greater than trial 8. This could be due to the slightly different methods used. The samples in trial 1 and 8 underwent sedimentation for 15 minutes and 5 minutes respectively, while the samples in trial 8 underwent 5 minutes of sedimentation. This could indicate that longer time for sedimentation produces better results. In trial 21, the samples only underwent sedimentation and were not run in the centrifuge. The results for this trial also show a high percent removal for most of the metals, which indicates that sedimentation without use of centrifuge is favourable. The metals that show low percent removal in trial 21 are arsenic and nickel.

Table 26: Percent removal of metals comparing Metalsorb HCO.

Metals/Trials	Trial 1: Standard Metalsorb HCO, NOAH (%)	Trial 8: Metalsorb HCO, Yara (%)	Trial 16: NOAH (%)	Trial 21: Metalsorb HCO, NOAH (%)
As	60.14	-2.80	45.18	39.16
Cd	84.60	67.54	74.96	86.26
Cu	84.12	66.97	91.48	91.61
Ni	61.50	-6.86	49.04	7.08
Pb	96.93	88.74	94.86	93.86
Zn	95.75	88.10	92.31	88.53

The metals that have more variation in the results are often the metals that are present in low concentrations in the wastewater. In Figure 13, the reference concentrations of metals are listed from the first and the second sampled wastewater. From the table it can be seen that arsenic and nickel are present in low concentrations. Arsenic, for example, has concentrations of 4.77 µg/L in the first sampled wastewater and 6.57 µg/L in the second sampled wastewater. Low concentrations could produce more uncertainty in the results due to the uncertainty of IPC-MS analysis where the uncertainty is ±20%. (21) Such an uncertainty will have a greater impact on the results of lower concentrations.

However, this does not explain all the variation in the results. Cadmium generally has more variation in the results than zinc even though these have similar concentrations in the sampled water. Moreover, lead is also present in low concentrations, and has stable results throughout the trials with percent removals around 90%. Thus, some reasons for the variation observed in the results could be due to multiple factors influencing the precipitation and flocculation reactions. Some factors could be the concentration of metals, the oxidation state of the metal ions and the presence of particles that interfere with the reaction. (10, 11)

4.12 Trial 21: Sedimentation test

In trial 21, Metalsorb HCO and Flopam EM 240 CT were used. Three samples were prepared, and samples 1-3 had adjusted pH values of 9.8, 9.9 and 10 respectively.

In Figure 50: Sample 1, pH=9.8, day 0 to Figure 52, the three samples tested are shown on day 0 when the reaction took place. In Figure 53 to Figure 55, the three samples are shown on day 2 when the samples have stood on the counter for 48 hours.

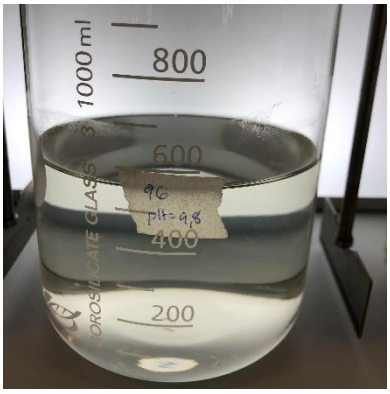

Figure 50: Sample 1, pH=9.8, day 0

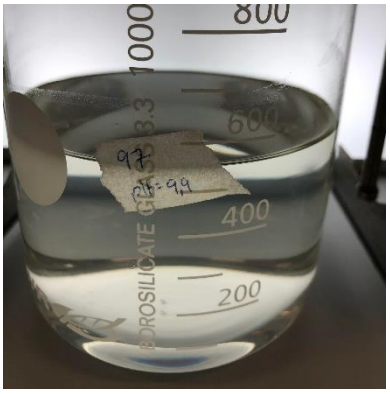

Figure 51: Sample 2, pH=9.9, day 0

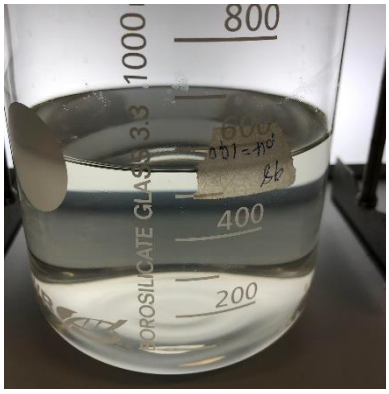

Figure 52: Sample 3, pH=10, day 0

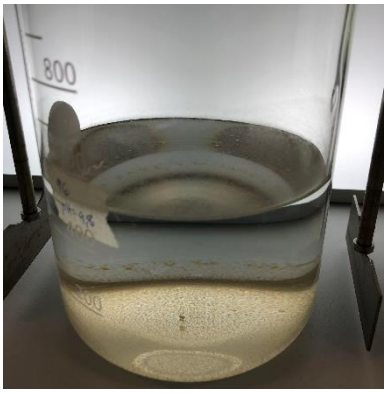

Figure 53: Sample 1, pH=9.8, day 2

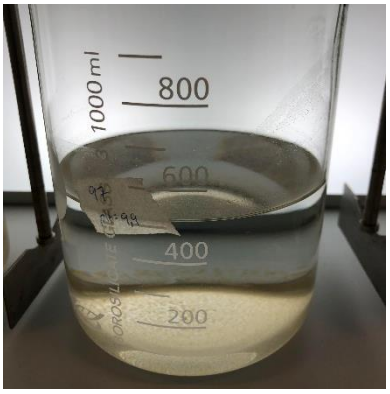

Figure 54: Sample 2, pH=9.9, day 2

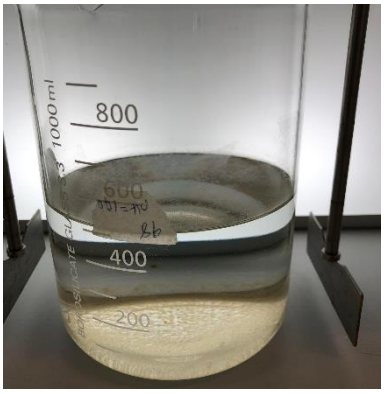

Figure 55: Sample 3, pH=10, day 2

In Figure 56, the pH change is shown over five days.

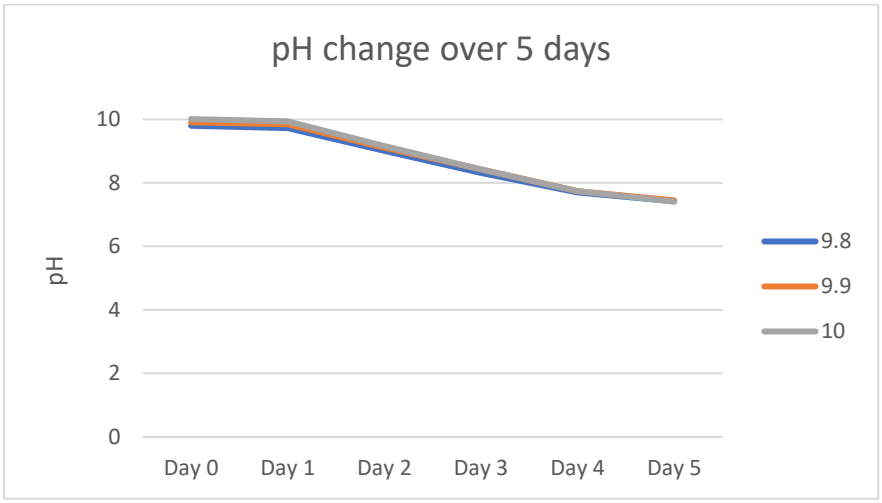

Figure 56: Trial 21, pH decreased over five days.

In Table 27, the pH values in the three samples are shown from day 0 to day 4.

Table 27: Trial 21, pH in samples over five days.

Samples/Days	Day 0	Day 0	Day 1	Day 2	Day 3	Day 4
1	9.8	9.73	9.01	8.31	7.70	7.42
2	9.91	9.85	9.11	8.42	7.74	7.45
3	10.01	9.94	9.16	8.42	7.74	7.41

In Table 28, the average reduction in pH is shown. Calculation example is shown in Appendix B5. On day 0, the change in pH is recorded after the addition of chemicals. On day 1, 2, 3 and 4, the pH change is recorded from one day to the next.

Table 28: Average pH reduction from previous day.

Days	Day 0	Day 1	Day 2	Day 3	Day 4
Average	0.07	0.75	0.71	0.66	0.30
Standard deviation	0.11	0.11	0.08	0.06	0.02

In Table 29, the total percent removal is shown at day 0 and day 2.

Table 29: Trial 21, total percent removal of metals.

Days/Samples (%)	1	2	3
0 days	82.17	86.17	85.58
2 days	84.99	84.13	84.36

On day 0, very small, grey/brown particles were formed in the three samples in trial 21, which were difficult to observe due to their small size. This can be seen in Figure 50-Figure 52. On day 1, visible precipitation had sunk to the bottom of the beaker as pictured in Figure 53 to Figure 55. The number of particles at the bottom of the beakers increased from day 1 to day 2.

In Figure 56, a trend can be observed where the pH gradually decreases over five days. In Table 28, the pH changes are listed. After the addition of Metalsorb HCO, the pH changes 0.07. After one, two, three and four days, the pH changes are 0.75, 0.71, 0.66 and 0.30 respectively. Thus, the pH change seems to decrease most rapidly in the beginning, and then the pH changes from day to day become smaller.

This pH change may occur because CO_2 from air dissolves in the water, increasing the acidity of the water. This increased acidity might cause metal complexes to redissolve. In Table 29, a decrease in total percent removal be observed from day 0 to day 2. In sample 1, there is a slight increase from 82.17% to 84.99%. For sample 2 and 3, the percent removal decreases

slightly from 86-17% to 84.13% and 85.58% to 84.36% respectively. These are not significant changes. Thus, it seems that the decrease in pH will not have a significant impact on the metal removal over the course of two days.

4.13 Metals in emission permit

NOAH's emission permit contains limits for the maximum concentration of certain metals that can be released into natural waters. These metals are listed in Table 30 and Table 31 below except for chromium, which was omitted from the results.

Table 30: Emission limits (NOAH) and concentrations of metals before reaction and after standard condition testing with Metalsorb HCO and polymer FLOPAM EM 240 CT. (5)

Metal	**Emission limit (µg/L) (average per day) (5)**	**Reference 1, average concentration (µg/L)**	**Trial 1: Concentration after reaction, standard test (µg/L)**
As	30	4.77	1.90
Cd	30	66.23	10.20
Ni	700	15.07	5.80
Pb	30	9.77	0.30

Table 31: Emission limits (NOAH) and concentrations of metals before reaction and after triplicate reactions.

Metals	**Emission limit (µg/L)** **(average per day)**	**Reference 2, average, concentration before reaction (µg/L)**	**Average concentration after reaction in triplicate tests**			
			Trial 16: Metalsorb HCO, NOAH (µg/L)	**Trial 17: Metalsorb ZT, Yara (µg/L)**	**Trial 18: PAX-18, Kemira (NOAH method) (µg/L)**	**Trial 19: PAX, 18, Kemira (µg/L)**
As	30	6.57	3.6	3.5	3.9	3.1
Cd	30	150.67	38	17.2	123	89
Ni	700	19.10	10	12.3	9.7	12.7
Pb	30	15.57	0.8	1.1	1.1	1.0

The reference values of arsenic, nickel and lead, see Figure 30 and Figure 31, are all below NOAH's emission limits before metal removal. (5) Emission limits for arsenic, cadmium, nickel and lead can be viewed in Table 1. Cadmium is the only metal in the emission permit that is found in higher concentrations than the limit before metal removal. This could be because cadmium is one of the metals that is present in high concentrations compared to the other metals, which can be seen in Table 30 and Table 31. This means that the metal removal needs to be higher for cadmium than for the metals present in lower concentrations.

Chemicals from Kemira show very efficient results when a high pH of 10.5 is used. When a lower pH of 10 was used, the results were slightly less efficient. Moreover, the results became significantly less efficient for cadmium. The concentrations of cadmium in the triplicate tests where chemicals from Kemira were used were 123 µg/L and 89 µg/L, shown in Table 31. This far exceeds the emission limit of 30 µg/L. Metalsorb ZT produced the most efficient results for cadmium among the triplicate test where a concentration of 17.2 µg/L was accomplished. The triplicate test conducted using Metalsorb HCO, produced less efficient results. The average concentration was 38 µg/L, which exceeds the emission limit. However, Metalsorb did show efficient results in other trials such as trial 1 where the concentration for cadmium was 10.2 µg/L, which is listed in Table 30.

Both Metalsorb HCO and Metalsorb ZT appears to be efficient for heavy metal removal with respect to cadmium. There are some varying results that may be influenced by other conditions present during the reaction such as the concentration of metals present, oxidation states of metals and precipitated particles present. Based on the results, overall, both Metalsorb HCO and ZT combined with Flopam EM 240 CT, produced high metal removal for the metals in the emission permit, including cadmium.

4.14 Improvements and further experimentation

Some of the variation between trials may be due to differences in metal concentrations present in the water before treatment. This postulate could be investigated if a reference value had been taken for each trial. Moreover, the results are compared to the reference values and the percent removals are calculated using the reference values. These results would be more accurate if a reference sample was obtained for each trial.

Another improvement could be to filter the water before experimentation. There was precipitation already present in the wastewater before treatment. Such particles may have interfered with the precipitation/flocculation reaction, thus influencing results and obscuring trends. Filtering the water would thus remove additional influences.

Chromium was not present in the wastewater in high enough concentrations to be analysed. However, this is one of the heavy metals specified in the permit from the Ministry of Climate and Environment. Further experimentation could be conducted where chromium is added to wastewater to investigate the effect of different chemicals and conditions on the removal of this metal.

A useful trial would be to test different pH values when using Metalsorb ZT. This metal binder shows efficient results; however, the trials are conducted at a pH of 10. Metalsorb HCO produces efficient results at a pH of 9.8. To determine the most optimal binder between Metalsorb HCO and ZT, the efficiency of Metalsorb ZT needs to be tested at lower pH values.

There are multiple tests in this bachelor’s thesis that gives an indication toward optimal conditions. However, multiple replicates should be conducted in order to confirm one optimal

solution for the prioritized metals. For example, more tests should be conducted to find the optimal dosage of metal binder and polymer.

Lastly, additional experimentation could be to test the effect of pH without the addition of chemicals. In this way, it could be investigated whether the concentration of some metals in solution could be reduced simply by adjusting the pH.

5. Conclusion

The standard test, based on NOAH's current wastewater treatment process, produced efficient results. The percent removals accomplished were 60.14%, 84.60%, 61.50% and 96.93% for arsenic, cadmium, nickel and lead respectively. The metal concentrations in this standard test were all under the emission limit drawn up by the Ministry of Climate and Environment.

The optimal chemical combinations among the chemicals retrieved from Yara were found to be Metalsorb ZT and Flopam EM 240 CT, while the optimal combination among chemicals form Kemira were PAX-18 and SUPERFLOC A-130. Metalsorb HCO and Metalsorb ZT combined with Flopam EM 240 CT are deemed the most efficient chemical combinations overall due to high metal removal at lower concentrations.

Excessive stirring should be minimized as this may break apart particles, reducing the efficiency of the metal removal. The duration of stirring, on the other hand, does not affect the results to a significant degree. Sedimentation produces efficient results, while the use of sentrifuge may break apart particles. Therefore, based on these results, heavy metal removal seems to be improved when mechanical means of stirring and separation are minimized.

Increasing the dosage of polymer showed positive results. Thus, increasing the dosage of Flopam EM 240 CT may produce greater heavy metal removal. Lastly, pH has significant impact on the efficiency of the metal removal. The optimal pH was found to be around 9.8-10.

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Appendix

A – Product information

A1 - Flopam EM 240 CT product information

Technical Data Sheet

SNF NORDIC AB - Järnvägsgatan 11 - 515 61 Svaneholm - Sverige
phone: +46.33.29.40.90 e-mail: sds@snf.fr

FLOPAM™ EM 240 CT

Form:	*Viscous liquid*
Color:	*Milky*
Ionic character:	*Cationic*
Charge density:	*Medium*
Molecular Weight:	*High*
Specific Gravity:	*1.04*
Average Non-Volatile Solids (%):	*42*
pH:	*4 - 6 @ 5 g/l*
Bulk viscosity (cps):	*1200*
Maximum use concentration (g/l):	*10*
Stability of D.I. solution (days):	*1*
Dilution to obtain 5 g/l active content:	*78*
Approx. viscosity @ 5 g/l (cps):	*1200*
Storage temperature (°C):	*0 - 35*
Shelf life (months)*:	*6*

* When stored inside a building at a stable temperature between 5°C and 30°C.

Packing sizes

Plastic pails	*25 kg*
Drums	*210 kg*
I.B.C.	*1050 kg*
Other dimensions	*On request*

A2 – Metalsorb HCO product information

SNF
WATER SCIENCE

Andrézieux, 05th December 2023

Subject: Specifications – Modification
METALSORB™ HCO

Dear customer,

We would like to inform you about the following specification modification for SNF product:

METALSORB™ HCO

After different studies, it has been determined that a higher pH of METALSORB™ HCO allows to significantly reduce the smell of the product. The new values are indicated in the following table:

Specifications *QC method*	Old values	New values
pH on diluted solution ***QC 3135A***	10.0 – 11.5	12.0 – 13.5

You will find enclosed the new specifications.
All the related documents such as certificate of analysis will be modified, effective immediately.
There are no changes in the safety data sheet.

Do not hesitate to contact us as if you need further information.

Best regards.

E. Marc
Quality Department

P. Cheucle
R&D Department

SNF SA - ZAC de Milieux -Rue Adrienne Bolland - 42163 Andrézieux, France - T +33 (0)4 77 36 86 00 - snf.com
Société Anonyme au capital de 40 000 000 € - 430 006 643 R.C.S. Saint-Étienne – SIRET 430 006 643 000 34 – Code APE 2016Z

A3 – Metalsorb HCO product information

SNF SA
ANDRÉZIEUX

SPECIFICATION PROPOSAL

ZAC DE MILIEUX
42163 ANDRÉZIEUX CEDEX
FRANCE
Tel: +33 (0)4 77 36 86 00
Email: info@snf.com
www.snf.com

SNF PRODUCT NAME:	**METALSORB HCO**
GENERIC NAME:	CHELATING AGENT
MATERIAL DESCRIPTION:	YELLOW TO REDDISH LIQUID

	UNIT	SPECIFICATION	QC
PH ON DILUTED SOLUTION		12.0 - 13.5	3135A
NON VOLATILE SOLIDS	%	38.0 - 42.0	3100A
LVT BROOKFIELD VISCOSITY (LV2, 60 rpm)	cP	<= 500	3420A

SNF APPROBATION		CUSTOMER APPROBATION	
Version:	05	Customer Name:	
Date:	05/12/23	Date:	
Signature:	P.CHEUCLE	Responsible:	
Responsible:	E.KNIECZAK		

If the # symbol appears in the 'QC' column, then the data on that line is given for information only, and does not constitute a specification.
If ND appears in the result column, that means under the limit of detection.
For personal care ingredients, the generic name is corresponding to the INCI name.

A4 – Metalsorb PCZ product information

Teknisk Datablad

SNF NORDIC AB, Järnvägsgatan 11, 515 61 Svaneholm, Sverige
phone: +46.33.29.40.90, e-mail: sds@snf.com

METALSORB™ PCZ

Form:	Flytende
Farge:	rød
Ladningstetthet:	Høy
Tyngdekraft:	1.05 - 1.15
Gjennomsnittlig innhold av ikke flyktig tørrstoff (%):	18.0 - 23.0
pH:	10 - 11.5 #
Bulk viskositet (cP):	< 500
Frysepunkt (°C):	< -7
Lagringstemperatur (°C):	0 - 30
Lagringstid (måneder)*:	12

* Ved lagring innendørs under stabile temperaturer mellom 5°C og 30°C.
# pH for en til ganger fortynning

Pakke størrelse

Plast kanner	25 kg
I.B.C.	1100 kg
Andre dimensjoner	På forespørsel

A5 – Metalsorb ZT product information

SNF WATER SCIENCE

Teknisk Datablad

SNF NORDIC AB, Järnvägsgatan 11 515 61 Svaneholm Sverige, phone: +46 33 29 40 90

METALSORB™ ZT

Form:	Flytende
Farge:	Gulaktig
Ladningstetthet:	Høy
Tyngdekraft:	1.15 - 1.25
Gjennomsnittlig innhold av ikke flyktig tørrstoff (%):	38.0 - 43.0
pH:	9 - 11 #
Bulk viskositet (cP):	0 - 50
Frysepunkt (°C):	-3
Lagringstemperatur (°C):	0 - 30
Lagringstid (måneder)*:	12

* Ved lagring innendørs under stabile temperaturer mellom 5°C og 30°C.
# pH for en ti ganger fortynning

Pakke størrelse

Plast kanner	25 kg
I.B.C.	1100 kg
Andre dimensjoner	På forespørsel

A6 – Metalsorb ZM 3 product information

Teknisk Datablad

SNF NORDIC AB, Järnvägsgatan 11, 515 61 Svaneholm, Sverige
phone: +46.33.29.40.90, e-mail: regs@snf.com

METALSORB™ ZM 3

Form:	Flytende
Farge:	Gul-grønn
Ladningstetthet:	Høy
Tyngdekraft:	1.10 - 1.20
Gjennomsnittlig innhold av ikke flyktig tørrstoff (%):	15.0 - 17.0
pH:	12 - 13
Frysepunkt (°C):	-3
Lagringstemperatur (°C):	0 - 30
Lagringstid (måneder)*:	12

* Ved lagring innendørs under stabile temperaturer mellom 5°C og 30°C.

Pakke størrelse

Plast kanner	25 kg
I.B.C.	1100 kg
Andre dimensjoner	På forespørsel

A7 – KEMIRA PAX-18 product information

kemira

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Produktdatablad
2019-03-14

KEMIRA PAX-18

Polyaluminiumklorid Løsning

KEMIRA PAX-18, polyaluminumklorid med middels basisitet, er en effektiv koagulant for behandling av både drikkevann og avløpsvann. KEMIRA PAX-18 er basert på høyladet aluminium, slik at man trenger mindre av produktet for å gjøre mer. Dette resulterer i lavere doser og derfor reduseres slamvolum og behov for justering av pH. KEMIRA PAX-18 er også mer effektiv til å fjerne partikler og/eller fosfor i forhold til tradisjonelle koagulanter.

Produktspesifikasjon

Utseende	Gulaktig til ravgul væske
Aluminum (Al^{3+})	9,0 ± 0,3 %
Al_2O_3	17,0 ± 0,6 %
Basisitet	42 ± 3 %
Tetthet (20°C)	1,37 ± 0,03 g/cm³

Typiske analyser

Aktive substanser	Ca. 3,3 mol/kg
Jern (Fe_{tot})	<0,01 %
Klorider (Cl^-)	21 ± 1 %
Viskositet (20°C)	35 ± 10 mPas
pH (20°C)	<1
Krystalliseres ved	-20°C

Dosering

Dosering med membran doseringspumper av ikke-korroderende materiale er best egnet. KEMIRA PAX-18 bør doseres uten fortynning.

Lagring

Lagertanker og rørsystemer skal bygges av egnet ikke-korroderende materiale slik som glassfiberarmert polyester eller tverrbundet polyeten. KEMIRA PAX-18 er sterkt etsende og kontakt med utstyr må unngås. KEMIRA PAX-18 har en anbefalt holdbarhet på 6 måneder. Som med ethvert kjemikalie, anbefales det å rengjøre tanken hvert år. Den første leveransen av et produkt skal gjøres til en ren oppbevaringsinnretning for å sikre optimal ytelse og lagring. Ved utendørs lagring, bør tank og rør isoleres og varmebeskyttes. Temperaturen på produktet bør opprettholdes over 0°C.

Sikker håndtering

Håndteringen av ethvert kjemikalie krever forsiktighet. Enhver ansvarlig for bruk eller håndtering av KEMIRA PAX-18 bør gjøre seg kjent med fullstendige sikkerhetstiltak beskrevet i vårt HMS-datablad.

Leveranse

Veitransport: FN-nummer 3264
ETSENDE VÆSKE, SUR, UORGANISK, N.O.S. (polyaluminiumklorid), Klasse 8,
Emballasjegruppe: III
Risikokode 80, Fareseddel ADR/RID: 8

Kundeservice

Hvis du har spørsmål vedrørende dette materialet, vennligst kontakt vår kundeserviceavdeling eller din lokale salgsrepresentant.

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1630 Gamle Fredrikstad
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A8 – KEMIRA PAX-XL3103G product information

kemira

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Produktdatablad
12-03-2019

KEMIRA PAX-XL3103G

Polyaluminiumklorid Løsning

KEMIRA PAX-XL3103G, polyaluminumklorid med middels basisitet,er en effektiv koagulant for behandling av både prosess- og avløpsvann. KEMIRA PAX-XL3103G er basert på høyladet aluminium og organisk koagulant, slik at man trenger mindre av produktet for å gjøre mer. Dette resulterer i lavere doser og derfor reduseres slamvolum og behov for justering av pH. KEMIRA PAX-XL3103G er også mer effektiv til å fjerne partikler i forhold til tradisjonelle koagulanter.

Produktspesifikasjon

Utseende	Gulaktig væske
Aluminum (Al^{3+})	7,7 ± 0,3 %
Al_2O_3	14,5 ± 0,6 %
Basisitet	42 ± 3 %
Tetthet (20°C)	1,33 ± 0,03 g/cm³

Typiske analyser

Aktive substanser	Ca. 2,8 mol/kg
Jern (Fe_{tot})	<0,01 %
Klorider (Cl^-)	14 ± 1 %
Viskositet (20°C)	140 ± 10 mPas
pH (20°C)	<1
Krystalliseres ved	-20°C

Dosering

Dosering med membran doseringspumper av ikke-korroderende materiale er best egnet. KEMIRA PAX-XL3103G bør doseres uten fortynning.

Lagring

Lagertanker og rørsystemer skal bygges av egnet ikke-korroderende materiale slik som glassfiberarmert polyester eller tverrbundet polyeten. KEMIRA PAX-XL3103G er sterkt etsende og kontakt med utstyr må unngås. KEMIRA PAX-XL3103G har en anbefalt holdbarhet på 12 måneder. Som med ethvert kjemikalie, anbefales det å rengjøre tanken hvert år. Den første leveransen av et produkt skal gjøres til en ren oppbevaringsinnretning for å sikre optimal ytelse og lagring. Ved utendørs lagring, bør tank og rør isoleres og varmebeskyttes. Temperaturen på produktet bør opprettholdes over 0°C med en -30°C omgivelsetemperatur.

Sikker håndtering

Håndteringen av ethvert kjemikalie krever forsiktighet. Enhver ansvarlig for bruk eller håndtering av KEMIRA PAX-XL3103G bør gjøre seg kjent med fullstendige sikkerhetstiltak beskrevet i vårt HMS-datablad.

Leveranse

Veitransport: FN-nummer 3264
ETSENDE VÆSKE, SUR, UORGANISK, N.O.S. (polyaluminiumklorid), Klasse 8,
Emballasjegruppe: III
Risikokode 80, Fareseddel ADR/RID: 8

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A9 – KEMIRA PIX-311 product information

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Produktdatablad
2021-02-15

KEMIRA PIX-311

Jernklorid Løsning

KEMIRA PIX-311, jernklorid, er en effektiv koagulant i flytende form basert på treverdig jern (Fe^{3+}). KEMIRA PIX-311 fungerer godt for både drikkevann og avløpsvann, og kan brukes for farge, fosfat og tungmetallfjerning. KEMIRA PIX-311 kan også brukes for reduksjon av hydrogensulfid og beleggdannelse og slamkondisjoneringsapplikasjoner.

Produktspesifikasjon

Utseende	Mørk brun flytende
Jern (Fe_{tot})	13,8 ± 0,4 %
Jern (Fe^{2+})	<0,3 %
$Fe_2(SO_4)_3$	39 - 41 %
Fri syre (HCl)	<2 %
Tetthet (20°C)	1,42 ± 0,03 g/cm³

Typiske analyser

Aktive substanser	Ca. 2,5 mol/kg
Klorider (Cl^-)	26 ± 2 %
Sulfater (SO_4^{2-})	<0,5 %
Vann uløselighet	<0,02 %
Viskositet (20°C)	10 ± 5 mPas
pH (20°C)	<1
Krystalliseres ved	-20°C

Kvalitet

KEMIRA PIX-311 er godkjent av Mattilsynet til bruk som koagulant ved drikkevannsrensing.

Dosering

Dosering med membran doseringspumper av ikke-korroderende materiale er best egnet. KEMIRA PIX-311 bør doseres uten fortynning.

Lagring

Lagertanker og rørsystemer skal bygges av egnet ikke-korroderende materiale slik som glassfiberarmert polyester eller tverrbundet polyeten. KEMIRA PIX-311 er sterkt etsende og kontakt med metallutstyr må unngås. KEMIRA PIX-311 har en anbefalt holdbarhet på 12 måneder. Som med ethvert kjemikalie, anbefales det å rengjøre tanken hvert år. Den første leveransen av produktet skal gjøres til en ren lagertank for å sikre optimal ytelse og lagring. Ved utendørs lagring, bør tank og rør isoleres og varmebeskyttes. Temperaturen på produktet bør opprettholdes over 0°C .

Sikker håndtering

Håndteringen av ethvert kjemikalie krever forsiktighet. Enhver ansvarlig for bruk eller håndtering av KEMIRA PIX-311 bør gjøre seg kjent med fullstendige sikkerhetstiltak beskrevet i vårt HMS-datablad.

Leveranse

Veitransport: FN-nummer 2582
JERNKLORIDLØSNING, Klasse 8,
Emballasjegruppe: III

Kundeservice

Hvis du har spørsmål vedrørende dette materialet, vennligst kontakt vår kundeserviceavdeling eller din lokale salgsrepresentant.

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A10 – SUPERFLOC C-491K product information

kemira

Technical Data Sheet 1(2)

August 2023

SUPERFLOC C-491K

SUPERFLOC C-491K

Cationic Dry Polyacrylamide (DPAM)

SUPERFLOC C-491K is one of Kemira's highly effective cationic flocculants. They condition solids for dewatering operations and aid water clarification processes in various industries. They show exceptional performance in liquid-solid separations in a wide range of conditions.

Applications

SUPERFLOC C-491K This product may be beneficial in any liquid- solid separation process. They are especially recommended for:

- Belt filter, centrifuge and screw press dewatering
- Dissolved air flotation
- Filtration
- Thickening
- Water Clarification

Benefits

- Dry product minimizes storage requirements
- Economical to use - effective at low dosage levels
- Effective high solids removal
- Effective over a wide range of pH; does not alter the system pH
- Improve production and cake solids

Handling and Storage

Solutions are no more corrosive than water. Recommended materials of construction include stainless steel, fibreglass, plastic, and glass or epoxy-lined vessel. Do not use iron, copper or aluminum.

The shelf life of these products is 24 months when stored at temperatures no higher than 40°C/104°F.

Health and Safety

Before handling these materials read the corresponding Kemira Safety Data Sheets (SDS) for safety and health data.

For chemical inventory regulatory control listing information, see the SDS.

Regulatory Approvals

These products may conform to certain regulatory requirements. Please contact your Kemira sales representative for more details, or refer to the appropriate regulatory information sheet.

Product Addition

Stock solutions can be prepared up to 0.5 % concentration via an automated make-up unit or on a batch basis. Solutions should be aged 30-60 minutes for maximum effectiveness. High quality make up water should be used. Secondary dilution water should be added to the stock solution prior to the addition point at a ratio up to 10:1. Centrifugal pumps should be avoided for polymer transfer.

Delivery

SUPERFLOC C-491K is typically available in 25 kg & 750 kg moisture-resistant bags. Other pack sizes may be available on request.

SUPERFLOC C-491K

Typical Product Properties

Chemical Type	Cationic
Relative Charge	V. low
Molecular Weight	Low
Bulk Density (kg / litre)	0,75
pH of 0.5% Solution (25'c)	3-5

The product properties are stated for guidance only and may change overtime.

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A11 – Superfloc A-110HMW product information

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Where water meets chemistry™

Technical Data Sheet 1 (2)

12.10.2021

Superfloc ® A-110HMW

Anionisk polyakrylamid polymer i pulverform (DPAM)

Superfloc A-110HMW

Ett anionisk flokkuleringsmiddel med høy ytelse og høy molekylvekt. Det brukes som hjelpeflokkulant i vannreneseprosesser i ulike næringer og applikasjoner.
Dette flokkuleringsmiddelet gir særdeles gode resultater mtp reduksjon av partikler i en vann-/ væskefase i ulike prosesstekniske løsninger.

Applikasjoner

Dette produktet kan være fordelaktig i enhver separasjonsprosess for væske og fast stoff.
Det anbefales spesielt i forbindelse med:

- Flotasjon
- Filtrering
- Sedimentering
- Mekanisk avvanning
- Fosforfjerning – i kombinasjon med jern- og aluminiumsbaserte fellingsmidler.

Fordeler

- Økonomisk i bruk - effektivt ved lave doseringsmengder
- Effektiv fjerning av tørrstoff
- Effektiv over et bredt pH -område
- Kan redusere bruken av uorganiske salter
- Høy lagringsstabilitet

Oppbevaring

Polymeren er hygroskopisk og skal lagres tørt i temperaturer mellom 0-40 ° C.

Polymeren bør ikke lagres i mer enn 24 mnd.

Sikker håndtering

Håndteringen av ethvert kjemikalie krever forsiktighet. Enhver ansvarlig for bruk eller håndtering av SUPERFLOC A-110HMW bør gjøre seg kjent med fullstendige sikkerhetstiltak beskrevet i vårt sikkerhetsdatablad. Unngå kontakt med øyne og hud. I mangel på tilstrekkelig ventilasjon brukes egnet åndedrettsvern. Bruk hansker og briller/skjerm, fjern tilsølte klær og vask huden med rikelig mengder vann og såpe.
Bruk fortrinnsvis et automatisk doserings- og tilberednings utstyr, og sørg for tilstrekkelig ventilasjon.
NB! Søl kan føre til meget glatte overflater.

Dosering / Innblanding

Bruksløsningen kan tilberedes opptil 0,5 % konsentrasjon via en automatisk polymeroppløser. Den fortynnede løsningen bør modnes i ca 60 minutter for maksimal effektivitet.
Sekundært fortynningsvann kan tilsettes bruksløsningen før tilsetningspunktet i et forhold opptil 10:1. Sentrifugalpumper bør unngås i forbindelse med polymerdosering.

Leveranseformer

Sekker 25 kg
Big bags 500 kg og 750 kg

Kundeservice

Hvis du har spørsmål vedrørende dette materialet, vennligst kontakt din lokale salgsrepresentant.

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Produktspesifikasjoner

	A-110HMW
Kjemikalie type	Anionisk Polyakrylamid
Fysisk form	Off-white, Granulert pulver
Ladning	Lav
Molekylvekt	Meget høy
Egenvekt (kg/liter)	0.80
pH av 0.5% løsning (25°C)	7-9
Viskositet @ 25°C (Cp /mPa sec)	
0.10%	200
0.25%	400
0.50%	950

De typiske produktegenskapene er kun angitt som veiledning og kan endre seg over tid.

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A12 – SUPERFLOC C-494 product information

kemira
Where water meets chemistry™

Teknisk datablad 1 (2)

Sept 22

SUPERFLOC® C-494

Kationisk pulver polyakrylamid

SUPERFLOC® C-494 er en kationisk polyakrylamid I pulverform som brukes i forbindelse med avvanning og fortykking av slam i de fleste kommunale og industrielle renseprosesser. SUPERFLOC® C-494 benyttes også i noen applikasjoner som hjelpekoagulant / flokkulant i ulike fellingsprosesser.

Bruksområder

Kationisk pulver polyakrylamid kan være fordelaktig ved alle prosesser for separasjon av væske fra faste stoffer.

De anbefales spesielt til:

- Avvanning med silbandpresse, sentrifuge og skruepresse
- Filtrering
- Fortykning
- Rensing av vann
- Flotasjonsprosesser

Fordeler

- Tørt produkt, lang holdbarhet og god lagrings stabilitet
- Svært effektiv for separasjon av væske fra faste stoffer
- Økonomisk i bruk – effektivt ved lave doseringsnivåer
- Effektive over et bredt pH-område, endrer ikke prosessen sin pH verdi

Sikker håndtering

Håndtering av ethvert kjemikalie krever forsiktighet. Enhver ansvarlig for bruk eller håndtering av SUPERFLOC® C-494 bør gjøre seg kjent med fullstendige sikkerhetstiltak beskrevet i vårt sikkerhetsdatablad.

Bruk fortrinnsvis et automatisk doserings- og tilberedningsutstyr og sørg for tilstrekkelig ventilasjon.

NB! Søl kan føre til svært glatte overflater.

Lagring

SUPERFLOC® C-494 er hygroskopisk og skal lagres tørt i temperaturer mellom 0-40 °C.

Lagringstid bør ikke overstige mer enn 24 måneder.

Dosering

Bruksløsningen doseres fra blande- / lagertank med feks. eksenterskrue eller impeller pumpe og kan ved behov fortynnes med vann på vei til doseringspunkt.

For de fleste applikasjoner oppnås best resultat om SUPERFLOC® C-494 tilsettes i en turbulent sone.

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Produktegenskaper

	C-494
Kjemisk type	Kationisk Polyakrylamid
Fysisk form	Hvitt, Granulert Pulver
Ladning	Middels
Molekylvekt	Høy
Tetthet (kg/liter)	0,75
pH av 0,5 % løsning (25 °C)	3 – 5
Viskositet @ 25 °C (cP / mPa•sec)	
0,10 %	130
0,25 %	300
0,50 %	600
1,00 %	1400

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A13 – SUPERFLOC A-130HMW product information

kemira

Where water
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Technical Data Sheet 1 (1)

01.08.2020

SUPERFLOC® A-130HMW

SUPERFLOC® A-130HMW anionisk polyakrylamid polymer i pulverform, brukes som hjelpeflokkulant i forbindelse med rensing av avløpsvann.Brukes også i forbindelse med avvanning og fortykking av slam.

Produktspesifikasjon

Fysisk form	Hvitt pulver
Ladning	Medium anionisk
Molekylvekt	Høy
Tørrstoff	88-100%
Uløst rest	< 2,00 %
Egenvekt	0,85 kg/l ± 0,05
Viskositet, CPS (30 rpm 25 oC)	900-1100 (0,5 % løsning)
SPORSTOFFER	
Monomer (ureagert akrylamid)	< 500 ppm

Kvalitet

Kemira Chemicals AS er sertifisert ihht ISO 9001.2015 og 14001.2015.

Dosering

Bruksløsningen doseres fra blande-/lagertank med for eks. eksenterskrue- eller impeller pumpe og kan ved behov fortynnes med vann på vei til doseringspunktet. For de fleste applikasjoner oppnås best resultat om polymeren tilsettes i en turbulent sone.

Lagring

Polymeren er hygroskopisk og skal lagres tørt i temperaturer mellom 0-35 °C. Polymeren bør ikke lagres i mer enn 24 mnd.

Sikker håndtering

Unngå kontakt med øyne og hud. I mangel av tilstrekkelig ventilasjon brukes egnet åndedrettsvern.
Bruk hansker og briller/skjerm, fjern tilsølte klær og vask huden med rikelig mengder vann og såpe.
Les alltid sikkerhetsdatablad før bruk. Bruk fortrinnsvis et automatisk doserings- og tilberednings utstyr, og sørg for tilstrekkelig ventilasjon. NB! Søl kan føre til meget glatte overflater.

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B – Calculations

B1 – Calculations of standard concentrations of Metalsorb and Flopam EM 240 CT based on NOAH's current process

Calculations used to find the concentrations used in the experimentation are shown below, followed by calculations of dilutions.

Calculations to find the standard concentration of Flopam EM 240 CT:

These calculations are based on values received from NOAH that are often used in their wastewater treatment process.

The mass polymer used in the process per hour is calculated:

$$m_{polymer} = 3.0\ \frac{g\ polymer}{min} \times 60\ \frac{min}{h} = 180\ \frac{g\ polymer}{h}$$

This mass is mixed in a water stream of 90 L/h, which constitutes the initial volume, V_0.

$$V_0 = 90\ \frac{L\ water}{h}$$

The initial concentration (c_0), before the polymer is mixed with the wastewater:

$$c_0 = \frac{180\ \frac{g\ polymer}{h}}{90\ \frac{L\ water}{h}} = 2.0\ g\ polymer/L\ \ vann$$

The final concentration (c_1) is the concentration after the 90 L/h water stream mixed with the polymer is mixed with the wastewater in the sedimentation pool at Langøya:

$$c_1 = \frac{c_0 V_o}{V_1}$$

The volume in the sedimentation pool is 120 000 L/h. Thus, the final volume, V_1, is the total volume of wastewater, polymer solution and metal binder solution.

$$V_1 = 120\ 000\ \frac{L}{h} + 90\ \frac{L}{h} + 2.28\ \frac{L}{h} = 120\ 092.28\ L/h\ \approx 120 \times 10^3\ L/h$$

$$c_1 = \frac{c_0 V_o}{V_1} = \frac{2.0\ g\ polymer/L\ \ water \times 90\ \frac{L\ water}{h}}{120 \times 10^3\ L/h} = 1.5 \times 10^{-3}\ \ g/L$$

This concentration is used as standard concentration in trials that uses Flopam EM 240 CT.

Now that the final concentration is found, the concentration that is to be added to the samples can be calculated. First, the mass of polymer (m_p) to be weighed and diluted needs to be found.

The final volume in the samples, V_T = 0.52L, is a selected working volume consisting of 0.5L wastewater, 10 mL polymer solution and 10 mL metal binder solution. Finding total mass of polymer (m_p), to be added to the final solution of wastewater (V_T) in most trials:

$$m_p = c_1 \times V_T = 1.5 \times 10^{-3}\ g/L \times 0.52L = 7.8 \times 10^{-4} g$$

Thus, $7.8 \times 10^{-4} g$ polymer with a volume of 10mL is added to the wastewater. The polymer solution is the following concentration(c_{pl}):

$$c_{pl} = \frac{7.8 \times 10^{-4}}{10mL} = 0.078\ g/L$$

To achieve the correct mass of polymer more accurately, a larger amount was added to a volumetric flask and diluted to the correct concentration. 1L of polymer solution was to be made.

By measuring out/weighing an amount10 times larger than the amount polymer needed per Litre, a dilution of 1/10 is required. The larger amount of polymer is added to a 1000 mL measuring flask and diluted. 1/10 of this volume = 100 mL was diluted to 1000 mL in a second measuring flask.

$$m_{polymer} = 0.78g$$

Concentration (c) after dilution:

$$c = \frac{0.78g}{1000mL} \times \frac{100mL}{1000mL} = 0.078\ g/L$$

$$c_{pl} = c = 0.078g/L$$

Metalsorb HCO:

2.28L/h Metalsorb in 120 000L/h process water + 90L/h polymer solution

Total volume $V_1 \approx 120 \times 10^3\ L/h$

$$c_m = \frac{2.28\ \frac{L\ metalsorb}{h}}{120 \times 10^3\ \frac{L\ final\ solution}{h}} = \frac{1.9 \times 10^{-5} L\ metalsorb}{L\ final\ solution}$$

A final volume of V_T = 0.52L including 10mL Metalsorb solution was used in the trials (based on recommended numbers from NOAH).

Volume Metalsorb (V_m): $V_m = \frac{1.9 \times 10^{-5} L\ metalsorb \times 0.52}{1L\ prosessløsning \times 0.52} = \frac{9.88 \times 10^{-6} L\ metalsorb}{0.52L\ prosessløsning}$

$9.88 \times 10^{-6} L\ metalsorb$ in 10mL Metalsorb solution is needed.

Concentration(c_m): $c_m = \frac{9.88 \times 10^{-6} L\ metalsorb}{10mL\ vann} = 9.88 \times 10^{-4}\ \frac{L\ metalsorb}{L\ vann} = 988\ \frac{\mu L\ metalsorb}{L\ vann}$

The volume of micropipettes available can be increased by increments of 5µL. The volume Metalsorb solution is rounded to the nearest available volume:

$$988\,\frac{\mu L\ metalsorb}{L\ water} \approx 990\,\frac{\mu L\ metalsorb}{L\ water}$$

990µL Metalsorb was added to the 1000mL measuring flask and diluted (to the mark).

SUPERFLOC A-130, A110, C-494 and C-491:

It was recommended by the supplier to prepare 1g/L of SUPERFLOC. (19) 200 µL of this solution was added to the beakers when conducting the Jar-tests. The final concentration of SUPERFLOC in the beakers is calculated below:

$$\frac{1L}{(200 \times 10^{-6})L} = 5000$$

$$\frac{\frac{1g}{L}}{5000} = 2 \times 10^{-4}\ \frac{g}{L}$$

Example of total removal. Calculation example table 11 results trial 2, 3, 4

Example sample 1 trial 2. Total metal concentration 116.4 µg/L.

$$\left(1 - \frac{116.4}{400.9667}\right) \times 100 = 70.97016$$

B2 – Calculation of metalsorb and polymer concentrations in trial 2, 3 and 4;

Metalsorb HCO in trial 2:

$$c_1 = \frac{1}{2} \times 0.990 \frac{mL}{L} = 0.495 g/L$$

$$c_2 = \frac{V_1 c_1}{V_2} = \frac{10\ mL\ \times 0.495 g/L}{0.520\ L} = 0.00952\ mL/L$$

Flopam EM 240 CT in trial 3:

$$c_1 = \frac{1}{2} \times 0.078 \frac{g}{L} = 0.039\ g/L$$

$$c_2 = \frac{V_1 c_1}{V_2} = \frac{10\ mL\ \times 0.039\ g/L}{0.520\ L} = 7.5\ \times 10^{-4} g/L$$

Volume of polymer added to final flask:

Sample 6: 100 mL of diluted polymer was transferred to a new flask to make up a concentration of 0.117g/L before reaction. This concentration is 3/2 of the standard solution. To find the other volumes that needs to be added and diluted, divide the fraction of standard solution by 3/2, and multiply by 100mL.

Example, sample 1 (concentration is half of standard concentration):

$$\frac{1/2}{3/2} \times 100\ mL\ \approx 33\ mL$$

B3 – Percentage removal calculation example

Calculation example for percent removal for arsenic in trial 1.

The concentration of arsenic in sample 1, trial 1 is divided by the concentration of the average reference concentration of arsenic.

$$\frac{3.3\ \mu g/L}{4.766667\ \mu g/L} = 0.692$$

To find the percent of arsenic removed, the following calculation was made:

$$(1 - 0.692) \times 100\% = 30.77\%$$

B4 – Total percent removal calculation example

Calculation example for total percentage removal where all the metals are added for sample 1, trial 8.

First, the concentrations of all the metals in the sample are added together.

$$1.9 + 3.7 + 10.2 + 9.7 + 0.3 + 3.1 = 28.9\ \mu g/L$$

The same was repeated for the average reference concentrations where the total concentration is 221.23 µg/L.

Then the percentage removal was then calculated:

$$\left(1 - \frac{28.9}{221.23}\right) \times 100\% = 70.032\%$$

B5 – Average change in pH in trial 21 calculation example

The difference between preceding measurements was found for each of the three samples. Then the average was calculated of the three samples.

$$9.8 - 9.73 = 0.07$$

$$\frac{0.07 + 0.07 + 0.07}{3} = 0.07$$

C – Concentrations in Samples

Table 32: Mass weighed of polymers from Kemira for the preparation of liquid polymer.

Polymer	Mass (g)
SUPERFLOC A- 110HMW	1.0075
SUPERFLOC A- 130HMW	1.0020
SUPERFLOC C- 491K	1.0140
SUPERFLOC C- 494	1.0039

Table 33: Trial 1, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	0.99	0.01904	10	0.078	0.0015	10

Table 34: Trial 2, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	0.495	0.00952	10	0.078	0.0015	10
2	0.74	0.0142	10	0.078	0.0015	10
3	0.87	0.0167	10	0.078	0.0015	10
4	1.1	0.0212	10	0.078	0.0015	10
5	1.2	0.0231	10	0.078	0.0015	10
6	1.5	0.0288	10	0.078	0.0015	10

Table 35: Trial 3, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	0.99	0.990	10	0.039	0.000743	10
2	0.99	0.990	10	0.059	0.00113	10
3	0.99	0.990	10	0.068	0.00131	10
4	0.99	0.990	10	0.088	0.00169	10
5	0.99	0.990	10	0.098	0.00188	10
6	0.99	0.990	10	0.117	0.00225	10

Table 36: Trial 4, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	0.495	0.00952	10	0.039	0.000743	10
2	0.74	0.0142	10	0.059	0.00113	10
3	0.87	0.0167	10	0.068	0.00131	10
4	1.1	0.0212	10	0.088	0.00169	10
5	1.2	0.0231	10	0.097	0.00188	10
6	1.5	0.0288	10	0.117	0.00225	10

Table 37: Trial 5, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	0.99	0.01904	10	0.078	0.0015	10
2	0.99	0.01904	10	0.078	0.0015	10
3	0.99	0.01904	10	0.078	0.0015	10
4	0.99	0.01904	10	0.078	0.0015	10
5	0.99	0.01904	10	0.078	0.0015	10
6	0.99	0.01904	10	0.078	0.0015	10

Table 38: Trial 6, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	0.99	0.01904	10	0.078	0.0015	10
2	0.99	0.01904	10	0.078	0.0015	10
3	0.99	0.01904	10	0.078	0.0015	10
4	0.99	0.01904	10	0.078	0.0015	10
5	0.99	0.01904	10	0.078	0.0015	10
6	0.99	0.01904	10	0.078	0.0015	10

Table 39: Trial 7, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	0.99	0.01904	10	0.079	0.001512	10
2	0.99	0.01904	10	0.079	0.001512	10
3	0.99	0.01904	10	0.079	0.001512	10
4	0.99	0.01904	10	0.079	0.001512	10
5	0.99	0.01904	10	0.079	0.001512	10
6	0.99	0.01904	10	0.079	0.001512	10

Table 40: Trial 8, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Metalsorb	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	HCO	0.99	0.01904	10	0.079	0.001512	10
2	PCZ	0.99	0.01904	10	0.079	0.001512	10
3	ZT	0.99	0.01904	10	0.079	0.001512	10
4	ZM 3	0.99	0.01904	10	0.079	0.001512	10

Table 41: Trial 9, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Metalsorb	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	HCO	0.99	0.01904	10	0.079	0.001512	10
2	PCZ	0.99	0.01904	10	0.079	0.001512	10
3	ZT	0.99	0.01904	10	0.079	0.001512	10
4	ZM 3	0.99	0.01904	10	0.079	0.001512	10

Table 42: Trial 10, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	0.99	0.0077	4	0.079	0.001512	10
2	0.99	0.012	6	0.079	0.001512	10
3	0.99	0.015	8	0.079	0.001512	10
4	0.99	0.023	12	0.079	0.001512	10
5	0.99	0.026	14	0.079	0.001512	10
6	0.99	0.03	16	0.079	0.001512	10

Table 43: Trial 11, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (µL/L)	Final conc. metal binder (µL/L)	Vol. metal binder added to solution (µL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (µL)
1	Pure chemical	50	50	1	0.0002	200
2	Pure chemical	50	50	1	0.0002	200
3	Pure chemical	50	50	1	0.0002	200
4	Pure chemical	50	50	1	0.0002	200
5	Pure chemical	50	50	1	0.0002	200
6	Pure chemical	50	50	1	0.0002	200

Table 44: Trial 12, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (µL/L)	Final conc. metal binder (µL/L)	Vol. metal binder added to solution (µL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (µL)
1	Pure chemical	50	50	1	0.0002	200
2	Pure chemical	50	50	1	0.0002	200
3	Pure chemical	50	50	1	0.0002	200
4	Pure chemical	50	50	1	0.0002	200
5	Pure chemical	50	50	1	0.0002	200
6	Pure chemical	50	50	1	0.0002	200

Table 45: Trial 13, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (µ/L)	Final conc. metal binder (µ/L)	Vol. metal binder added to solution (µL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (µL)
1	Pure chemical	20	20	1	0.0002	200
2	Pure chemical	30	30	1	0.0002	200
3	Pure chemical	40	40	1	0.0002	200
4	Pure chemical	50	50	1	0.0002	200
5	Pure chemical	60	60	1	0.0002	200
6	Pure chemical	70	70	1	0.0002	200

Table 46: Trial 14, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (µL/L)	Final conc. metal binder (µL/L)	Vol. metal binder added to solution (µL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (µL)
1	Pure chemical	50	50	1	0.00014	140
2	Pure chemical	50	50	1	0.00016	160
3	Pure chemical	50	50	1	0.00018	180
4	Pure chemical	50	50	1	0.0002	200
5	Pure chemical	50	50	1	0.00022	220
6	Pure chemical	50	50	1	0.00024	240

Table 47: Trial 15, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (µL/L)	Final conc. metal binder (µL/L)	Vol. metal binder added to solution (µL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (µL)
1	Pure chemical	20	20	1	0.00014	140
2	Pure chemical	30	30	1	0.00016	160
3	Pure chemical	40	40	1	0.00018	180
4	Pure chemical	50	50	1	0.0002	200
5	Pure chemical	60	60	1	0.00022	220
6	Pure chemical	70	70	1	0.00024	240

Table 48: Trial 16, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (µL)
1	0.99	0.019038462	10	0.118	0.002269	10
2	0.99	0.019038462	10	0.118	0.002269	10
3	0.99	0.019038462	10	0.118	0.002269	10

Table 49: Trial 17, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (µL)
1	0.99	0.019038462	10	0.118	0.002269	10
2	0.99	0.019038462	10	0.118	0.002269	10
3	0.99	0.019038462	10	0.118	0.002269	10

Table 50: Trial 18, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (µL/L)	Final conc. metal binder (µL/L)	Vol. metal binder added to solution (µL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (µL)
1	Pure chemical	50	50	1	0.0015	10
2	Pure chemical	50	50	1	0.0015	10
3	Pure chemical	50	50	1	0.0015	10

Table 51: Trial 19, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (µL/L)	Final conc. metal binder (µL/L)	Vol. metal binder added to solution (µL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (µL)
1	Pure chemical	50	50	1	0.0002	200
2	Pure chemical	50	50	1	0.0002	200
3	Pure chemical	50	50	1	0.0002	200

Table 52: Trial 20, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	0.99	0.019038462	10	0.078	0.0015	10
2	0.99	0.019038462	10	0.078	0.0015	10
3	0.99	0.019038462	10	0.078	0.0015	10
4	0.99	0.019038462	10	0.078	0.0015	10
5	0.99	0.019038462	10	0.078	0.0015	10
6	0.99	0.019038462	10	0.078	0.0015	10

Table 53: Trial 21, concentrations and volumes of chemicals.

Samples/Conc. and vol.	Conc. metal binder (mL/L)	Final conc. metal binder (ml/L)	Vol. metal binder added to solution (mL)	Conc. Polymer (g/L)	Final conc. polymer (g/L)	Vol. polymer added to solution (mL)
1	0.99	0.019038462	10	0.079	0.001512	10
2	0.99	0.019038462	10	0.079	0.001512	10
3	0.99	0.019038462	10	0.079	0.001512	10

D – pH in samples

The uncertainty in trial 1-7 is ±0.03.

Table 54: pH in samples. Trials 1-7 where chemicals retrieved from NOAH were used.

Samples/Trials	1	2	3	4	5	6	7
1	9.80	9.81	9.81	9.81	9.20	9.82	9.80
2	-	9.80	9.81	9.81	9.41	9.81	9.80
3	-	9.80	9.80	9.80	9.61	9.81	9.80
4	-	9.80	9.81	9.84	9.81	9.80	9.80
5	-	9.81	9.80	9.80	10.01	9.80	9.80
6	-	9.80	9.80	9.80	10.20	9.80	9.80

Table 55: pH in samples. Trials 8-10 where chemicals retrieved from Yara were used. The pH is also shown after the reaction in trials 8 and 9.

Samples/Trials	8	8 (after)	9	9 (after)	10
1	9.81	9.72	10.03	9.96	10.02
2	9.81	9.72	10.01	9.94	10.02
3	9.81	9.72	10.01	9.94	10.01
4	9.81	9.73	10	9.93	10.02
5					10.01
6					10.03

Table 56: pH in samples. Trials 11-15 where chemicals retrieved from Kemira were used. The pH is shown after the reaction for trial 11.

Samples/Trials	11	11 (after)	12	13	14	15
1	10.5	9.98	10.5	10.05	10.01	10.02
2	10.5	9.99	10.5	10.02	10.02	10.04
3	10.5	10.05	10.53	10.03	10	10.01
4	10.5	9.98	10.53	10	10	10.01
5	10.5	10.01	10.5	10	10.01	10.02
6	10.5	10.07	10.5	10.01	10.02	10.01

Table 57: pH in samples. Trials 16-19, which are the triplicate tests. The pH is shown after the reaction for trials 16-19.

Samples/Trials	16	16 (after)	17	17 (after)	18	18 (after)	19	19 (after)
1	10	10.01	10	9.93	10.03	9.82	10.01	9.74
2	10	9.94	10	9.96	10.03	9.82	10	9.74
3	10	9.91	10	9.9	10.02	9.81	10.01	10.74

Table 58: pH test and sedimentation/pH test, which are trial 20 and 21 respectively.

Samples/Trials	20	21
1	9.6	9.8
2	9.7	9.91
3	9.8	10.01
4	9.92	
5	10.01	
6	10.15	

E – Concentration results

Table 59: Concentrations of metals (µg/L). Reference values from first sampling.

Metals/samples	Reference 1	Reference 2	Reference 3
Al	186	221	389
As	3.6	4	6.7
Ba	3800	3500	3340
Cd	65	67.6	66.1
Co	8.7	9.6	9.3
Cr	3	3	5.3
Cu	47	58.4	59
Fe	23.7	173	224
Mn	18.4	41.4	32.7
Mo	875	889	916
Ni	13.8	13.2	18.2
Pb	1.9	13.8	13.6
Sb	52.8	53.3	62.2
Se	12.9	13	13.6
Sn	10	10	10
Tl	2.5	2.4	2.8
U	7.7	10.7	7.6
V	31.9	32.3	34.6
Zn	15.9	86.9	109

Table 60: Reference values before water treatment from second sampling of water, concentrations of metals (µg/L).

Metals/samples	Reference 1	Reference 2	Reference 3
Al	209	219	190
As	7.5	5.9	6.3
Ba	4770	4730	4680
Cd	149	152	151
Co	15	14.4	15.4
Cr	3	3	3
Cu	49.5	47.3	44
Fe	297	266	215
Mn	166	158	150
Mo	908	913	924
Ni	17.3	19.1	20.9
Pb	17.6	15.7	13.4
Sb	115	113	108
Se	11.6	11	10.4
Sn	10	10	10
Tl	2.9	2.7	2.7
U	9.8	9.8	9.8
V	23	23.1	23.1
Zn	131	113	102

Table 61: Trial 1 Standard, concentrations of metals (µg/L).

Metals/samples	1
Al	20.0
As	1.9
Ba	3120.0
Cd	10.2
Co	8.1
Cr	3.0
Cu	8.7
Fe	14.5
Mn	2.5
Mo	819.0
Ni	5.8
Pb	0.3
Sb	47.9
Se	10.7
Sn	10.0
Tl	0.1
U	2.2
V	28.9
Zn	3.0

Table 62: Trial 2, varying concentration of Metalsorb HCO, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	20	20	26.6	165	57.2	20
As	3.3	1.9	2.5	4.8	2.9	1.7
Ba	3310	3360	3430	3150	3300	3360
Cd	17.2	16.8	8.7	10.4	9.8	13
Co	8.2	8.5	8.7	8.8	7.6	8.8
Cr	3	3.8	3	3	3	3
Cu	15.5	4	6.7	34.7	25	4
Fe	22.6	14	13.5	22.8	14.1	9.4
Mn	4.4	2.6	2.8	9.3	4.3	2.8
Mo	842	852	881	817	817	804
Ni	6.6	5.9	2.9	5.4	5.5	4.6
Pb	0.7	0.3	0.4	1	0.9	0.2
Sb	48.5	48.7	50	45.6	45.5	47.7
Se	11.1	11.9	11.8	12.5	13.1	11.6
Sn	10	10	10	10	10	10
Tl	0.8	0.5	0.2	0.6	0.3	0.3
U	3.1	2.5	1.4	3.4	1.9	0.8
V	30	30	32	37	34.7	26.8
Zn	23	5.2	15	10.9	3	4.6

Table 63: Trial 3, varying concentration Flopam EM 240 CT, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	20	20	20	20	20	20
As	2.1	2	1.8	2.5	2.9	1.8
Ba	3330	3310	3380	3400	3170	3140
Cd	3.3	9.2	9.2	7.9	10.9	9.8
Co	8.4	8.1	8.4	8.2	8.9	8.2
Cr	3	3	3	3	3	3
Cu	4	14	15.9	5.9	18.4	14.3
Fe	9.6	12.7	11.8	10.3	26.4	29.8
Mn	1.3	2.1	1.5	2.4	3.4	2.5
Mo	813	816	820	823	827	818
Ni	2.2	5.2	4.1	3.5	7.5	9.3
Pb	0.2	0.2	0.2	0.2	0.2	0.2
Sb	46.1	44.3	44	45.4	43.7	45
Se	11.1	11.8	10.7	11.4	11.8	11.7
Sn	10	10	10	10	10	10
Tl	0.1	0.2	0.2	0.1	0.5	0.5
U	0.6	1.4	1.4	1.2	2.5	2.2
V	28.6	25.7	29.1	29.1	31.8	27.4
Zn	3	3	3	3	3	3

Table 64: Trial 4, varying concentration Metalsorb HCO and Flopam EM 240 CT, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	20.5	20	20	20	21.1	20
As	2.7	2.8	1.8	2.1	2.2	1.9
Ba	3300	3420	3390	3400	3410	3370
Cd	5.4	5.4	4.9	10.5	14.5	34.2
Co	8.9	8.8	8.3	7.7	8.5	7.8
Cr	3	3	3	3	3	3
Cu	7.2	4	4	4	6.7	31
Fe	13.9	13.6	10.8	9.8	12.1	12.8
Mn	1.1	2.1	1	1	1	1.6
Mo	818	836	836	840	825	810
Ni	4	2.3	2.2	3.1	2.9	8.1
Pb	0.2	0.2	0.2	0.2	0.4	1.7
Sb	44.4	46.8	45	47.1	44	46.4
Se	10.9	11.7	11.1	11.8	10.7	11.6
Sn	10	10	10	10	10	10
Tl	0.2	0.2	0.1	0.1	0.4	0.6
U	1.5	1	0.8	0.9	2	5.1
V	28.9	27	29.4	32.8	28.5	28.9
Zn	3	3	3	3	3	3

Table 65: Trial 5, pH, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	223	171	76.5	20	20	20
As	2.4	2.8	2.6	1.7	2.3	1.7
Ba	3130	3230	3210	3280	3160	3200
Cd	16.8	32.7	16.2	9.2	3.5	11.7
Co	8.6	8.4	7.6	8.3	8.4	8
Cr	3	3	3	3	3	3
Cu	12.2	11.6	6.8	4	4.1	4.1
Fe	30	15.6	8.9	9.5	14.4	17.7
Mn	18.4	7.6	2.6	1.4	1.4	1
Mo	823	844	822	840	821	826
Ni	9.4	5	4.4	2.8	5.4	3.3
Pb	0.4	0.3	0.2	0.2	0.2	0.2
Sb	45.3	49.3	46.3	46.2	47.6	45.8
Se	11.3	11.3	9.9	10.3	11.6	12.5
Sn	10	10	10	10	10	10
Tl	0.5	1.1	0.4	0.3	0.1	0.3
U	3.4	3	1.7	1.3	1	1.4
V	31.8	31.4	29.7	30.8	34.1	30.5
Zn	13.8	8.6	3	3	3	3

Table 66: Trial 6, Stirring duration, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	41.1	42.1	57.4	44	45.3	43.9
As	3.2	3	2.7	2.6	2.8	2.5
Ba	2870	2910	2940	2860	2860	2900
Cd	12.8	10.6	15.5	9.1	8.4	8.5
Co	8.7	8.5	8.6	9.2	8.5	9
Cr	3	3	3	3.2	3	3.7
Cu	4	4.1	6.3	4.2	4	4.4
Fe	24.2	31.1	38.5	29	30.6	29.5
Mn	3.1	3.1	3.9	3.4	2.4	3
Mo	865	871	887	862	871	868
Ni	8.3	10	12.9	11.2	9.7	11.3
Pb	0.4	0.4	0.5	0.4	0.4	0.4
Sb	50.1	49	50.6	49.3	50.1	50.9
Se	12	11.8	11.8	11.7	12.1	11.6
Sn	10	10	10	10	10	10
Tl	0.7	0.6	0.8	0.6	0.5	0.5
U	1.4	1.3	1.8	1.3	1	1.2
V	30.6	1	30.3	30.4	28.5	30.3
Zn	6.8	1	6.5	4.6	3	4.2

Table 67: Trial 7, Stirring speed, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	50	40.2	28.4	30.2	28	50.1
As	3	2.4	2.9	2.9	3.7	3.7
Ba	2740	2710	2700	2720	2750	2790
Cd	13	23	12.3	14.5	27.7	19.2
Co	9	8.8	8.7	8.8	8.8	9
Cr	3.6	3.2	3	3.1	3	3.9
Cu	5.4	26.4	4.4	4.1	5.4	7.6
Fe	28	52.7	32.9	36.3	30.6	36.6
Mn	2.8	3.6	2.2	2.2	3	4.2
Mo	864	865	874	864	871	899
Ni	9.5	18	10.4	10.3	10.9	10.4
Pb	0.9	1.3	0.5	0.6	0.8	0.8
Sb	50.3	50.1	50.4	49.9	49.4	50.3
Se	11.5	12.8	10.9	12.1	12	12.3
Sn	10	10	10	10	10	10
Tl	0.7	1.2	0.7	0.9	1.1	0.9
U	1.2	2.5	1.4	1.6	2.2	2.6
V	30.5	31.3	31.7	30.1	30.5	34.2
Zn	7.6	9.9	4.2	4.7	7.7	6.2

Table 68: Trial 8, Yara chemicals, concentrations of metals (µg/L).

Metals/samples	1	2	3	4
Al	119	129	41.1	142
As	4.9	4.7	4.1	4.1
Ba	2940	3020	2990	2970
Cd	21.5	17.1	12.7	24.8
Co	8.8	9.1	8.4	8.8
Cr	6	5.3	5.4	8.2
Cu	18.1	17.5	11	20.3
Fe	47.6	31.6	41.6	50.6
Mn	5.2	3.6	4.4	4.8
Mo	878	902	900	897
Ni	16.1	15.3	12.3	20.5
Pb	1.1	0.8	0.7	0.9
Sb	54.3	55	55.4	53.8
Se	12.6	13.8	12.7	13
Sn	10	10	10	10
Tl	1	0.8	2.7	2.5
U	2.4	2.5	5.3	5.7
V	33	35.1	33.5	34
Zn	8.4	7.2	7.9	20.5

Table 69: Trial 9, Yara chemicals, concentrations of metals (µg/L).

Metals/samples	1	2	3	4
Al	35.4	30.1	53.7	29.2
As	4.1	3.7	3.6	4.1
Ba	3040	2950	2960	2940
Cd	8.3	10.2	6.4	13.1
Co	8.7	8.2	8.6	8.9
Cr	4.4	4.1	3.3	4.1
Cu	9.7	9.1	6.3	12.6
Fe	23.5	25	22.5	24
Mn	2.9	2.5	2.1	2
Mo	902	887	898	890
Ni	11.3	8.8	7.6	9.3
Pb	0.7	0.7	0.9	0.8
Sb	53.4	50.9	53.5	53
Se	13.7	12.2	12.8	12.4
Sn	10	10	10	10
Tl	0.5	0.7	2.6	2.6
U	1.2	1.8	3.7	3.1
V	33.9	34.8	36.2	35.7
Zn	5.2	7.1	7.1	6.2

Table 70: Trial 10, varying concentration of metalsorb ZT, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	22.6	51.5	37.5	27.1	50.7	37.6
As	3.1	3.8	3	3.6	3.3	3.7
Ba	4610	4720	4550	4690	4700	4580
Cd	10.6	73.8	11.6	11.5	17	9.4
Co	14.5	14.7	14.5	14.4	14.2	13.4
Cr	3	3	3	3	3	3
Cu	4	5.4	4	4	5.4	4
Fe	12	12.8	12.9	13	30.4	12.1
Mn	12.2	15.8	13.3	9.4	15.1	12.4
Mo	888	910	871	884	900	862
Ni	11	10.1	7.8	8.9	11	9
Pb	0.6	0.8	0.5	0.5	0.6	0.5
Sb	77.1	105	77.3	99.6	103	99.9
Se	7.5	8.5	9	9	8.4	7.8
Sn	10	10	10	10	10	10
Tl	2.8	2.7	2.5	2.5	2.6	2.5
U	7.2	7.5	7.4	7.1	7.8	6.6
V	23	21.4	21.2	22.5	23.3	20.9
Zn	7.4	6.1	6.6	7.1	8.5	6.6

Table 71: Trial 11, Kemira chemicals A and B, concentrations of metals (µg/L).

Metals/samples	1 (1A)	2 (2A)	3 (3A)	4 (1B)	5 (2B)	6 (3B)
Al	394	330	20	671	193	20
As	1.9	1.7	1.5	1.4	1.7	1.6
Ba	2650	2650	2640	2650	2650	2630
Cd	3.7	3.5	9.5	4	4.7	10.3
Co	8.2	8.2	8.4	7.9	8	8.5
Cr	3.2	3.9	3	3.5	3.2	3.2
Cu	10.2	12	12	10.1	10.6	8.5
Fe	17.7	18.4	360	16.8	18.5	387
Mn	1	1	1.1	1	1	1.2
Mo	815	817	797	814	799	801
Ni	9.7	9.7	8.7	10.5	9.2	8.9
Pb	0.3	1	0.9	0.3	0.3	0.2
Sb	46.7	46.5	43.4	46.6	46.1	41.2
Se	12.3	11.6	11.8	11.3	11.6	11.5
Sn	10	10	10	10	10	10
Tl	2.3	2.4	2.4	2.5	2.3	2.5
U	1.7	3.7	0.5	1.6	4.9	0.6
V	28	28.4	13.8	25.1	27.3	12.2
Zn	3.1	3	3	3	3	3

Table 72: Trial 12, Kemira chemicals C and D, concentrations of metals (µg/L).

Metals/samples	1 (1C)	2 (2C)	3 (3C)	4 (1D)	5 (2D)	6 (3D)
Al	2560	612	20	1760	768	20
As	1.6	1.7	1.8	1.3	1.5	1.8
Ba	2640	2670	2650	2640	2660	2650
Cd	9.7	5.8	16.9	5.9	4.9	17.5
Co	8.4	8.4	8.6	7.9	8.4	8
Cr	3.6	4.4	3.5	3	4.2	3
Cu	8.4	7.6	7	6.9	7.9	8.4
Fe	20.7	22.4	338	21.5	21.8	607
Mn	1	1	1.1	1	1	1.4
Mo	807	822	811	814	817	803
Ni	10.9	10.6	10.6	9.5	9.4	8.3
Pb	0.3	0.4	0.2	0.3	0.4	0.3
Sb	45.7	47.4	40.2	47.7	47.1	41.9
Se	11.5	12.2	11.5	11.2	11.3	11.6
Sn	10	10	10	10	10	10
Tl	2.4	2.5	2.3	2.5	2.6	2.4
U	2.4	2.3	0.5	1.8	2.2	0.7
V	27.6	27.1	9.8	24.4	26.7	10.7
Zn	3	3	3	3	3	3

Table 73: Trial 13, varying concentration of PAX-18, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	1130	2300	3220	4800	5770	6820
As	2.6	2.8	2.9	2.6	3.1	3
Ba	2560	2610	2620	2620	2590	2640
Cd	23	27.2	29.1	34.6	34.3	34.4
Co	9.6	8.8	9.5	9.7	8.8	9.4
Cr	3	3	3	3	3	3
Cu	13.7	12.5	11.9	14.5	14.9	14.5
Fe	27.3	21.1	21.6	20.6	20.2	29
Mn	1.6	1	1	2.1	2.2	1.8
Mo	898	938	925	933	919	941
Ni	17.1	18.9	16.3	16.3	17.1	19.8
Pb	0.7	0.7	0.7	0.8	0.9	0.7
Sb	52	51.7	55.6	51	52.7	52.1
Se	12.5	11.8	11.5	11.9	11.5	11.9
Sn	10	10	10	10	10	10
Tl	2.4	2.3	2.4	2.5	2.3	2.5
U	3.4	3.5	3.8	3.9	4	4.1
V	31.2	32.5	32.1	32.3	33.2	30.9
Zn	4.1	4.8	4.3	5.8	5.5	5.9

Table 74: Trial 14, varying polymer A-130, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	5950	6100	6890	6390	4700	4820
As	3	3.1	3.3	2.3	2.9	2.3
Ba	2590	2660	2650	2710	2640	2670
Cd	29.6	31.5	37.5	31.9	26.7	24.7
Co	8.9	9.5	8.9	9.7	8.9	9.5
Cr	3	3	3	3	3	3
Cu	19.3	16.7	18.2	18	14.5	15.7
Fe	22.1	18.8	20.6	20.2	17.3	17.8
Mn	1	1.3	1.6	1	1.2	1
Mo	912	923	915	927	920	943
Ni	11.5	13.5	14	15.2	15.9	17.1
Pb	1.3	0.8	0.7	0.7	0.6	0.6
Sb	55.7	57.5	58.9	56.2	52.3	50.9
Se	12.1	12.4	12.2	12.2	11.1	11.4
Sn	10	10	10	10	10	10
Tl	2.4	2.3	2.3	2.4	2.4	2.4
U	3.3	3.7	4.8	4.9	3.8	3.5
V	34	32.7	32	34.9	32.8	32.3
Zn	6.3	4.6	5.6	5.8	3.1	4.3

Table 75: Trial 15, varying concentration of PAX-18 and A-130, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	996	2580	4170	5500	5400	9210
As	2.3	2.7	2.6	2.9	2.7	2.9
Ba	2710	2720	2630	2640	2670	2730
Cd	20.3	23.1	26.9	25.8	28.3	33.1
Co	9.8	9.2	9.5	9.3	9.7	9.5
Cr	3	3	3	3	3	3
Cu	13.9	15.6	18.3	22.6	14.9	17.3
Fe	20.1	17.6	19.6	21.6	18.3	20.7
Mn	1.2	1	1.4	2.1	1	1
Mo	930	945	921	921	928	938
Ni	13.2	16.5	17.6	16.5	15.2	17.7
Pb	0.8	0.8	1	1.6	0.5	0.6
Sb	51.5	52.1	53.1	56.4	49.8	61.7
Se	11.7	12.2	12.1	12.3	11.9	12
Sn	10	10	10	10	10	10
Tl	2.4	2.2	2.4	2.4	2.4	2.4
U	2.3	2.9	3.3	2.4	3.5	5.1
V	34.3	34.5	33.7	38.2	33	35.7
Zn	6.4	4.7	7.6	7.6	5.7	5.8

Table 76: Trial 16, triplicate test where Metalsorb HCO and Flopam EM 240 CT were used (µg/L).

Metals/samples	1	2	3
Al	39.9	37.6	35.3
As	3.1	4.1	3.6
Ba	4550	4600	4540
Cd	39.5	37.7	36
Co	13.9	13.9	14.8
Cr	3	3	3
Cu	4	4	4
Fe	18.6	16.1	15.3
Mn	17.1	14.8	11
Mo	883	852	976
Ni	8.3	8.7	12.2
Pb	0.9	0.7	0.8
Sb	71.3	85.5	87.2
Se	7.9	7.6	10.4
Sn	10	10	10
Tl	0.6	0.6	0.6
U	2.8	2.5	2.5
V	22.4	23	21.6
Zn	9	8.9	8.7

Table 77: Trial 17, triplicate test where Metalsorb ZT and Flopam EM 240 CT were used (µg/L).

Metals/samples	1	2	3
Al	28.6	28	20
As	3.7	3.9	2.9
Ba	4630	4570	4600
Cd	12.5	20.2	19
Co	14.3	14.4	14.6
Cr	3	3	3
Cu	4	5.3	4.4
Fe	15	16	17.4
Mn	8.9	8.7	12
Mo	858	875	880
Ni	12	11.8	13.2
Pb	1	1.3	0.9
Sb	73	102	84.3
Se	8.2	8.4	7.5
Sn	10	10	10
Tl	2.6	2.7	2.6
U	5.6	5.7	5.9
V	23.4	22.7	23.9
Zn	8.2	6.8	8

Table 78: Trial 18, triplicate test where PAX-18 and SUPERFLOC A-130 were used. Method based on NOAH's process (µg/L).

Metals/samples	1	2	3
Al	1200	1350	1200
As	3	3.4	3
Ba	4580	4690	4700
Cd	86.4	91.2	89.1
Co	13.8	14.5	14.2
Cr	3	3	3
Cu	9.3	9	7
Fe	17	14.9	12.4
Mn	12.3	8.8	5.8
Mo	886	907	911
Ni	12.9	13.4	11.8
Pb	1	1	0.9
Sb	98.8	104	103
Se	10.3	9	9.1
Sn	10	10	10
Tl	2.6	2.3	2.5
U	5.8	6.9	6.3
V	22.7	25.3	23.3
Zn	6.1	6.1	4

Table 79: Trial 19, triplicate test where PAX-18 and SUPERFLOC A-130 were used (µg/L).

Metals/samples	1	2	3
Al	5450	4310	6040
As	4.4	3.3	3.9
Ba	4810	4690	4810
Cd	123	116	130
Co	14.2	14.3	14.8
Cr	3	3	3
Cu	7.9	6.9	8.6
Fe	15.1	12.2	13
Mn	6.1	5.6	8.9
Mo	920	917	922
Ni	7.2	10	12
Pb	1.2	0.9	1.1
Sb	108	104	107
Se	10.1	10.7	9.6
Sn	10	10	10
Tl	2.6	2.5	2.6
U	7.3	6.5	7.8
V	21	22.7	24.1
Zn	6.3	5.3	4.9

Table 80: Trial 20, pH test, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	191	112	92.6	61.2	59	45.9
As	3.4	3.1	3.2	3.2	3	3.1
Ba	2560	2570	2540	2560	2540	2600
Cd	44	25.1	22.1	14.1	13.9	19.8
Co	8.9	8.6	9.3	9	9.6	8.9
Cr	3.9	3	3	3	3.6	6.2
Cu	14.3	13.2	13	10.7	9.9	7.6
Fe	57.4	33.2	37.6	43.6	60.6	88.9
Mn	8.6	6.1	5	4.1	3.3	3.7
Mo	891	878	868	883	858	848
Ni	13.3	14	14.1	12.8	14.4	15.2
Pb	2.1	1.6	1.5	1.3	1.4	0.8
Sb	47.7	49.6	48.3	47	47.8	45.3
Se	10.7	10.5	11.6	11.1	10.3	11.5
Sn	10	10	10	10	10	10
Tl	1.5	1	0.8	0.7	0.7	1
U	4.7	3	2.1	1.4	1.2	2.3
V	28.4	31	31	34.3	32.7	29.9
Zn	22.2	12.9	10.9	8.7	9.9	6.1

Table 81: Trial 21, sedimentation test, concentrations of metals (µg/L).

Metals/samples	1	2	3	4	5	6
Al	99.9	40.7	58.5	106	80.2	109
As	2.9	2.6	2.6	2.9	2.4	2.8
Ba	2700	2770	2770	2880	2950	3000
Cd	9.1	3.5	3.7	2.9	3.1	3.5
Co	9.4	10	9.7	10.2	10.2	10.3
Cr	3.3	3.8	3.3	3	3	3
Cu	4.6	4	4	4	4	4
Fe	35.1	28	32.3	24.4	23.3	22.6
Mn	3.2	2	1.6	5.4	4.5	4.6
Mo	931	947	962	985	1020	1040
Ni	14	15.3	16.4	16.6	18.4	17.4
Pb	0.6	0.6	0.5	0.5	0.5	0.4
Sb	52.7	53.4	53.8	55.6	57.6	58.2
Se	12.3	11.2	12.8	12.2	13.6	13.5
Sn	10	10	10	10	10	10
Tl	0.4	0.2	0.2	0.7	0.5	0.4
U	3.6	2.7	2.3	4	3.7	3.1
V	31.3	31.4	32.8	29.4	32.8	33.3
Zn	8.1	4.6	4.7	6.3	6.7	6.5

F – Percent removal of metals results

Table 82: Trial 1, standard test. Percent removal of metals. (%)

Metals/samples	1
Al	92,46231
As	60,13986
Ba	12,03008
Cd	84,5999
Co	11,95652
Cr	-
Cu	84,12409
Fe	89,66009
Mn	91,89189
Mo	8,320896
Ni	61,50442
Pb	96,92833
Sb	14,61676
Se	18,73418
Sn	-
Tl	96,1039
U	74,61538
V	12,24696
Zn	95,75071

Table 83: Trial 2, varying concentration of Metalsorb HCO, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	92,46231	92,46231	89,97487	37,81407	78,44221	92,46231
As	30,76923	60,13986	47,55245	-0,6993	39,16084	64,33566
Ba	6,672932	5,263158	3,289474	11,18421	6,954887	5,263158
Cd	74,0312	74,63513	86,86462	84,29794	85,20382	80,37242
Co	10,86957	7,608696	5,434783	4,347826	17,3913	4,347826
Cr	-	-	-	-	-	-
Cu	71,71533	92,70073	87,77372	36,67883	54,37956	92,70073
Fe	83,884	90,01664	90,37319	83,74138	89,94533	93,29689
Mn	85,72973	91,56757	90,91892	69,83784	86,05405	90,91892
Mo	5,746269	4,626866	1,380597	8,544776	8,544776	10
Ni	56,19469	60,84071	80,75221	64,15929	63,49558	69,46903
Pb	92,83276	96,92833	95,90444	89,76109	90,78498	97,95222
Sb	13,54724	13,19073	10,87344	18,71658	18,89483	14,97326
Se	15,6962	9,620253	10,37975	5,063291	0,506329	11,89873
Sn	-	-	-	-	-	-
Tl	68,83117	80,51948	92,20779	76,62338	88,31169	88,31169
U	64,23077	71,15385	83,84615	60,76923	78,07692	90,76923
V	8,906883	8,906883	2,834008	-12,3482	-5,36437	18,62348
Zn	67,4221	92,63456	78,75354	84,56091	95,75071	93,48442

Table 84: Trial 3, varying concentration of Flopam EM 240 CT, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	92,46231	92,46231	92,46231	92,46231	92,46231	92,46231
As	55,94406	58,04196	62,23776	47,55245	39,16084	62,23776
Ba	6,109023	6,672932	4,699248	4,135338	10,6203	11,46617
Cd	95,01761	86,10971	86,10971	88,07247	83,54303	85,20382
Co	8,695652	11,95652	8,695652	10,86957	3,26087	10,86957
Cr	-	-	-	-	-	-
Cu	92,70073	74,45255	70,9854	89,23358	66,42336	73,90511
Fe	93,15427	90,94367	91,58545	92,6551	81,17423	78,7497
Mn	95,78378	93,18919	95,13514	92,21622	88,97297	91,89189
Mo	8,992537	8,656716	8,208955	7,873134	7,425373	8,432836
Ni	85,39823	65,48673	72,78761	76,76991	50,22124	38,27434
Pb	97,95222	97,95222	97,95222	97,95222	97,95222	97,95222
Sb	17,82531	21,03387	21,56863	19,07308	22,10339	19,7861
Se	15,6962	10,37975	18,73418	13,41772	10,37975	11,13924
Sn	-	-	-	-	-	-
Tl	96,1039	92,20779	92,20779	96,1039	80,51948	80,51948
U	93,07692	83,84615	83,84615	86,15385	71,15385	74,61538
V	13,15789	21,96356	11,63968	11,63968	3,441296	16,80162
Zn	95,75071	95,75071	95,75071	95,75071	95,75071	95,75071

Table 85 Trial 4, varying concentration of Metalsorb HCO and Flopam EM 240 CT, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	92,27387	92,46231	92,46231	92,46231	92,04774	92,46231
As	43,35664	41,25874	62,23776	55,94406	53,84615	60,13986
Ba	6,954887	3,571429	4,417293	4,135338	3,853383	4,981203
Cd	91,84701	91,84701	92,60191	84,14696	78,1077	48,36437
Co	3,26087	4,347826	9,782609	16,30435	7,608696	15,21739
Cr	-	-	-	-	-	-
Cu	86,86131	92,70073	92,70073	92,70073	87,77372	43,43066
Fe	90,08795	90,30188	92,29855	93,01165	91,37152	90,87236
Mn	96,43243	93,18919	96,75676	96,75676	96,75676	94,81081
Mo	8,432836	6,41791	6,41791	5,970149	7,649254	9,328358
Ni	73,45133	84,73451	85,39823	79,42478	80,75221	46,23894
Pb	97,95222	97,95222	97,95222	97,95222	95,90444	82,59386
Sb	20,85561	16,57754	19,7861	16,04278	21,56863	17,29055
Se	17,21519	11,13924	15,6962	10,37975	18,73418	11,89873
Sn	-	-	-	-	-	-
Tl	92,20779	92,20779	96,1039	96,1039	84,41558	76,62338
U	82,69231	88,46154	90,76923	89,61538	76,92308	41,15385
V	12,24696	18,01619	10,72874	0,404858	13,46154	12,24696
Zn	95,75071	95,75071	95,75071	95,75071	95,75071	95,75071

Table 86: Trial 5, pH, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	15,95477	35,55276	71,16834	92,46231	92,46231	92,46231
As	49,65035	41,25874	45,45455	64,33566	51,74825	64,33566
Ba	11,74812	8,928571	9,492481	7,518797	10,90226	9,774436
Cd	74,63513	50,62909	75,54102	86,10971	94,71565	82,33518
Co	6,521739	8,695652	17,3913	9,782609	8,695652	13,04348
Cr	-	-	-	-	-	-
Cu	77,73723	78,83212	87,59124	92,70073	92,51825	92,51825
Fe	78,60708	88,87568	93,65343	93,22558	89,7314	87,37818
Mn	40,32432	75,35135	91,56757	95,45946	95,45946	96,75676
Mo	7,873134	5,522388	7,985075	5,970149	8,097015	7,537313
Ni	37,61062	66,81416	70,79646	81,41593	64,15929	78,09735
Pb	95,90444	96,92833	97,95222	97,95222	97,95222	97,95222
Sb	19,25134	12,12121	17,46881	17,64706	15,15152	18,36007
Se	14,17722	14,17722	24,81013	21,77215	11,89873	5,063291
Sn	-	-	-	-	-	-
Tl	80,51948	57,14286	84,41558	88,31169	96,1039	88,31169
U	60,76923	65,38462	80,38462	85	88,46154	83,84615
V	3,441296	4,65587	9,817814	6,477733	-3,54251	7,388664
Zn	80,45326	87,8187	95,75071	95,75071	95,75071	95,75071

Table 87: Trial 6, Stirring duration, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	84,51005	84,13317	78,36683	83,41709	82,92714	83,45477
As	32,86713	37,06294	43,35664	45,45455	41,25874	47,55245
Ba	19,07895	17,95113	17,10526	19,3609	19,3609	18,23308
Cd	80,67438	83,99597	76,59789	86,26069	87,31756	87,16658
Co	5,434783	7,608696	6,521739	0	7,608696	2,173913
Cr	-	-	-	-	-	-
Cu	92,70073	92,51825	88,50365	92,33577	92,70073	91,9708
Fe	82,74305	77,82268	72,54576	79,32018	78,17923	78,96363
Mn	89,94595	89,94595	87,35135	88,97297	92,21622	90,27027
Mo	3,171642	2,5	0,708955	3,507463	2,5	2,835821
Ni	44,9115	33,62832	14,38053	25,66372	35,61947	25
Pb	95,90444	95,90444	94,88055	95,90444	95,90444	95,90444
Sb	10,69519	12,65597	9,803922	12,12121	10,69519	9,269162
Se	8,860759	10,37975	10,37975	11,13924	8,101266	11,89873
Sn	-	-	-	-	-	-
Tl	72,72727	76,62338	68,83117	76,62338	80,51948	80,51948
U	83,84615	85	79,23077	85	88,46154	86,15385
V	7,08502	96,96356	7,995951	7,692308	13,46154	7,995951
Zn	90,36827	98,58357	90,7932	93,48442	95,75071	94,05099

Table 88: Trial 7, Stirring speed, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	81,15578	84,84925	89,29648	88,61809	89,44724	81,11809
As	37,06294	49,65035	39,16084	39,16084	22,37762	22,37762
Ba	22,74436	23,59023	23,87218	23,30827	22,46241	21,33459
Cd	80,37242	65,27428	81,42929	78,1077	58,17816	71,01158
Co	2,173913	4,347826	5,434783	4,347826	4,347826	2,173913
Cr	-	-	-	-	-	-
Cu	90,14599	51,82482	91,9708	92,51825	90,14599	86,13139
Fe	80,03328	62,41978	76,5391	74,11457	78,17923	73,90064
Mn	90,91892	88,32432	92,86486	92,86486	90,27027	86,37838
Mo	3,283582	3,171642	2,164179	3,283582	2,5	-0,63433
Ni	36,9469	-19,469	30,97345	31,63717	27,65487	30,97345
Pb	90,78498	86,68942	94,88055	93,85666	91,80887	91,80887
Sb	10,33868	10,69519	10,16043	11,05169	11,94296	10,33868
Se	12,65823	2,78481	17,21519	8,101266	8,860759	6,582278
Sn	-	-	-	-	-	-
Tl	72,72727	53,24675	72,72727	64,93506	57,14286	64,93506
U	86,15385	71,15385	83,84615	81,53846	74,61538	70
V	7,388664	4,959514	3,744939	8,603239	7,388664	-3,84615
Zn	89,23513	85,97734	94,05099	93,34278	89,09348	91,21813

Table 89: Trial 8, Yara chemicals, percent removal of metals. (%)

Metals/samples	1	2	3	4
Al	55,15075	51,38191	84,51005	46,48241
As	-2,7972	1,398601	13,98601	13,98601
Ba	17,10526	14,84962	15,69549	16,2594
Cd	67,539	74,18218	80,82536	62,55662
Co	4,347826	1,086957	8,695652	4,347826
Cr	-	-	-	-
Cu	66,9708	68,06569	79,92701	62,9562
Fe	66,05657	77,46613	70,33516	63,91728
Mn	83,13514	88,32432	85,72973	84,43243
Mo	1,716418	-0,97015	-0,74627	-0,41045
Ni	-6,85841	-1,54867	18,36283	-36,0619
Pb	88,7372	91,80887	92,83276	90,78498
Sb	3,208556	1,960784	1,247772	4,099822
Se	4,303797	-4,81013	3,544304	1,265823
Sn	-	-	-	-
Tl	61,03896	68,83117	-5,19481	2,597403
U	72,30769	71,15385	38,84615	34,23077
V	-0,20243	-6,57895	-1,72065	-3,23887
Zn	88,10198	89,8017	88,8102	70,96317

Table 90: Trial 9, Yara chemicals, percent removal of metals. (%)

Metals/samples	1	2	3	4
Al	86,65829	88,65578	79,76131	88,99497
As	13,98601	22,37762	24,47552	13,98601
Ba	14,28571	16,82331	16,54135	17,10526
Cd	87,46855	84,5999	90,33719	80,22144
Co	5,434783	10,86957	6,521739	3,26087
Cr	-	-	-	-
Cu	82,29927	83,39416	88,50365	77,0073
Fe	83,24222	82,17257	83,95531	82,88567
Mn	90,59459	91,89189	93,18919	93,51351
Mo	-0,97015	0,708955	-0,52239	0,373134
Ni	25	41,59292	49,55752	38,27434
Pb	92,83276	92,83276	90,78498	91,80887
Sb	4,812834	9,269162	4,634581	5,525847
Se	-4,05063	7,341772	2,78481	5,822785
Sn	-	-	-	-
Tl	80,51948	72,72727	-1,2987	-1,2987
U	86,15385	79,23077	57,30769	64,23077
V	-2,93522	-5,66802	-9,91903	-8,40081
Zn	92,63456	89,94334	89,94334	91,21813

Table 91: Trial 10, varying concentration of of metalsorb ZT, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	89,02913	75	81,79612	86,84466	75,38835	81,74757
As	52,79188	42,13198	54,31472	45,17766	49,74619	43,65482
Ba	2,468265	0,141044	3,737659	0,77574	0,564175	3,102962
Cd	92,9646	51,0177	92,30088	92,36726	88,71681	93,76106
Co	2,901786	1,5625	2,901786	3,571429	4,910714	10,26786
Cr	-	-	-	-	-	-
Cu	91,47727	88,49432	91,47727	91,47727	88,49432	91,47727
Fe	95,37275	95,06427	95,02571	94,98715	88,27763	95,33419
Mn	92,27848	90	91,58228	94,05063	90,44304	92,1519
Mo	2,95082	0,546448	4,808743	3,387978	1,639344	5,79235
Ni	42,40838	47,12042	59,1623	53,40314	42,40838	52,87958
Pb	96,14561	94,86081	96,78801	96,78801	96,14561	96,78801
Sb	31,16071	6,25	30,98214	11,07143	8,035714	10,80357
Se	31,81818	22,72727	18,18182	18,18182	23,63636	29,09091
Sn	-	-	-	-	-	-
Tl	-1,20482	2,409639	9,638554	9,638554	6,024096	9,638554
U	26,53061	23,46939	24,4898	27,55102	20,40816	32,65306
V	0,289017	7,225434	8,092486	2,456647	-1,01156	9,393064
Zn	93,58382	94,71098	94,27746	93,84393	92,63006	94,27746

Table 92: Trial 11, Kemira chemicals A and B, percent removal of metals. (%)

Metals/samples	1 (1A)	2 (2A)	3 (3A)	4 (1B)	5 (2B)	6 (3B)
Al	-48,4925	-24,3719	92,46231	-152,889	27,26131	92,46231
As	60,13986	64,33566	68,53147	70,62937	64,33566	66,43357
Ba	25,28195	25,28195	25,56391	25,28195	25,28195	25,84586
Cd	94,41369	94,71565	85,65677	93,96074	92,90388	84,44892
Co	10,86957	10,86957	8,695652	14,13043	13,04348	7,608696
Cr	-	-	-	-	-	-
Cu	81,38686	78,10219	78,10219	81,56934	80,65693	84,48905
Fe	87,37818	86,87901	-156,715	88,01997	86,8077	-175,969
Mn	96,75676	96,75676	96,43243	96,75676	96,75676	96,10811
Mo	8,768657	8,544776	10,78358	8,880597	10,5597	10,33582
Ni	35,61947	35,61947	42,25664	30,30973	38,93805	40,9292
Pb	96,92833	89,76109	90,78498	96,92833	96,92833	97,95222
Sb	16,75579	17,1123	22,63815	16,93405	17,82531	26,55971
Se	6,582278	11,89873	10,37975	14,17722	11,89873	12,65823
Sn	-	-	-	-	-	-
Tl	10,38961	6,493506	6,493506	2,597403	10,38961	2,597403
U	80,38462	57,30769	94,23077	81,53846	43,46154	93,07692
V	14,97976	13,76518	58,09717	23,78543	17,10526	62,95547
Zn	95,60907	95,75071	95,75071	95,75071	95,75071	95,75071

Table 93: Trial 12, Kemira chemicals C and D, percent removal of metals. (%)

Metals/samples	1 (1C)	2 (2C)	3 (3C)	4 (1D)	5 (2D)	6 (3D)
Al	-864,824	-130,653	92,46231	-563,317	-189,447	92,46231
As	66,43357	64,33566	62,23776	72,72727	68,53147	62,23776
Ba	25,56391	24,71805	25,28195	25,56391	25	25,28195
Cd	85,35481	91,24308	74,48415	91,0921	92,60191	73,57826
Co	8,695652	8,695652	6,521739	14,13043	8,695652	13,04348
Cr	-	-	-	-	-	-
Cu	84,67153	86,13139	87,22628	87,40876	85,58394	84,67153
Fe	85,23889	84,02662	-141,027	84,66841	84,45448	-332,85
Mn	96,75676	96,75676	96,43243	96,75676	96,75676	95,45946
Mo	9,664179	7,985075	9,216418	8,880597	8,544776	10,11194
Ni	27,65487	29,64602	29,64602	36,9469	37,61062	44,9115
Pb	96,92833	95,90444	97,95222	96,92833	95,90444	96,92833
Sb	18,53832	15,50802	28,34225	14,97326	16,04278	25,31194
Se	12,65823	7,341772	12,65823	14,93671	14,17722	11,89873
Sn	-	-	-	-	-	-
Tl	6,493506	2,597403	10,38961	2,597403	-1,2987	6,493506
U	72,30769	73,46154	94,23077	79,23077	74,61538	91,92308
V	16,19433	17,71255	70,24291	25,91093	18,92713	67,51012
Zn	95,75071	95,75071	95,75071	95,75071	95,75071	95,75071

Table 94: Trial 13, varying concentration of of PAX-18, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	-325,879	-766,834	-1113,57	-1709,05	-2074,62	-2470,35
As	45,45455	41,25874	39,16084	45,45455	34,96503	37,06294
Ba	27,81955	26,40977	26,12782	26,12782	26,97368	25,56391
Cd	65,27428	58,93306	56,06442	47,76044	48,21339	48,06241
Co	-4,34783	4,347826	-3,26087	-5,43478	4,347826	-2,17391
Cr	-	-	-	-	-	-
Cu	75	77,18978	78,28467	73,54015	72,81022	73,54015
Fe	80,53245	84,95365	84,5971	85,3102	85,59544	79,32018
Mn	94,81081	96,75676	96,75676	93,18919	92,86486	94,16216
Mo	-0,52239	-5	-3,54478	-4,4403	-2,87313	-5,33582
Ni	-13,4956	-25,4425	-8,18584	-8,18584	-13,4956	-31,4159
Pb	92,83276	92,83276	92,83276	91,80887	90,78498	92,83276
Sb	7,308378	7,843137	0,891266	9,090909	6,060606	7,130125
Se	5,063291	10,37975	12,65823	9,620253	12,65823	9,620253
Sn	-	-	-	-	-	-
Tl	6,493506	10,38961	6,493506	2,597403	10,38961	2,597403
U	60,76923	59,61538	56,15385	55	53,84615	52,69231
V	5,263158	1,315789	2,530364	1,923077	-0,80972	6,174089
Zn	94,19263	93,20113	93,90935	91,7847	92,20963	91,64306

Table 95: Trial 14, varying polymer A-130, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	-2142,46	-2198,99	-2496,73	-2308,29	-1671,36	-1716,58
As	37,06294	34,96503	30,76923	51,74825	39,16084	51,74825
Ba	26,97368	25	25,28195	23,59023	25,56391	24,71805
Cd	55,30951	52,44087	43,38198	51,83694	59,68797	62,7076
Co	3,26087	-3,26087	3,26087	-5,43478	3,26087	-3,26087
Cr	-	-	-	-	-	-
Cu	64,78102	69,52555	66,78832	67,15328	73,54015	71,35036
Fe	84,24055	86,59377	85,3102	85,59544	87,66342	87,30687
Mn	96,75676	95,78378	94,81081	96,75676	96,10811	96,75676
Mo	-2,08955	-3,3209	-2,42537	-3,76866	-2,98507	-5,5597
Ni	23,67257	10,39823	7,079646	-0,88496	-5,53097	-13,4956
Pb	86,68942	91,80887	92,83276	92,83276	93,85666	93,85666
Sb	0,713012	-2,49554	-4,99109	-0,17825	6,773619	9,269162
Se	8,101266	5,822785	7,341772	7,341772	15,6962	13,41772
Sn	-	-	-	-	-	-
Tl	6,493506	10,38961	10,38961	6,493506	6,493506	6,493506
U	61,92308	57,30769	44,61538	43,46154	56,15385	59,61538
V	-3,23887	0,708502	2,834008	-5,97166	0,404858	1,923077
Zn	91,07649	93,48442	92,06799	91,7847	95,60907	93,90935

Table 96: Trial 15, varying concentration of of PAX-18 and A-130, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	-275,377	-872,362	-1471,61	-1972,86	-1935,18	-3371,11
As	51,74825	43,35664	45,45455	39,16084	43,35664	39,16084
Ba	23,59023	23,30827	25,84586	25,56391	24,71805	23,02632
Cd	69,35078	65,1233	59,38601	61,0468	57,27227	50,02516
Co	-6,52174	0	-3,26087	-1,08696	-5,43478	-3,26087
Cr	-	-	-	-	-	-
Cu	74,63504	71,53285	66,60584	58,75912	72,81022	68,43066
Fe	85,66675	87,44949	86,02329	84,5971	86,95032	85,23889
Mn	96,10811	96,75676	95,45946	93,18919	96,75676	96,75676
Mo	-4,10448	-5,78358	-3,09701	-3,09701	-3,8806	-5
Ni	12,38938	-9,51327	-16,8142	-9,51327	-0,88496	-17,4779
Pb	91,80887	91,80887	89,76109	83,61775	94,88055	93,85666
Sb	8,199643	7,130125	5,347594	-0,53476	11,22995	-9,98217
Se	11,13924	7,341772	8,101266	6,582278	9,620253	8,860759
Sn	-	-	-	-	-	-
Tl	6,493506	14,28571	6,493506	6,493506	6,493506	6,493506
U	73,46154	66,53846	61,92308	72,30769	59,61538	41,15385
V	-4,1498	-4,75709	-2,32794	-15,9919	-0,20243	-8,40081
Zn	90,93484	93,34278	89,23513	89,23513	91,92635	91,7847

Table 97: Trial 16, triplicate test where Metalsorb HCO and Flopam EM 240 CT were used. (%)

Metals/samples	1	2	3
Al	80,63107	81,74757	82,86408
As	52,79188	37,56345	45,17766
Ba	3,737659	2,679831	3,949224
Cd	73,78319	74,97788	76,10619
Co	6,919643	6,919643	0,892857
Cr	-	-	-
Cu	91,47727	91,47727	91,47727
Fe	92,82776	93,79177	94,10026
Mn	89,17722	90,63291	93,03797
Mo	3,497268	6,885246	-6,66667
Ni	56,5445	54,45026	36,12565
Pb	94,21842	95,50321	94,86081
Sb	36,33929	23,66071	22,14286
Se	28,18182	30,90909	5,454545
Sn	-	-	-
Tl	78,31325	78,31325	78,31325
U	71,42857	74,4898	74,4898
V	2,890173	0,289017	6,358382
Zn	92,19653	92,28324	92,45665

Table 98: Trial 17, triplicate test where Metalsorb ZT and Flopam EM 240 CT were used. (%)

Metals/samples	1	2	3
Al	86,1165	86,40777	90,29126
As	43,65482	40,60914	55,83756
Ba	2,045134	3,314528	2,679831
Cd	91,70354	86,59292	87,38938
Co	4,241071	3,571429	2,232143
Cr	-	-	-
Cu	91,47727	88,70739	90,625
Fe	94,21594	93,83033	93,29049
Mn	94,36709	94,49367	92,40506
Mo	6,229508	4,371585	3,825137
Ni	37,17277	38,2199	30,89005
Pb	93,57602	91,64882	94,21842
Sb	34,82143	8,928571	24,73214
Se	25,45455	23,63636	31,81818
Sn	-	-	-
Tl	6,024096	2,409639	6,024096
U	42,85714	41,83673	39,79592
V	-1,44509	1,589595	-3,61272
Zn	92,89017	94,10405	93,06358

Table 99: Trial 18, triplicate test where PAX-18 and SUPERFLOC A-130 were used. Method based on NOAH's process. (%)

Metals/samples	1	2	3
Al	-482,524	-555,34	-482,524
As	54,31472	48,22335	54,31472
Ba	3,102962	0,77574	0,564175
Cd	42,65487	39,46903	40,86283
Co	7,589286	2,901786	4,910714
Cr	-	-	-
Cu	80,18466	80,82386	85,08523
Fe	93,44473	94,2545	95,21851
Mn	92,21519	94,43038	96,32911
Mo	3,169399	0,874317	0,437158
Ni	32,46073	29,84293	38,2199
Pb	93,57602	93,57602	94,21842
Sb	11,78571	7,142857	8,035714
Se	6,363636	18,18182	17,27273
Sn	-	-	-
Tl	6,024096	16,86747	9,638554
U	40,81633	29,59184	35,71429
V	1,589595	-9,68208	-1,01156
Zn	94,71098	94,71098	96,53179

Table 100: Trial 19, triplicate test using PAX-18 and SUPERFLOC A-130

Metals/samples	1	2	3
Al	-2545,63	-1992,23	-2832,04
As	32,99492	49,74619	40,60914
Ba	-1,76305	0,77574	-1,76305
Cd	18,36283	23,00885	13,71681
Co	4,910714	4,241071	0,892857
Cr	-	-	-
Cu	83,16761	85,2983	81,67614
Fe	94,17738	95,29563	94,98715
Mn	96,13924	96,4557	94,36709
Mo	-0,54645	-0,21858	-0,76503
Ni	62,30366	47,64398	37,17277
Pb	92,29122	94,21842	92,93362
Sb	3,571429	7,142857	4,464286
Se	8,181818	2,727273	12,72727
Sn	-	-	-
Tl	6,024096	9,638554	6,024096
U	25,5102	33,67347	20,40816
V	8,959538	1,589595	-4,47977
Zn	94,53757	95,40462	95,75145

Table 101: Trial 20, pH test, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	28,01508	57,78894	65,1005	76,93467	77,76382	82,70101
As	28,67133	34,96503	32,86713	32,86713	37,06294	34,96503
Ba	27,81955	27,53759	28,38346	27,81955	28,38346	26,69173
Cd	33,56819	62,10367	66,63312	78,71163	79,01359	70,10569
Co	3,26087	6,521739	-1,08696	2,173913	-4,34783	3,26087
Cr	-	-	-	-	-	-
Cu	73,90511	75,91241	76,27737	80,47445	81,93431	86,13139
Fe	59,06822	76,32517	73,18754	68,90896	56,78631	36,60566
Mn	72,10811	80,21622	83,78378	86,7027	89,2973	88
Mo	0,261194	1,716418	2,835821	1,156716	3,955224	5,074627
Ni	11,72566	7,079646	6,415929	15,04425	4,424779	-0,88496
Pb	78,49829	83,61775	84,64164	86,68942	85,66553	91,80887
Sb	14,97326	11,58645	13,90374	16,22103	14,79501	19,25134
Se	18,73418	20,25316	11,89873	15,6962	21,77215	12,65823
Sn	-	-	-	-	-	-
Tl	41,55844	61,03896	68,83117	72,72727	72,72727	61,03896
U	45,76923	65,38462	75,76923	83,84615	86,15385	73,46154
V	13,76518	5,870445	5,870445	-4,1498	0,708502	9,210526
Zn	68,55524	81,72805	84,56091	87,67705	85,97734	91,35977

Table 102: Trial 21, sedimentation test, percent removal of metals. (%)

Metals/samples	1	2	3	4	5	6
Al	62,34925	84,6608	77,95226	60,05025	69,77387	58,9196
As	39,16084	45,45455	45,45455	39,16084	49,65035	41,25874
Ba	23,87218	21,8985	21,8985	18,79699	16,82331	15,41353
Cd	86,26069	94,71565	94,41369	95,62154	95,31958	94,71565
Co	-2,17391	-8,69565	-5,43478	-10,8696	-10,8696	-11,9565
Cr	-	-	-	-	-	-
Cu	91,60584	92,70073	92,70073	92,70073	92,70073	92,70073
Fe	74,97029	80,03328	76,96696	82,60043	83,38483	83,884
Mn	89,62162	93,51351	94,81081	82,48649	85,40541	85,08108
Mo	-4,21642	-6,00746	-7,68657	-10,2612	-14,1791	-16,4179
Ni	7,079646	-1,54867	-8,84956	-10,177	-22,1239	-15,4867
Pb	93,85666	93,85666	94,88055	94,88055	94,88055	95,90444
Sb	6,060606	4,812834	4,099822	0,891266	-2,6738	-3,74332
Se	6,582278	14,93671	2,78481	7,341772	-3,29114	-2,53165
Sn	-	-	-	-	-	-
Tl	84,41558	92,20779	92,20779	72,72727	80,51948	84,41558
U	58,46154	68,84615	73,46154	53,84615	57,30769	64,23077
V	4,959514	4,65587	0,404858	10,72874	0,404858	-1,11336
Zn	88,52691	93,48442	93,34278	91,07649	90,50992	90,7932

G- Risk assessment

RISIKOANALYSE (alternativ til bruk av RiskManager)

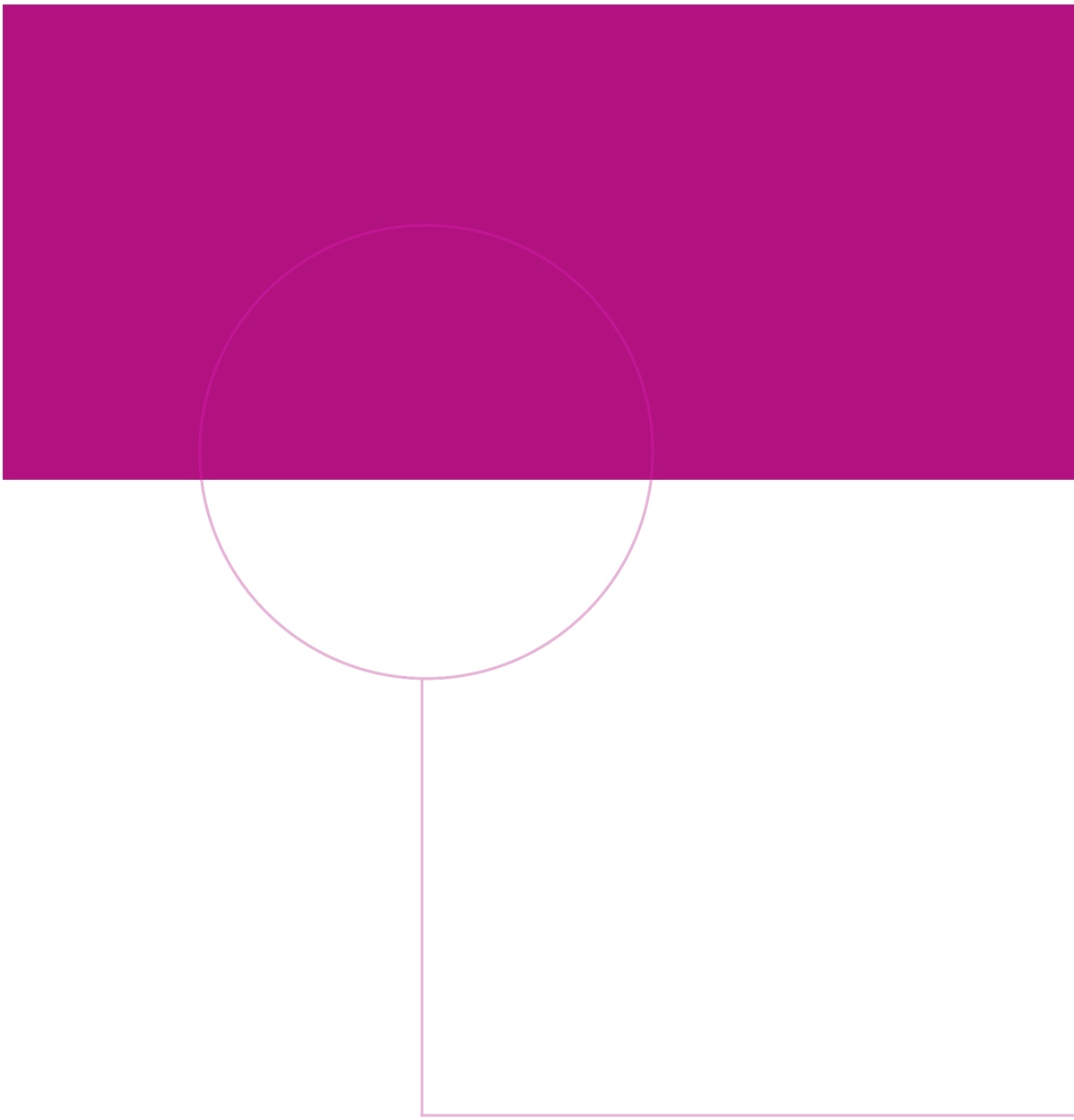
Enhet/Institutt:	IMA
Ansvarlig linjeleder (navn):	Ida Westermann
Ansvarlig for aktiviteten som risikovurderes (navn):	Fredisima Hviding, Borghild Espejord og Ina Merete Stuen (veileder)
Deltakere (navn):	Fredisima Hviding, Borghild Espejord

Beskrivelse av den aktuelle aktiviteten, området mv.:

Skal teste ulike fellingsreagenser for å felle ut tungmetaller fra prøvevann. Prosessen innebærer å tilsette fellingsreagens, la utfelllingen sedimentere og analysere det restrerende vannet ved bruk av ICP-MS. ICP-MS analysen blir gjort av bedriften bacheloren skrives med.

Aktivitet/arbeidsoppgave	Mulig uønsket hendelse	Eksisterende risikoreduserende tiltak	Vurdering av sannsynlighet (S) (1-5)	Vurdering av konsekvens (K) *Vurder en konsevenskategori om gangen. Menneske skal alltid vurderes* Menneske (1-5)	Øk/materiell (1-5)	Ytre miljø (1-5)	Omdømme (1-5)	Risikoverdi (S x K)	Forslag til forebyggende og/eller korrigendene tiltak *Prioriter tiltak som kan forhindre at hendelsen innnefler (sannsynlighetsreduserende tiltak) foran skjerpet beredskap (konsekvensreduserende tiltak)*	Restrisiko etter tiltak (S x K)
Håndtering av Natronlut	Søling av kjemikaliet	Bruk av hansker ved håndtering av kjemikaliet. Mindre søl tørkes opp med tørkepapir. Nøytraliseres om nødvendig. Større mengder absorberes i vermiklutt, tørr sand eller jord. Samles	4	-	2	-	1	0	Ta i bruk trakter. I tilfelle hvor væsker skal overføres fra større beholdere, overfør væsken til en mindre beholder først. Ha sølabsorberende materiell i nærheten slik at dette enkelt kan bli tatt i bruk.	0
	Å få kjemikaliet i øyet.	Bruk vernebriller. Skyll øyet forsiktig med vann i flere minutter.	2	4	-	-	1	8	Bruk vernebriller eller ansiktsskjerm.	4 (s=1)
	Søle kjemikaliet på huden.	Bruk egnede verneklær for å beskytte mot enhver mulighet for hudkontakt. Bruk gummiforkle. Bruk gummistøvler. Skyll straks tilsølt hud med vann. Kontakt lege i tilfelle etseskader.	3	2	-	-	1	6	Bruk gummi hansker til en hver tid dette kjemikaliet håndteres.	2 (s=1)
	Svelging av kjemikaliet.	Skyll munnen grundig. Drikk et par glass vann eller melk. Ikke fremkall brekninger. Kontakt lege.	1	5	-	-	1	5	Ikke stå for nærme kjemikaliet med ansiktet.	4 (p=4)
	Innånding av kjemikaliet.	Sørg for tilstrekkelig ventilasjon. Hvis stoffet innåndes, skyll nese og munn med vann. Få frisk luft, ro og varme. Kontakt lege. Ved pustevansker kan oksygentilførsel være nødvendig.	3	2	-	-	1	6	Ikke stå for nærme kjemikaliet med ansiktet. Bruk avtrekk.	4 (s=2)
	Brann.	Bruk pulver, karbondioksid, vanntåke eller skum som slokningsmiddel, ikke vannstråle.	1	2	-	-	2	2	Vær godt klar over hvor brannslukningsutstyret er.	1 (p=1)
	Brann og eksplosjon.	Hold unna visse organiske materialer, vær oppmerksom på gassdannelse og reduser kontakt	2	2	-	-	2	4	Vit på forhånd hvilke stoffer Natronluten kan reagere sterkt med.	2 (s=1)
	Utslipp til miljøet.	Forhindre utslipp til kloakk, vassdrag eller grunn.	3	0	-	2	1	0	Håndter avfall riktig og oppbevar stoffet slik som beskrevet i sikkerhetsdatabladet.	0
Håndtering av FLOPAM EM 240 C	Svelging av kjemikaliet.	Vask munnen grundig med vann. Om stoffet blir svelget, drikk små mengder vann og drikke.	1	5	-	-	1	5	Ikke stå for nærme kjemikaliet med ansiktet.	3 (p=3)
	Få kjemikaliet i øyet.	Bruk beskyttende briller. Skylles med store mengder rennende vann. Ta ut eventuelle kontaktlinser. Kontakt lege ved irritasjon.	2	4	-	-	1	8	Ikke står for nærme kjemikaliet med ansiktet.	3 (s=1,p=3)
	Innånding av kjemikaliet.	Få frisk luft. Kontakt lege hvis ubehag oppstår.	2	2	-	-	1	4	Ikke stå for nærme kjemikaliet. Ikke sett nesen nærme beholder for å lukte.	2 (s=1)
	Søle kjemikaliet på huden.	Vask med vann og såpe. Kontakt lege hvis irritasjonen vedvarer.	3	1	-	-	1	3	Bruk hansker.	2 (s=2)
	Brann.	Bruk brannslokningsmiddel som er egnet for omkringliggende brann. Unngå inhalering av støv, damp eller røyk fra brennende materiale.	1	2	-	-	2	2	Vær godt klar over hvor brannslukningsutstyret er.	1 (p=1)
	Utslipp til miljøet.	Unngå spredning av utslipp av materialet, avrenning og kontakt med jord, vassdrag, avløp og kloakk.	3	0	-	1	1	0	Oppbevares og håndteres slik at forurensing i miljøet unngås.	0
Håndtering av Metalsorb HCO	Få kjemikaliet i øyet.	Bruk beskyttende briller. Skylles med store mengder rennende vann. Ta ut eventuelle kontaktlinser. Kontakt lege ved irritasjon.	2	1	-	-	1	2	Ikke står for nærme kjemikaliet med ansiktet.	1 (s=1)
	Innånding av kjemikaliet.	Få frisk luft.	2	1	-	-	1	2	Ikke stå for nærme kjemikaliet med ansiktet. Ikke sett nesen nærme beholder for å lukte.	1 (s=1)
	Søle kjemikaliet på huden.	Vask med vann og såpe. Kontakt lege hvis irritasjonen vedvarer.	3	1	-	-	1	3	Bruk hansker.	2 (s=2)
	Svelging av kjemikaliet.	Vask munnen grundig med vann. Om stoffet blir svelget, drikk små mengder vann og drikke.	1	1	-	-	1	1	Ikke stå for nærme kjemikaliet med ansiktet.	1
	Brann.	Bruk brannslokningsmiddel som er egnet for omkringliggende brann. Unngå inhalering av støv, damp eller røyk fra brennende materiale.	1	2	-	-	2	2	Vær godt klar over hvor brannslukningsutstyret er.	1 (p=1)
	Utslipp til miljøet.	Unngå spredning av utslipp av materialet, avrenning og kontakt med jord, vassdrag, avløp og kloakk.	3	0	-	-	1	0	Oppbevares og håndteres slik at forurensing i miljøet unngås. Håndter avfall i henhold til anbefaling.	0
Håndtering av prosessvann	Søling av prosessvann.	Benytt vernehansker, verneklær og øyevern. Bruk av hansker ved håndtering av kjemikaliet. Mindre søl tørkes opp med tørkepapir. Nøytraliseres om nødvendig. Større mengder absorberes i vermiklutt, tørr sand eller jord. Samles opp i egne beholdere.	4	1			1	4	Ta i bruk trakter. I tilfelle hvor væsker skal overføres fra større beholdere, overfør væsken til en mindre beholder først. Ha sølabsorberende materiell i nærheten slik at dette enkelt kan bli tatt i bruk.	3 (s=3)
	Søling av prosessvann på hud.	Skyll huden med vann.	3	1	-	-	1	3	Bruk hansker.	2 (s=2)
	Svelging av prosessvann.	Skyll munnen.	1	3	-	-	1	3	Ikke stå for nærme prosessvannet med ansiktet.	2 (p=2)
	Få prosessvann i øynene.	Skyll forsiktig med vann i flere minutter.	2	1	-	-	1	2	Ikke stå for nærme prosessvannet med ansiktet.	1 (s=1)
	Utslipp til miljøet.	Unngå spredning av utslipp av materialet, avrenning og kontakt med jord, vassdrag, avløp og kloakk.	3	0	-	1	1	3	Oppbevares og håndteres slik at forurensing i miljøet unngås.	2 (s=2)
Oppbevaring av kjemikalier og prøver	Ødelagt beholder.	Lagres i original emballasje, beskyttet mot direkte solskinn i et tørt, kjølig og godt ventilert område, vekk fra uforenelige materialer samt mat og drikke. Oppbevar beholderen tett lukket og forseglet til alt er klart til bruk. Åpnede beholdere må lukkes forsvarlig og oppbevares stående for å unngå lekkasje. Må ikke oppbevares i umerkede	1	1	-	-	1	1	Følg innstruksene for oppbevaring	1

Håndtering av KEMIRA PAX-18	Få kjemikaliet i øyet.	Får man stoffet i øynene, skyll straks grundig med store mengder vann og kontakt lege. Bruk	2	1	-	-	1	1	Ikke står for nærme kjemikaliet med ansiktet.	1
	Innånding av kjemikaliet.	Flytt ut i frisk luft.	2	1	-	-	1	1	Ikke stå for nærme kjemikaliet med ansiktet. Ikke sett nesen nærme beholder for å lukte.	1
	Søle kjemikaliet på huden.	Bruk hansker. Vask straks med store mengder	3	1	-	-	1	1	Bruk hansker.	1
	Svelging av kjemikaliet.	Skyll munnen med vann. Drikk 1 eller 2 glass vann. Ikke fremkall brekninger. Sørg for legetilsyn.	1	2	-	-	1	2	Ikke stå for nærme kjemikaliet med ansiktet.	2
Håndtering av KEMIRA PAX-XL3103G	Få kjemikaliet i øyet.	Skyll umiddelbart med rikelige mengder med vann, også under øyelokkene, i minst 10 minutter. Bruk lunkent vann hvis mulig. Kontakt lege.	2	4	-	-	1	8	Ikke stå for nærme kjemikaliet med ansiktet. Bruk bril	3 (p=1, s=3)
	Innånding av kjemikaliet.	Flytt ut i frisk luft.	2	3	-	-	1	6	Ikke stå for nærme kjemikaliet. Ikke lukt på kjemikalie	2 (p=1, s=2)
	Søle kjemikaliet på huden.	Rens med mye vann. Hvis hudirritasjon vedvarer, oppsøk lege.	3	2	-	-	1	6	Bruk hansker.	1 (p=1, s=1)
	Svelging av kjemikaliet.	Skyll munnen med mye vann. Drikk 1 eller 2 glass vann. Tilkall lege hvis symptomene vedvarer.	1	2	-	-	1	2	Ikke stå for nærme kjemikaliet med ansiktet.	2
Håndtering av KEMIRA PIX-311	Få kjemikaliet i øyet.	Skyll umiddelbart med rikelige mengder med vann, også under øyelokkene, i minst 10 minutter. Bruk lunkent vann hvis mulig. Kontakt lege.	2	4	-	-	1	8	Ikke stå for nærme kjemikaliet med ansiktet. Bruk bril	3 (p=1, s=3)
	Innånding av kjemikaliet.	Flytt ut i frisk luft.	2	2	-	-	1	4	Ikke stå for nærme kjemikaliet med ansiktet. Ikke sett nesen nærme beholder for å lukte.	2 (p=1)
	Søle kjemikaliet på huden.	Rens med mye vann. Hvis hudirritasjon vedvarer, oppsøk lege.	3	1	-	-	1	3	Bruk hansker.	2 (p=2)
	Svelging av kjemikaliet.	Skyll munnen med mye vann. Drikk 1 eller 2 glass vann. Tilkall lege hvis symptomene vedvarer.	1	3	-	-	1	3	Ikke stå for nærme kjemikaliet med ansiktet.	3
Håndtering av SUPERFLOC A-115V	Få kjemikaliet i øyet.	Skyll umiddelbart med rikelige mengder vann, også under øyelokkene, i minst 15 minutter. Bruk lunkent vann hvis mulig.	2	1	-	-	1	2	Ikke stå for nærme kjemikaliet med ansiktet.	2
	Innånding av kjemikaliet.	Flytt ut i fiirsk luft.	2	1	-	-	1	1	Ikke stå for nærme kjemikaliet med ansiktet.	
	Søle kjemikaliet på huden.	Vask øyeblikkelig med såpe og vann.	3	1	-	-	1	3	Bruk hansker.	1 (p=1)
	Svelging av kjemikaliet.	Fremkall ikke brekninger uten å ha rådspurt lege.	1	1	-	-	1	1	Ikke stå for nærme kjemikaliet med ansiktet.	1
Håndtering av Metalsorb ZM 3	Få kjemikaliet i øyet.	Skyll grundig med rikelig med vann i 15 minutter og kontakt lege.	2	4	-	-	1	8	Ikke stå for nærme kjemikaliet med ansiktet. Bruk bril	3 (p=1, s=3)
	Innånding av kjemikaliet.	Ved innånding, umiddelbart flyttes til frisk luft. Hvis personen ikke puster, gi kunstig åndedrett. Ved pustevansker, gu oksygen. Ring lege.	2	2	-	-	1	4	Ikke stå for nærme kjemikaliet med ansiktet. Ikke sett nesen nærme beholder for å lukte.	2 (p=1)
	Søle kjemikaliet på huden.	Vask øyeblikkelig med rikelig med vann i minst 15 minutter og kontakt lege.	3	1	-	-	1	3	Bruk hansker.	2 (p=2)
	Svelging av kjemikaliet.	Fremkall ikke brekninger uten å ha rådspurt lege.	1	3	-	-	1	3	Ikke stå for nærme kjemikaliet med ansiktet.	3
Metalsorb PCZ	Få kjemikaliet i øyet.	Skyll omgående med mye vann, også under øyelokkene, i minst 15 minutter. Alternativt, skyll straks med Dihoterine. Få øyeblikkelig legehjelp.	2	2	-	-	1	4	Ikke stå for nærme kjemikaliet med ansiktet. Bruk bril	3 (p=1, s=3)
	Innånding av kjemikaliet.	Flytt ut i frisk luft. Ingen farer som krever spesielle forholdsregler med førstehjelp.	2	2	-	-	1	4	Ikke stå for nærme kjemikaliet med ansiktet. Ikke sett nesen nærme beholder for å lukte.	2 (p=1)
	Søle kjemikaliet på huden.	Vask bort øyeblikkelig med såpe og rikelig med vann og fjern alle forurensede klær og sko. Ved varig og kraftig irritasjon på huden, kontakt lege.	3	1	-	-	1	3	Bruk hansker.	2 (p=2)
	Svelging av kjemikaliet.	Skyll munnen med vann. Fremkall IKKE brekninger. Ta kontakt med lege øyeblikkelig hvis symptomer forekommer.	1	3	-	-	1	3	Ikke stå for nærme kjemikaliet med ansiktet.	3
	Utslipp til miljøet.	Unngå utslipp til miljøet.	2	-	-	3	1	-	Oppbevares og håndteres slik at forurensing i miljøet unngås. Håndter avfall i henhold til anbefaling.	-
Metalsorb ZT	Få kjemikaliet i øyet.	Skyll omgående med mye vann, også under øyelokkene, i minst 15 minutter. Alternativt, skyll straks med Dihoterine. Ta kontakt med lege hvis irritasjon utvikles og vedvarer.	2	2	-	-	1	4	Ikke stå for nærme kjemikaliet med ansiktet. Bruk bril	3 (p=1, s=3)
	Innånding av kjemikaliet.	Flytt ut i frisk luft. Ingen farer som krever spesielle forhåndsregler med førstehjelp.	2	2	-	-	1	4	Ikke stå for nærme kjemikaliet med ansiktet. Ikke sett nesen nærme beholder for å lukte.	2 (p=1)
	Søle kjemikaliet på huden.	Vask bort øyeblikkelig med såpe og rikelig med vann og fjern alle forurensede klær og sko. Ved varig og kraftig irritasjon på huden, kontakt lege.	3	1	-	-	1	3	Bruk hansker.	2 (p=2)
	Svelging av kjemikaliet.	Skyll munnen med vann. Drikk vann som en forsiktighetsregel. Fremkall IKKE brekninger. Ta kontakt med lege øyeblikkelig hvis symptomer	1	3	-	-	1	3	Ikke stå for nærme kjemikaliet med ansiktet.	3
	Utslipp til miljøet.	Unngå utslipp til miljøet.	2	-	-	3	1	-	Oppbevares og håndteres slik at forurensing i miljøet unngås. Håndter avfall i henhold til anbefaling.	-



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