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The ReAl Process – A COMBINED MEMBRANE AND PRECIPITATION PROCESS FOR RECOVERY OF ALUMINIUM FROM WATERWORK SLUDGE

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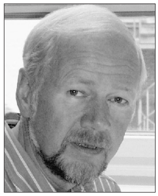

Abstract

The aim with this study has been to find a process which can recover aluminium from waterworks sludge. The separation processes used include acidification, ultrafiltration, nanofiltration and precipitation. The result of this study, which has been carried out over a period of three years, strongly indicates that it is technically possible to use acidification combined with membrane filtration for the recovery of Al^{3+} from waterworks sludge. The study also indicates that aluminium recovered by an additional precipitation process can replace virgin flocculation chemicals. In addition the recovery process will give positive environmental effects.

Key words – sludge treatment, aluminium recovery, water treatment.

Sammanfattning

Syftet med denna studie är att söka finna en process med vilken man kan återvinna aluminium ur vattenverksslam. De separationsmetoder som kombinerats är surgörning, ultrafiltrering, nanofiltrering samt kemisk fällning. Resultatet av studien, som pågått under tre år, visar att det är tekniskt möjligt att återvinna Al^{3+} genom att kombinera surgörning och membranfiltrering. Adderar man ett fällningssteg erhålls ett återvunnet aluminiumsalt med en sådan renhet att det kan användas som flockningsmedel i vattenverk. Återvinningsprocessen ger dessutom positiva miljöeffekter.

Background

Waterworks world-wide are treating surface water using chemical precipitation. The most common chemicals used in the precipitation process are salts containing Al^{3+} like aluminium sulphate, polyaluminium chloride etc. The yearly (2004) consumption of these chemicals can be estimated to 2 million ton. (Stendahl 2005) If an average of 40 g is used to treat one m^3, the total production of purified water is 50 billion m^3 per year. In the treatment process sludge is formed and removed. The sludge contains suspended solids and organic substances like humus as well as precipitated aluminium hydroxide. If one assumes that 50 % of the sludge produced arises from precipitated aluminium hydroxide and the remaining 50 % from impurities in the water, then the total production of DS (Dry Solids) is appr.1 million ton per year. With a DS content of 0.5 % the sludge volume will be 200 million ton per year or if the sludge is dewatered to 16 % DS, 6 million ton. Today there are a number of ways used to treat and dispose of waterworks sludge:

- Untreated sludge is pumped back to the source of surface water.
- Untreated or dewatered sludge is pumped into a sludge lagoon.
- Untreated sludge is pumped to a municipal waste water treatment plant.
- Dewatered sludge is disposed of in a garbage dump
- Dewatered sludge is mixed with earth.
- Dewatered sludge is burned.

In none of these cases aluminium is recovered. In the first case, when sludge is pumped back to the source of surface water, it is not uncommon that there is a build-up of sludge in a rather vast area around the outlet point. Not only do the sludge banks formed present a sore sight for the eyes, but also the layer of sludge that settles will have a negative effect on aquatic organisms.

In the second case, where sludge is pumped to a sludge lagoon, it is obvious that such a solution must be a temporary one. Sludge from waterworks is almost completely sterile and it also takes a very long time for lower layers of sludge in the lagoon to dry out. It is therefore very difficult and costly to restore an area where a lagoon has been situated.

If waterwork sludge is pumped to a municipal waste water treatment plant, the aluminium present in the sludge will form very stable compounds with phosphorous. This makes the total amount of sludge produced at the municipal plant less valuable as fertilizer.

Organic matter in sludge from waterwork is very hard to break down. Therefore, when the waterwork sludge is treated in the municipal plant, the reduction of the organic matter will be very low. As a consequence the bulk of sludge produced at the waterwork will only be transferred from one place to another.

If waterwork sludge is to be disposed of in a garbage dump the sludge has to be dewatered in order to reduce cost of transportation, cost for disposal and in most cases, tax. Another problem that can occur is that many garbage dumps either are not willing or are not allowed by law to handle waterwork sludge.

Waterworks sludge can be mixed with earth. The high content of aluminium will however have the same negative effect on phosphorus as described above. High costs for dewatering, transportation, mixing etc must also be taken into consideration.

Burning waterworks sludge will lower the sludge amount significantly but with a high content of water and a low content of organic material, the energy consumption will make this process very costly. (Bache and Papavasilopoulos 2000, Rahman and Bache 1993, VAV1990, Öman 1998)

With this background, efforts have been made to develop a process where the aluminium added as coagulant can be recovered. The main aim is that the process should be able to give both positive economical and environmental effects.

The Basic Concept

The ReAl process to recover aluminium consists of 4 main process steps as shown in figure 1.

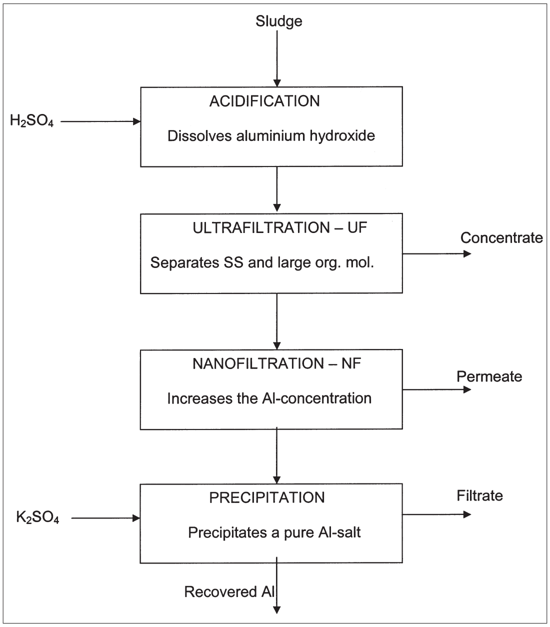

Figure 1. *Basic concept for recovery of aluminium ($KAl(SO_4)_2$ and Al^{3+}) from water works sludge.*

First Process Step – Acidification

It is a well-known fact that lowering the pH by adding acid to the sludge will dissolve the hydroxide and release aluminium ions. At the same time suspended solids and organic materials which were incorporated in the aluminium hydroxide are also released.

Any strong inorganic acid like sulphuric acid, nitric acid or hydrochloric acid can be used. It is however an advantage to use sulphuric acid as it is less corrosive than hydrochloric acid, it does not contain nitrogen as nitric acid, and it contributes with sulphate ions necessary for the crystallization process step "4". Furthermore it is the cheapest source for hydrogen ions. To dissolve 1 g of Al^{3+} (as $Al(OH)_3$) a stoichiometric amount of 5.4 g of H_2SO_4 is needed. (Sengupto and Shi1992)

Second Process Step – Ultra Filtration (UF)

In the second process step the acidified sludge is treated in an UF. An UF will retain all suspended solids, colloids and larger molecules while ions like tri-valent aluminium will pass through the membrane. (Scott 1995) Treating the acidified sludge in an UF will therefore give a concentrate of the impurities in the sludge and a permeate mainly containing the aluminium added as flocculant, salts and part of the dissolved organic substances.

Dia-filtration

Dia-filtration means that after a certain VRF (Volume Reduction Factor) has been reached, clean water (or NF permeate) is used as feed. The clean water will wash out molecules from the concentrate that can pass through the membrane. In this case the method can be used to recover more aluminium. In order not to effect the pH, NF permeate with low pH can be used instead of clean water.

Third Process Step – Nano filtration (NF)

As the UF permeate is free from suspended solids, NF can be used to increase the concentration of aluminium. This is due to the fact that the NF will retain tri-valent ions like aluminium. Treating the UF permeate in a NF will give a concentrate containing aluminium ions and organic substances, while the permeate will contain mono- and di-valent ions, small amounts of aluminium and organic substances. The limit for the maximum concentration of aluminium in the concentrate is set by the applied pressure (driving force) over the membrane which must be higher than the osmotic pressure in the concentrate. (Scott, 1995) The NF concentrate can be used as flocculant and for phosphorus removal in a waste water treatment plant. According to the next process step a pure aluminium salt can also be precipitated from the concentrate.

Fourth Process Step – Precipitation

The UF permeate and NF concentrate will contain so many impurities that, if it is used as flocculant in the waterworks, negative accumulation effects would very soon occur. To be able to re-circulate the recovered aluminium a pure Al^{3+} solution or salt must be produced. One way of doing this is to add potassium ions. When added to the NF concentrate, crystals of $KAl(SO_4)_2$ x 12 H_2O will rapidly form. (If K_2SO_4 is used no additional source of sulphate ions has to be used.) The lower the temperature the lower the solubility of the salt (See figure 2). In order to minimize the losses the NF concentrate should therefore be cooled to just above the freezing point. It is also obvious that the losses will be lower the higher the concentration of aluminium in the NF concentrate is. After cooling and crystallization the crystals can easily be separated on filter. Washing the crystals with clean cold water will remove any remaining NF concentrate. After draining the water the crystals will not contain more than 10 % of free water. The separated crystals can then be dissolved in water and used as flocculant in water works.

Selection of sludge in regards to Dissolved Solids content

There is water works sludge with three different DS contents to choose from.

One is sludge with a low DS content (appr. 0.5 %) e.g. from the bottom cones of lamellas, bottom sludge from conventional sedimentation tanks or wash water from continuous filters. The low DS content results in large sludge volumes. As the price of a membrane plant is mainly dependent on the feed flow (in this case the sludge volume to be treated) this alternative is, for economical reasons, not feasible.

The second alternative is to use a pre-thickened sludge with a DS content of appr. 2.5 %. This will give a lower feed flow and the price of the membrane plant

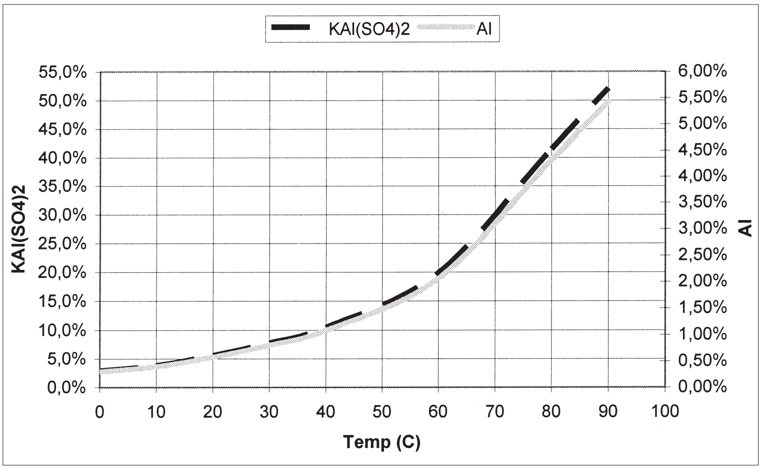

Figure 2. *Solubility of $KAl(SO_4)_2$ as a function of temperature.*

will be substantially lower. The loss of aluminium ions in the remaining UF concentrate will also be at an acceptable level.

The third alternative is to use dewatered sludge with a DS of appr. 16 % (from a pre-thickener in combination with a decanter centrifuge). Although the cost for the membrane plant will be lower than for both the other alternatives, there are some major disadvantages. It is difficult to mix acid with the dewatered sludge. It is also difficult to reach an acceptable VRF in the UF, due to the already high concentration of undissolved substances, and the loss of aluminium ions in the concentrate will therefore be unacceptably high.

Based on the above, all trials have been made using a sludge with a DS content of appr. 2.5 %.

Sludge sources used

The trials have been done using "aluminium sludge" from Karlskrona, Västerås and Lovön Water Works. Karlskrona Waterworks is located in the southern part of Sweden and the raw water source is a river. The river water is very dark in colour and the dosage of aluminium is appr. 9 g Al/m^3. The waterworks of Västerås and Lovön take the raw water from Lake Mälaren. The water from the lake is low in colour and turbidity and the dosage is appr. 3 g Al/m^3.

Trials

A portable digital pH-instrument with a glass electrode has been used to measure pH. A portable digital thermometer has been used in measuring temperature. Analogue pressure gauges installed in the pilot units have been used in measuring pressure. Flow rates have been measured with "rota-meters" installed in the pilot units and also by using stopwatch and measuring glass. Metals including B, S and P has been analysed by an external laboratory using ICP-OES. TOC has been analysed by an external laboratory using thermal oxidation. Flocculation trials have been made using a "mini-flocculator" fitted with 1 litre beakers and stirrers with variable speed.

Acidification

In a number of trials the amount of acid needed to reach a certain pH have been compared with the dissolved aluminium content in the sludge. This was to find the optimum pH, i.e. a pH where all aluminium hydroxide is dissolved. A pH instrument with a glass electrode has been used to measure pH. pH was measured at room temperature.

Ultra Filtration (UF)

All trials with UF have been done using a batch process, i.e. a working tank has been filled with acidified sludge. The acidified sludge (feed) has then been pumped to the UF. The concentrate produced has been returned to the tank while the permeate has been discharged or collected in a separate tank to be further used in the NF trials.

Flat sheet membranes

An UF pilot plant "type CR" manufactured by Metso Oy has been used for all trials with flat sheet polymer (UF) membranes. The CR filter has cells with an upper and a lower circular membrane sheet. In between the membranes there is a rotor connected to a shaft driven by an electric motor. The rotor does not touch the membranes but creates shear forces that continuously cleans the membrane surfaces and minimize the risk of fouling and build-up of unwanted filter cake. The total membrane area in the pilot filter was appr. 0.1 m^2.

The advantage of the CR filter is that liquids containing a high amount of suspended solids can be treated without clogging and that a high VRF can be reached, i.e. the concentrate can be very viscous. The aim with the trials was to find a membrane with a cut-off that gives a high retention of organic material and a low retention of aluminium, and at the same time an acceptable flux rate. Different membranes with a cut-off from 2,000 to100,000 dalton have been tested.

Ceramic membranes

As an alternative to the CR filter, ceramic membranes have also been tested. The ceramic membranes used have, according to the manufactures, a cut-off of 20,000 dalton. Each channel in the membrane had a diameter of appr. 3 mm and a length 1 m, giving a total membrane area of 0.2 m^2. The cross flow used was appr. 3 m/h giving a pressure drop over the membrane of appr. 0.7 bar. The average differential pressure between the feed and the permeate side was appr. 3 bar.

Nano filtration (NF)

If a waste water treatment plant is located very close to the water work, the UF permeate produced in the water work can be pumped directly to the waste water treatment plant and used as flocculant. This can be the case, for example in the pulp- and paper industry or in the petrochemical industry. In other cases the aluminium concentration must be increased in order to save the cost of transportation. Also, if a pure aluminium salt is to be produced, the concentration has to be increased in order to minimize the aluminium losses. A water work sludge with a DS concentration of appr. 2.5 % contains in the range of 2,000 to 4,000 mg Al^{3+}/l and the concentration in the UF permeate will be in the same range.

In order to increase the aluminium concentration trials have been done in which UF permeate has been treated in a NF. The NF trials have been using the same batch process as for the UF trials. Spiral-wound elements are the cheapest and most common NF in the market. The NF membrane selected had a membrane area of 2.4 m^2 and could be operated at a maximum pressure of 40 bar at a maximum temperature of 40°C.

The use of NF concentrate for flocculation and phosphorus removal in municipal waste water treatment plants

Incoming municipal waste water was collected from Staffanstorp Municipal Waste Water Treatment Plant. Although the WWTP of Staffanstorp is not using any chemicals to pre-treat the water, the intention with the trial was to compare the flocculation and phosphorus removal properties between NF-concentrate and AVR (aluminium sulphate "waste water quality" from Kemira). NF concentrate containing 15,300 mg Al^{3+}/l was used as flocculant.

Precipitation

K_2SO_4 was added to NF concentrate in stoichiometric proportion to the aluminium content. The solution was stirred and cooled to 0°C. After approximately one hour the solution was filtered though a glass fibre filter and the separated crystals of $KAl(SO_4)_2 \times 12\ H_2O$ were washed with cold water.

Results

Acidification

The trials show that no more acid than the stoichiometric amount has to be added in order to dissolve all aluminium hydroxide present in the sludge. The pH when all hydroxide was dissolved was appr. 2.5.

UF – Flat sheet membranes

Figure 3 shows the retention of COD and Al^{3+} for membranes with different cut-offs. The conclusion that can be drawn from the graph is that none of the membranes tested had a high retention of COD and at the same time a low retention of Al^{3+}. The flux also declined from appr. 225 l/m^2h at a cut off of 100,000 dalton and a pressure of 1.5 bar to appr. 25 l/m^2h at a cut-off of 2,000 dalton and a pressure of 9 bar.

UF – Ceramic membranes

All trials with ceramic membranes have shown a relatively low retention 8–10 % of aluminium but also a retention of COD lower than expected (appr. 50 %). The flux was appr 100 l/m^2h at a temperature of 65°C. A centrifugal pump was used as feed pump. When a high feed viscosity was reached in combination with operating temperatures in the range of 80–90°C, cavitation in the pump occurred. A VRF higher than 10 was therefore not possible to reach starting with a DS content in feed of 2.5 %.

Dia-filtration

A number of trials have been made which indicate that 40–50 % of the aluminium remaining in the concen-

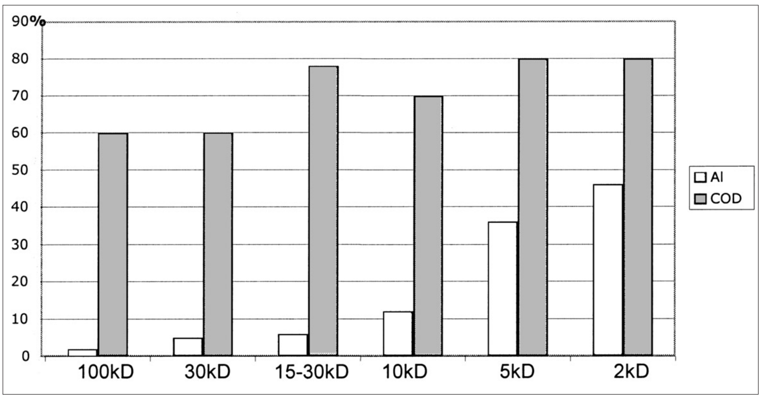

Figure 3. *Retention of COD and Al^{3+} for flat sheet membranes with different cut-offs.*

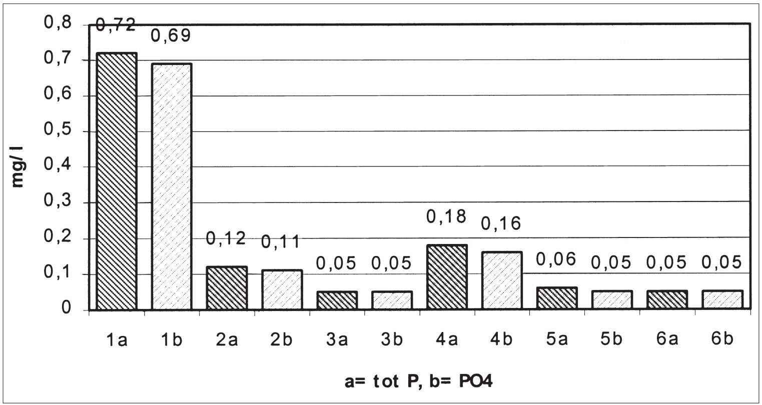

Figure 4. *Results from precipitation tests, where aluminium sulphate (AVR) and NF-permeate have been used as flocculants.* Sample 1, 2 and 3: 100, 200 and 300 g AVR/m^3 respectively. Sample 4, 5 and 6: NF permeate equivalent to 100, 200 and 300 g AVR/m^3 respectively.

trate can be washed out using dia-filtration. The amount of water used for the dia-filtration was equal to the remaining amount of concentrate.

NF

At a pressure of 40 bar and at a temperature of 40°C, it was possible to increase the Al^{3+} concentration to 25,000 mg/l. To keep a constant flux of 20 l/m^2h, starting with an aluminium concentration of appr. 3,500 mg/l and stopping at a concentration of appr. 15,000 mg/l the pressure had to be gradually increased from 15 to 40 bar.

The use of NF concentrate for flocculation and phosphorus removal in municipal waste water treatment plant

Figure 4 shows the phosphorus removal results.

The filtered waste water had a P content of 6.7 mg/l and a PO_4-P content of > 5 mg/l. COD in the water was 166 mg/l.

The trials using AVR gave a slightly better flocculation (faster growing and larger flocks) compared to the trials using NF concentrate. The sedimentation velocity was also slightly higher with AVR. The supernatant had a slight yellowish colour when the NF concentrate was used. There was however no difference in the COD between a sample treated with AVR (Sample 2 COD 109 mg/l) compared to NF concentrate (Sample 5 COD 110 mg/l). When a mix of AVR and NF concentrate was used the supernatants visible yellow colour disappeared.

The figure shows, as expected, that there was a steady decrease of phosphorus with an increasing dosage of AVR and NF concentrate. AVR had no better phosphorus removal effect than NF concentrate.

Waterworks sludge will contain heavy metals which arise from the treated raw water. As little as 0.005–0.01 mg/l of heavy metal ions present in the raw water will contribute to relatively high amounts of metals in the sludge.

Table 1 shows metal amounts in sludge from Lovön water work. Sludge from Karlskrona has appr. the same amount of Zn, slightly lower amount of Cu but only a fraction of the Ni amount.

Table 1. *Metal concentration in untreated and treated sludge from Lovön water work.* It appears to be difficult to analyze the metal content in the sludge and in the other liquids from the process. Repeated analyses on the same material and use of different laboratories frequently gave varying results. This should be taken into consideration when the figures presented are discussed.

Metal	Cu	Zn	Ni
Untreated sludge (2.74 % DS), mg/l	8.3	17.9	17.7
Untreated sludge, g/kg DS	0.30	0.65	0.65
UF concentrate (10.9 % DS), g/kg DS	0.46	0.18	0.19
UF concentrate, % of incoming amount	60	11	12
NF permeate + precipitated NF conc., mg/l	3.7	15.9	15.6
NF permeate + precipitated NF conc., % of incoming amount	40	89	88

Table 2. *Comparison of amount heavy metals in AVR and NF concentrate recovered from sludge from Lovön.* The calculation has been made for an aluminum concentration in the NF concentrate equal to the concentration in AVR. It appears to be difficult to analyze the metal content in the sludge and in the other liquids from the process. Repeated analyses on the same material and use of different laboratories frequently gave varying results. This should be taken into consideration when the figures presented are discussed.

Metal	Cu	Zn	Ni	Cr
AVR, mg/kg	<0.5	1.2	3.6	38
NF concentrate, mg/kg	10.9	47.2	46.2	Not analyzed

A comparison of the amount of heavy metals present in AVR (Kemira Kemwater 2005) with the amount present in NF concentrate recovered from sludge from Lovön water work is shown in table 2. The figures have been adjusted so that 2.5 % of aluminium in NF concentrate can be compared with 8.2 % in AVR i.e. contribution of heavy metals at equal dosage of Al^{3+}.

If the NF concentrate (or the UF permeate) is used as flocculant in a waste water treatment plant the metals present will, to a large extent, precipitate and appear in the sludge produced.

Precipitation

Washed $KAl(SO_4)_2$ x 12 H_2O precipitated from NF concentrate produced at Västerås Water Work had a heavy metal content that fulfils the highest demand according to the European standard prEN878 for iron free aluminium sulphate type 1. TOC was appr.100mg/kg Al. The filtered water had an aluminium content of 2,600 mg/l which well corresponds with the solubility at 0°C.

Discussion

Acidification

In a full-scale plant the amount of acid needed in order to dissolve all aluminium hydroxide can be regulated with a pH meter set to keep a constant pH of 2.5 by regulating a dosing pump for acid.

UF

Flat sheet membranes

It was not possible to find an UF membrane that has a low retention of aluminium and a high retention of organic material (COD). Therefore, one can conclude that it will not be possible to reuse the UF permeate as flocculant in the waterworks as impurities will cause negative accumulation effects. It is however possible to use the UF permeate (or NF concentrate) as flocculant and for removal of phosphorus in waste water treatment plants.

Ceramic membranes

The ceramic membranes used have, according to the manufactures, a cut-off of 20,000 dalton. The cut-off is most probably correct for disc-shaped molecules but lower for linear molecules and much higher for spherical molecules. (Membralox® 2001) The permeate was dark in colour which was caused by humus (humic and fulvic acid) passing through the membrane. The humic fraction consists of a complex system of molecules that have a wide range in molecular weights. The average humic acid is of the order of 50,000 to 100,000 daltons with few molecules having molecular weights exceeding 250,000 daltons. A "typical" fulvic acid will have a molecular weight in the 500–2,000 dalton range. The low retention of humic acid (and consequently COD) is most probably explained by the shape of the molecule as it is strongly influenced by pH. Under neutral or slightly alkaline conditions, the molecules are in an expanded state due to mutual repulsion of charged acidic groups (e.g. COO^-); at low pH contraction occurs due to charge reduction and the molecule becomes more spherical in shape. (Stevenson 1994)

As earlier shown, a low retention of organic molecules, i.e. a high concentration of COD in the permeate, has no negative influence on the purity of the recovered aluminium salt that is to be recycled in the water work. Other factors using ceramic membrane are of more importance:

- It is easier to operate and maintain a "ceramic UF plant" than a "CR-filter".
- The membranes can operate at high temperature which increases the flux and decreases the viscosity in the concentrate, i.e. a high VRF can be reached.
- More potent washing chemicals can be used for cleaning the membranes.

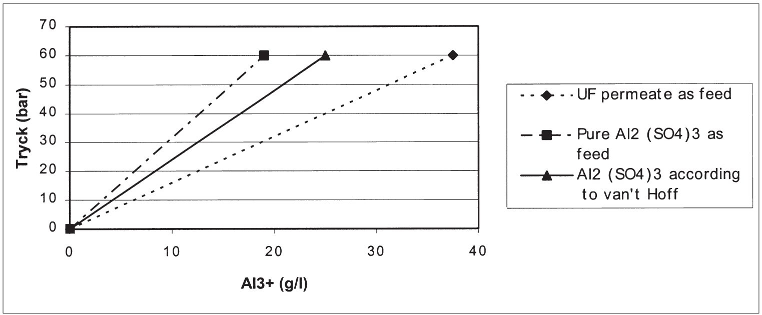

Figure 5. *Pressure as a function of aluminium concentration.*

- Result with NF using a pure solution of aluminium sulphate as feed.
- Pressure as a function of aluminium sulphate concentration according to van't Hoff equation
- Results with NF using UF permeate as feed.

Dia-filtration

With a retention of 8–10 % of the aluminum in the feed and adding a 40–50 % recovery using dia-filtration, the total losses of aluminium in the UF will be reduced to appr. 5 %.

NF

According to van't Hoffs equation ($\Pi = R\ T\ \sum C_i$; Π = Osmotic pressure, R = Gas constant; T = °K; C = Concentration of salt; The sum $\sum$ of all free ions i) it should only be possible to increase the concentration of an $Al_2(SO_4)_3$ solution to appr. 17,000 mg/l aluminium if the pressure applied is 40 bar. Still it was possible to reach more than 25,000 mg/l aluminium at 40 bar although the flux was low. Operating the membrane with a solution of pure aluminium sulphate at 40 bar a maximum concentration of appr. 12,500 mg/l could be reached. (See figure 5) The question now arises why a higher concentration than van't Hoffs equation allows can be reached when the UF permeate is concentrated. One possible explanation is that none or low charged complexes are formed between COO^- groups in the humic and fulvic acids and Al^{3+}. This should then reduce the "i" factor in the equation and the osmotic pressure in the solution allowing a higher concentration of Al^{3+}.

Precipitation

The result shows that the recovered aluminum salt has a very low concentration of impurities. The recovered salt can therefore replace virgin flocculants in water works without causing any negative accumulation effects. Regarding the content of heavy metals the quality also fulfills the European (EN878:1997) and Swedish standards (LIVSSFS2005:10).

The concentration of aluminium in the filtrate after precipitation is 2,600 mg/l. Even if the concentration of aluminium in the NF concentrate can be as high as 26,000 mg/l the loss will be as high as 10 %. (Giving a total loss of 15 % in the process) Further trials must therefore focus on lowering the losses. Ways of doing this can for example be using other NF membranes which allow both a higher temperature and a higher pressure.

UF concentrate, precipitated NF concentrate and NF permeate

The water work sludge treated in the ReAl process will be divided into three streams, namely UF concentrate, precipitated NF concentrate and NF permeate. All silt and appr. 50 % humus (COD) will be found in the UF concentrate, the remaining humus will be found in the NF permeate. The NF permeate will have a low pH but also a low buffer capacity and will contain only a small fraction of the impurities in the feed. The latter can therefore be mixed with incoming raw water without causing any negative effect in the water work. The silt in the UF concentrate is inert. The main parts of the humus in the UF concentrate are in the form of very large molecules or colloids. The humus in the NF concentrate consists of "dissolved" humic and fulvic acid. It is well known that humic acids have an ability to form stable complexes with heavy metals. As much as 160 mg of Cu can be bound to each gram of humic acid. The stability of the metal-chelate complex for some selected di-valent cat ions is as follows (Stevenson 1994):

Cu > Ni > Co > Zn > Fe > Mn

The fact that Cu forms the strongest complex might explain that the UF concentrate holds a higher percentage of copper than of other metals. If the neutralized liquids (i.e. UF concentrate and precipitated NF concentrate) are returned to the raw water source they will contain a high concentration of humic acid. The humic acid will then form stable complexes together with the heavy metals and the remaining aluminum, reducing the toxic effect to aquatic organisms including fish. One can also argue that all heavy metals, silt and humus returned to the raw water source originate from the raw water itself and will therefore not give any additional negative effect to the environment.

Conclusion

The most important findings are:

- No more acid than the stoichiometric amount need to be added in order to dissolve all aluminium hydroxide present in the sludge.
- It was not possible to find a UF membrane that has a low retention of aluminium and a high retention of organic material.
- It is possible to use UF permeate or NF permeate as flocculant in waste water treatment plants.
- Dia-filtration will lower the loss of aluminium.
- The UF permeate can be treated by using NF and a high concentration of aluminium can be reached.
- The aluminium salt precipitated from NF concentrate fulfils the highest demand according to EU standard.

Further trials

The equipment used for the trials have been of a type and size which means that data collected could be used for the design of a full-scale plant. The equipment is however not able to operate continuously and lacks the possibility to run trials with ceramic membranes at temperatures higher than 90°C. A plant that operates continuously will give important answers to long term effects such as wear and tear of membranes.

With economical and technical support from Feralco AB and Mercatus AB, a pilot plant with such features has been in operation at Västerås Waterworks since late autumn last year. Thanks to support from Tekn.dr. Professor Kenneth Persson at Sweco VIAK AB, the project has also been granted funds from VA-Forsk together with Sydvatten, Karlskrona and Västerås Waterworks. The results from the Västerås trials will be published soon.

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Evapotranspirationen triumferar

Besynnerliga brutna toppar
Omgärdar det öppna hygget
Kan ett träd knäckas av sympati
Med granngranens lott?
Blödande brungröna legor
Nedtrampade av fjorårskalvar
Oskönt övergivna gropar
Tysta som graven
Bara myggen dansar
Över vattenspeglarna
Men nästa skog tittar redan upp mellan moränens stenbumlingar
Små nätta skott mot himlen
Den är färdig om bara hundra år till
Ett träd må knäckas, men aldrig en hel skog
Evapotranspirationen triumferar igen

Kenneth M Persson

DELA MED DIG AV DINA KÄNSLOR OCH TANKAR KRING VATTEN

Vi inbjuder dig som läser VATTEN att dela med dig av dina personliga reflektioner kring vatten. Skicka oss text och/eller bild med fri association till vatten. Formatet är fritt, men utrymmet begränsas till en sida. Redaktionen förbehåller sig rätten att fritt utforma layouten av sidan och att eventuellt kombinera olika bidrag på samma sida. Ingen ekonomisk ersättning utgår.