Loenderveen (Waternet)

-- *Enhancing NOM removal*

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Preface

This report describes the design exercise for the course CT5520 Drinking Water Treatment 2. In this course, students are required to design a treatment step in a new or existing drinking water treatment plant.

As to my design, I devise alternative to enhance the removal of NOM in the pretreatment plant at Loenderveen. After the preliminary work, I focused on one alternative: the MIEX technology. I did some revision with the first draft and optimized the treatment processes.

I want to thank my supervisors: Professor Hans van Dijk, Bas Heijman, Luuk Rietveld and Anke Grefte. They toke a lot of time to read my report and gave me some critical suggestions. I also want to thank Jink Gude, who contributed a lot to this report.

During this design work, I learnt not only the professional knowledge but also some practical things, it was very important and gave me an unforgettable experience.

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Introduction

In this exercise, I design alternative to enhance the removal of NOM in pretreatment plant at Loenderveen. This drinking water pretreatment plant is managed by Waternet Company.

Waternet is the first company in Netherlands that combines all water services under one roof. It is responsible for drinking water, waste water, surface water and safety behind the dykes. For drinking water supply, Waternet supplies 260,000m^3 drinking water per day on average to Amsterdam and surrounding area.

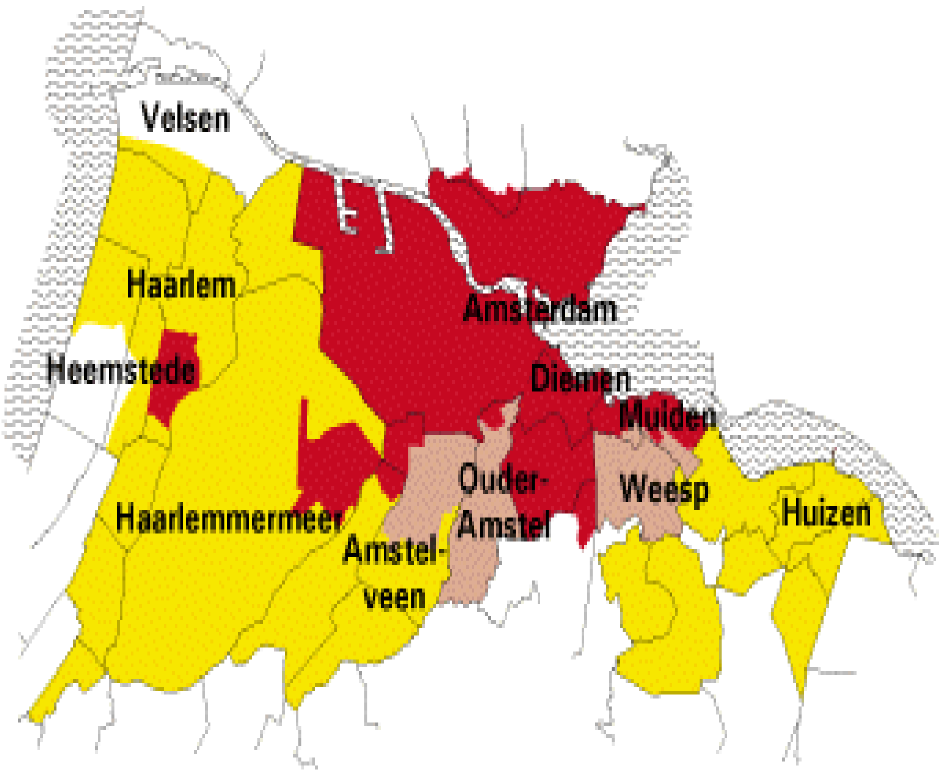


Figure 1: Drinking water supply area of Waternet

From this picture, you can know the drinking water supply area of Waternet. Waternet is responsible for production and distribution of drinking water in red area, in the pink area, Waternet is responsible for water production, but not for distribution, in the yellow area, drinking water is produced partly by Waternet.

In this design exercise, the water from the Bethunepolder is used as raw water, but at the low water level in polder it is also possible to abstract water from Amsterdam-Rhine canal. The water is transported to Loenderveen for the pretreatment firstly. From the picture below, you can see this processes include coagulation, self-purification in the reservoir with a residence time of 100 days and rapid sand filtration.

Figure 2: Pretreatment in Loenderveen

The treated water is transported to Weesperkarspel for the post-treatment. The post-treatment consists of: ozonation, softening, activated carbon filtration and slow sand filtration. At last, the treated water is supplied to customers.

Problem analysis

Problem definition

In this pretreatment plant, most of the raw water is from Bethunepolder, but at low water level in the polder it is also possible to abstract water from the Amsterdam-Rhine canal. By monitoring the water quality in Bethunepolder, Amsterdam-Rhine canal, and the effluent of the pretreatment and post-treatment plants, we can know that the DOC concentration is higher than our expectation. The DOC concentration of effluent from the post-treatment plant is 3.3 mg/l, the guideline of DOC concentration is no more than 1 mg/l.

DOC concentration represents the amount of the NOM (natural organic matter). NOM is a complex mixture of dissimilar organic species found in all potable water sources. It affects both the efficiency of treatment steps and processes in distribution network such as providing precursor material for disinfection by-products (DBPs), substrate for biogrowth, and complexation sites for heavy metals. We should removal the NOM as much as possible.

In the existing treatment plant, the DOC concentration of the effluent of pretreatment plant is about 6mg/l on average, the DOC concentration of the effluent of the post-treatment plant is about 3.3 mg/l. We can assume the removal efficiency in post-treatment plant is about 3 mg/l. If we want to decrease the effluent concentration of post-treatment plant to 1 mg/l, the effluent concentration of pretreatment plant should be no more than about 4 mg/l. As a result, we design a new treatment step to enhance the DOC removal in pretreatment phase.

Design Criteria

Design capacity:	Year capacity: 30 million m^3
	Average daily capacity: $82.2*10^3$ m^3
	Maximum day factor: 1.8
	Minimal day factor: 0.7
Coagulation:	Number of basin: 2
	Surface area per basin: 40*80m

Lake water reservoir:	Residence time: about 100 days
	Surface area: 123 ha
	Volume: 6.9 million m^3
Filters:	Number: 24 filters
	Surface area: 48 m^2 per filter
	Max.filter loading: 6 m/h
Transport mains:	Length: 10 km
	Diameter: 2*1000 mm
Buffering reservoir:	Surface area: 1.12 ha
	Volume: 40,000 m^3

Elaboration of alternative

MIEX

1. Generation information

In this design exercise, I install the MIEX treatment phase before the reservoir. We apply the split treatment processes. The main advantages of split treatment are decreasing the chemical consumption and new plant construction. The raw water is partly (2/3) pumped into the MIEX treatment plant and partly (1/3) pumped directly into the coagulation treatment plant. For the MIEX treatment step, the raw water is pumped into the mixing tank first, the water is mixed with the resin, retention time is about 30 minutes. Then water flows into the separator, the resin particles agglomerate and settle rapidly in separate tank. Most of the resin is recycled back to the contactor while a small side-stream is regenerated with a 12% NaCl solution and then returned to the contactor to maintain the ion exchange capacity of the processes. The effluent water overflows the separator to downstream existing treatment processes (coagulation treatment plant).

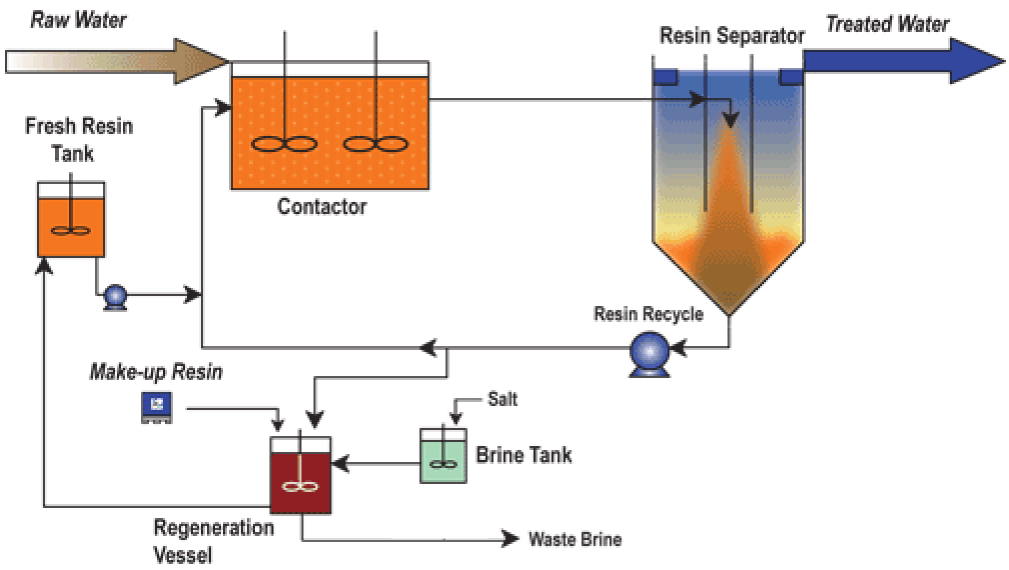


Figure 3: Scheme of the MIEX treatment processes

2. Basic calculation

2.1 Capacity

Total capacity: 30 million m^3/y $82*10^3$ m^3/d $3.4*10^3$ m^3/h

Maximum: $82*10^3$ *1.8=$150*10^3 m^3$/d   Minimum: $82*10^3$ *0.7=$57*10^3 m^3$/d

For this design, we do not need to consider the peak flow, because the treatment plant is in front of the reservoir. The water level of the reservoir will up and down, but difference of water level is smaller than 5 cm, it will not lead to any problems.

The capacity of the MIEX plant: 20 million m^3/y $55*10^3$ m^3/d $2.3*10^3$ m^3/h

2.2 Resin

①	Resin diameter:	150um
②	Resin dose:	8ml/l *300m^3*4=9.6m^3
		8% of resin slurry is removed for regeneration
		9.6m^3/12.5=0.77m^3
		0.77*24*2= 36.96m^3/d
		0.1% resin loss 36.96/(1-0.1%)=37m^3/d
③	Contact time:	30 minutes
④	Regeneration:	Contact time: 30 min
		Regeneration process: batch process
		Frequency: every 10 hours
		Regeneration system number: 2
⑤	Brine treatment:	Regenerant concentration: 100 g/l NaCl (Brine)
		90g NaCl per liter regenerated resin 90g/l*37m^3/d=3330 kg/d

2.3 Treatment plant

Contactor

①	Number:	4 contactors
②	Figure:	Circle
③	Dimensions:	Volume:300m^3 each Diameter: 8m Height: 6m
④	Retention:	30 minutes
⑤	Agitation:	low speed (tip speed<5m/sec)

Separator

① Number: 4 separators

② Figure: Circle

③ Dimensions: Volume:192m^3 each Diameter: 7m Height: 5m

④ Water rise rate: 15m/h

⑤ Retention: 20 minutes

3. Process scheme Pre-treatment plant Loenderveen

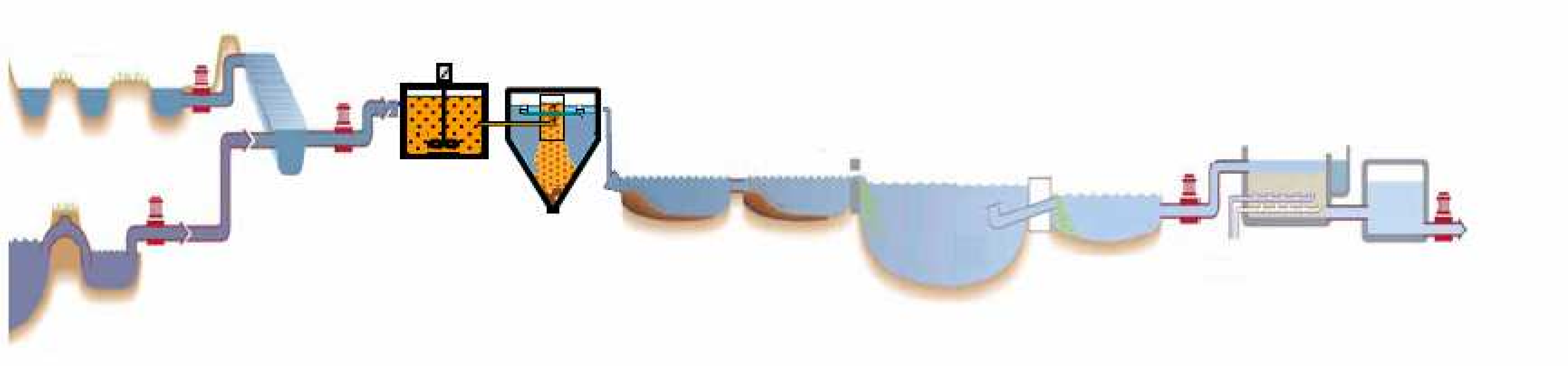


Figure 4: Scheme of the pretreatment processes

Raw water is from Bethunepolder and Amsterdam-Rhine canal	MIEX treatment plant: contactor and separator	Coagulation: 2 basins 40*80 m^3 per basin, $FeCl_3$	Water reservoir 6M m^3 100days	Filter: 24 filters,Max loading: 6m/h 48m^3	Buffer reservoir: Surface:1.12 ha

In this design, I add the MIEX treatment step into the existing treatment processes. First, before the MIEX plant, we will reconstruction the pumping station. We use the split treatment processes. Two thirds of the raw water from the Bethunepolder and Amsterdam-Rhine is pumped into to the MIEX treatment plant, one third of raw water is directly pumped into the coagulation basin. 60~75% DOC concentration can be removed by the MIEX treatment step (Raymond Lange et al, 2001; M Slunjski et al, 2002), by calculation, we can conclude that the effluent of pretreatment can achieve our requirement. Because of the split treatment processes, the chemical consumption and investment decrease. We can also neglect the peak flow due to the MIEX treatment step is in front of the reservoir, although the water level of the reservoir will up and down, it is no more than 5 cm. Compared to the depth of the reservoir, it can be neglected. The effluent from the MIEX flows into the coagulation tank by gravity. The later treatment processes are as same as before. In this design, I combine the MIEX and the coagulation to decrease the DOC concentration, compared to other real projects and researches, we believe that DOC concentration can be removed very well. The disadvantage of this design is that we can not remove the DOC after the coagulation tank, in the reservoir there are some biological activities, they may produce some NOM, but the effluent of the pretreatment can reach our requirement. We also suggest that the reservoir should be deepened, because by calculation the reservoir is about 5 meters, it may lead to eutrophication, it will deteriorate the water quality, it is better for us to deepen the reservoir. It will results in the increasing of the buffer capacity if we deepen the reservoir.

4. Hydraulic line scheme

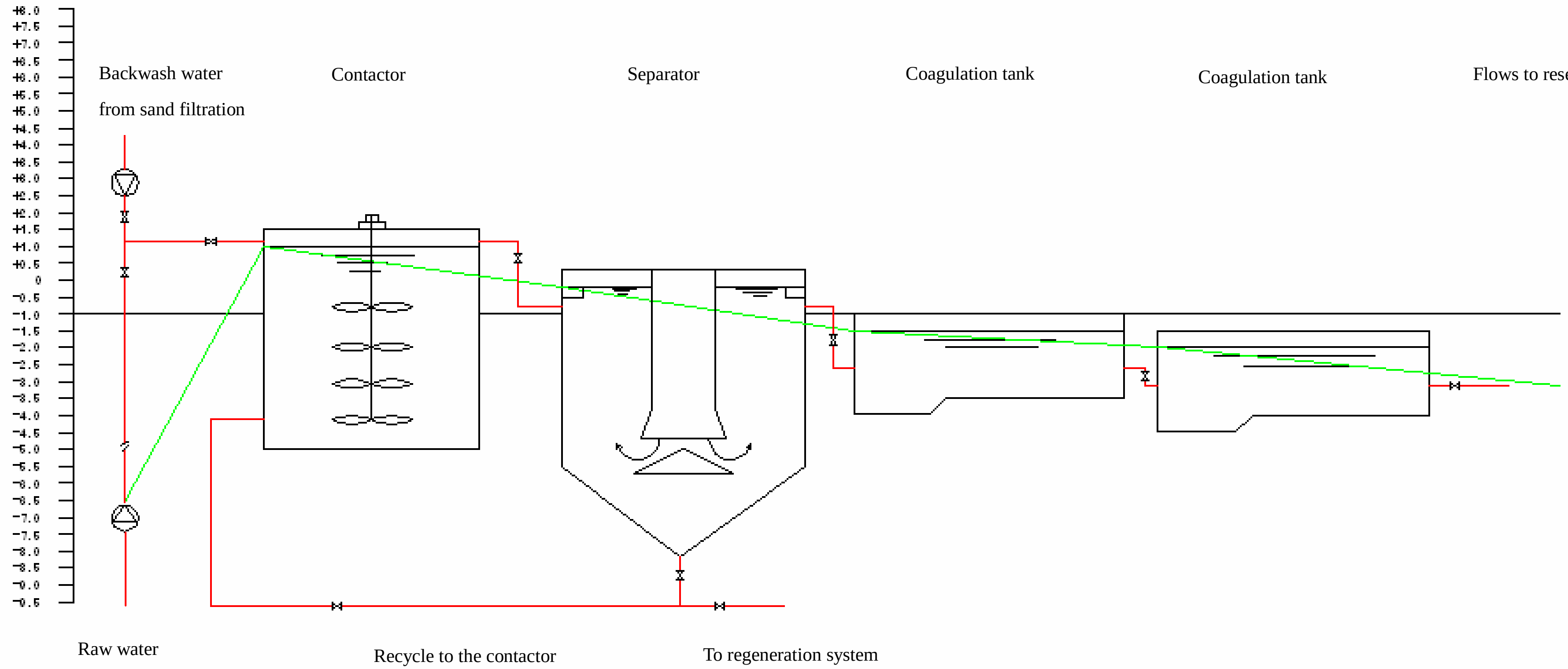


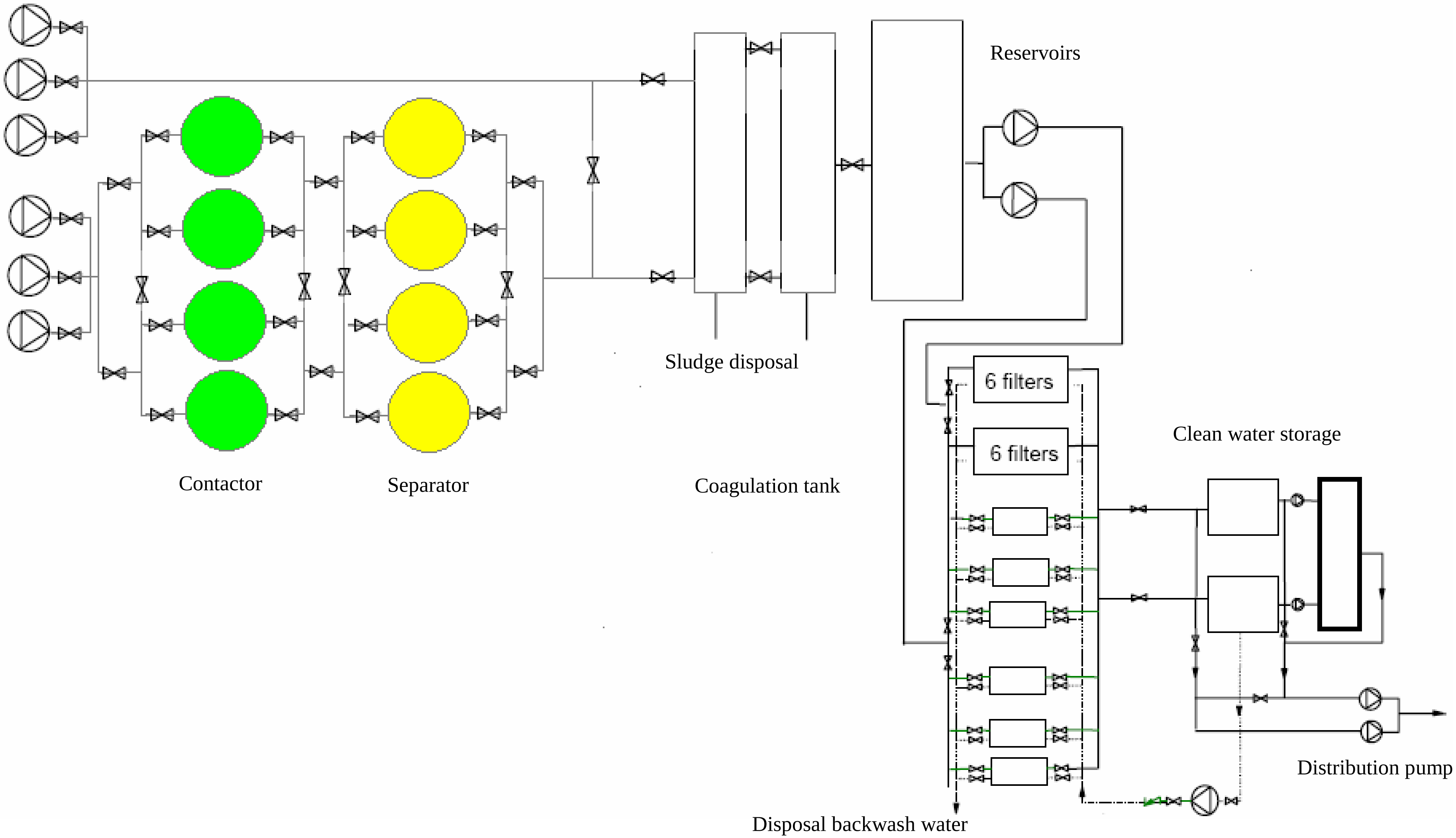
Figure 5: Hydraulic line scheme

As to the hydraulic line, I get some information from the project description document, it is provided on the blackboard. By studying the documents, I found the hydraulic line document is inaccurate. As a result, I only use partial information of the document.

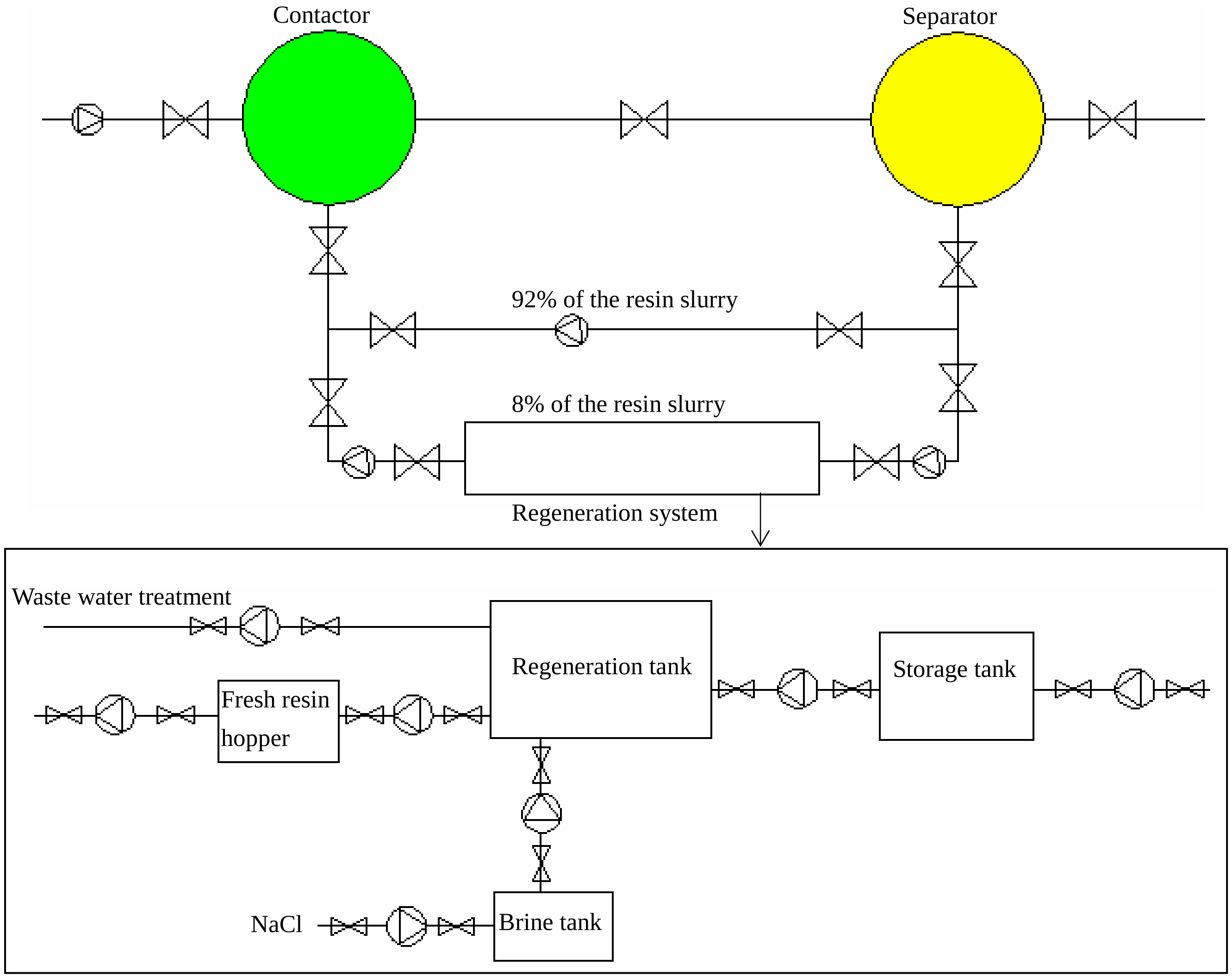
I add the MIEX treatment step in front of the coagulation tank, 2/3 of the raw water is pumped into MIEX treatment plant, 1/3 of the raw water is pumped into the coagulation tank directly. We reconstruct the pumping station. The raw water is pumped from -7m to 1m into the contactor, then flows into the separator by gravity, the water level in separator is -0.3m. After the MIEX treatment step, the hydraulic line is the same as before. The water goes into the coagulation tanks after the separator, the water levels in two tanks are -1.5m and -2.3m. The effluent from the coagulation tanks flows into the reservoir, the water level in the reservoir is -3.1m. All the water levels according to sea level.

It is important to choose the suitable pumps. We install 3 pumps for pumping water into the MIEX treatment plant, they are 1200 m^3/h, 80 kPa, two of them work at one time, another is standby. We install 3 pumps for pumping water into the coagulation tank directly, they are 600m^3/h, 55 kPa, two of them work at one time, another is standby.

5. Main water flow scheme



6. The regeneration system



Fresh resin hopper:
① Main Purpose: Transfer of regenerated resin to contactor
② Construction: Plastic
③ Capacity: $30m^3$
④ Resin concentration range: 60% v/v settled resin

Brine tank:
① Main purpose: Storage and supply of brine for regeneration
② Operation: Holding tank for batch regenerations
③ Construction: Plastic
④ Capacity: $30m^3$, 1/2 size of regeneration tank
⑤ Salt concentration: 100 g/l NaCl

Regeneration system:
① Main purpose: Storage and regeneration of loaded resin
② Operation: Modules include mixers, pumps and pipe work
③ Construction: Plastic
④ Capacity: 60 m^3
⑤ Mixing: Same as contactor, but with intermittent operation
⑥ Resin concentration :30% v/v settled resin

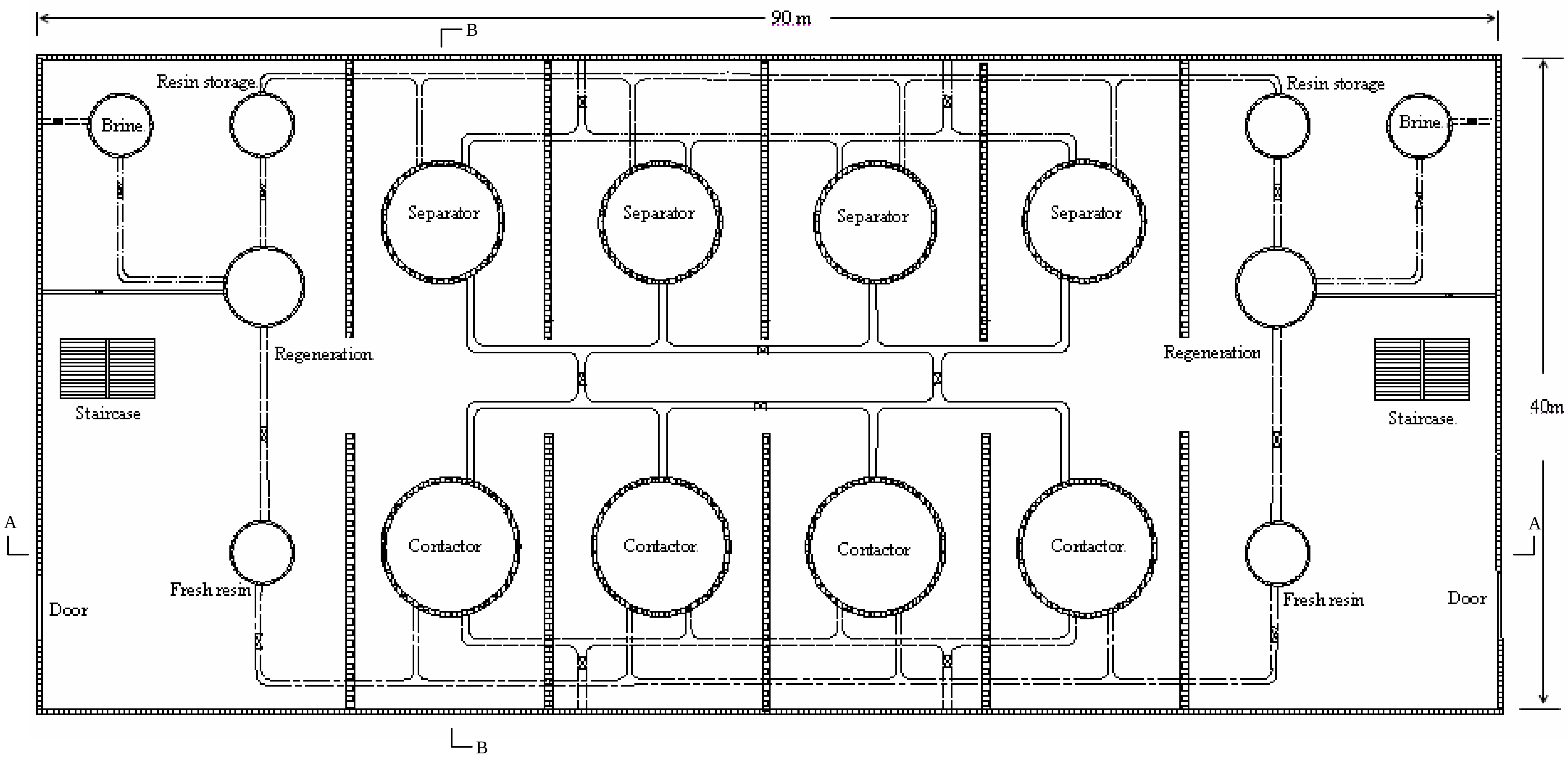
Resin storage tank:
① Main purpose: Storage resin from the settler and supplies it to the regeneration system
② Operation: Batch supply resin (10 hours)
③ Construction: Plastic
④ Capacity: 40 m^3
⑤ Resin concentration: 50% v/v settled resin

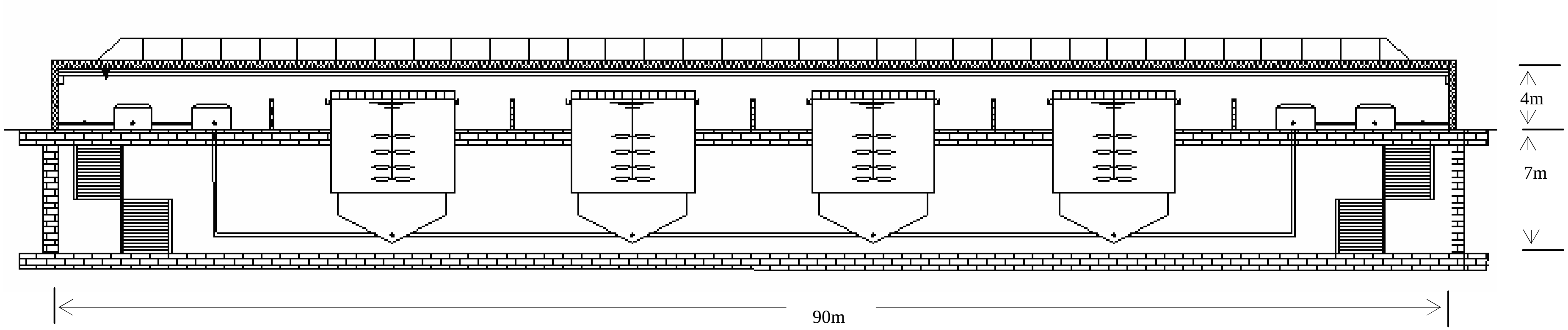
Resin pump:
① Main purpose: Return resin back to contactor
② Operation: Recycle, continuous operation
③ Type: Open impeller for resin slurry duty to minimize resin attrition

7. Lay out scheme

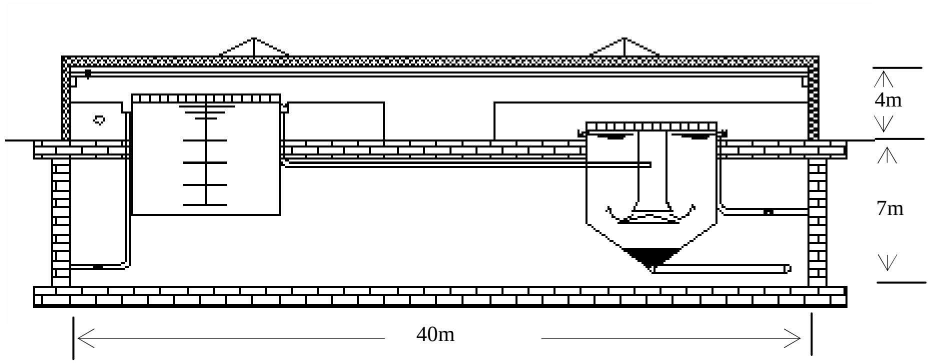
We will construct new building in front of the coagulation tanks. The new building for our design includes: 4 contactors, 4 separators and 2 regeneration systems. One contactor need 100 m^2, including the treatment plant, road and the auxiliary equipment, the 4 contactors need about 400 m^2. One separator need 100 m^2, including the treatment plant, road and auxiliary equipment. The 4 separators need 400 m^2. The regeneration systems need 400 m^2, including the regenerate tank, the brine storage tank and the auxiliary equipment. The height of the new building is 11 meters totally, 4 meters is on ground, 7 meters is underground, the width of the new building is 40 meters, the length of the new building is 90 meters.

8. Cross section scheme





Cross-section A-A



Cross-section B-B

9. The cost analysis

Summary of costs for implementing the MIEX technology:

Investment costs (in euro)

Ground costs	250,000
Construction costs	4,600,000
Furnishing costs	97,000
Additional costs	1,088,340
Construction interest	422,473
Total investment costs	**6,457,813**

Yearly operational costs (in euro)

Fixed costs	505,000
Consumption costs	603,170
Maintenance costs	101,700
Administration costs	146,818
Specific costs	258,312
Total yearly operational costs	**1,615,000**

Resulting in total operational costs of 5.4 cents per m^3 treated water.

For appendix B, you will see the detailed costs calculation.

Conclusion and recommendation

After consideration of the different aspects such as cost, sustainability and construction, I can conclude that: 1) the effluent water quality of pretreatment can achieve our requirement; 2) the MIEX treatment works efficiently; 3) the MIEX treatment works economically; 4) split treatment process is very attractive process.

However, there are some researches should be done in the future: 1) do some pilot experiments to decide the chemical dosing and other parameters; 2) familiar with local situation including regulations, laws and circumstances; 3) change the inaccurate information in the assignment documents; 4) make comparisons with other methods.

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http://www.miexresin.com/

Appendix A

Table 1: Water quality of Treatment plant Loenderveen

Water quality of Treatment plant Loenderveen.

Parameter	Unit	Raw water Bethune Polder			Raw water Amsterdam Rhine Canal			After pre-treatment			After post-treatment		
		Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max
Temperature	oC	10.9	<0.5	20.5	13.9	2.5	25.2	11.9	2.3	22	12.3	2.3	22.1
pH	pH	7.36	7.17	7.72	7.93	7.49	8.19	7.62	7.45	7.79	8.06	7.84	8.44
Turbidity	FTE	35	20	85	14	3.2	37	0.2	0.12	0.27	0.12	<0.1	0.32
UVA254	1/m	30	23.9	75.5	13	6.8	28.7	14.6	13.5	15.8	4.4	3.1	6.2
DOC	mg/l C	9.2	6	17	5	2.8	9.8	6	5.4	6.6	3.3	2.5	4.2
Colour	mg/l pt	34	22	142	17	8	37	10	7	15	2	<1	5
Oxygen	mg/l O2	3.2	<1	8.6	9.5	7	12.9	-	-	-	8	5	12.8
Suspended solids	mg/l	15	8.3	23	26	16	36	<1	<1	<1	<1	<1	<1
Conductivity	mS/m	53.2	37.5	58.4	60	49.7	65.7	53.2	51.5	54.6	50.8	48.5	52.2
Chloride	mg/l cl	44	29	49	75	54	97	75	69	79	79	71	85
HCO3	mg/l HCO3	291	270	309	181	160	204	204	196	213	176	170	186
Calcium	mg/l ca	88	81	95	72	64	79	80	78	83	49	47	53
Magnesium	mg/l mg	6.6	6.2	7.2	10.4	9.3	11.6	6.5	6.1	6.8	6.4	5.6	6.8

Appendix B

Table 2: Investment costs

Ground costs: purchase preparation others **Total ground costs**	 - 250,000 - **250,000**	 **250,000**
Construction costs per element: transports main raw water pumping phase contactor separator regeneration system Subtotal Unforeseen 15% **Total construction costs**	 500,000 800,000 1,000,000 1,200,000 500,000 4,000,000 600,000 **4,600,000**	 **4,600,000**
Furnishing costs **Additional costs** **Construction interest** **Special costs/ benefit**		**97,000** **1,088,340** **422,473** **-**
Total investment costs		**6,457,813**

Calculating the investment costs, the following percentages can be adopted:

- Unforeseen: percentage of construction costs, depending on detail of elaboration, complexity of project.
- Furnishing costs: 2% of total construction+ total ground costs
- Additional costs: 22% of total construction cost+ total ground costs+ total furnishing costs.
  * Preparation and supervision: 20%
  * Other additional costs: 2%
- Construction interest: 7% of total construction cost+ total ground costs+ total furnishing costs+ additional costs.

Table 3: Yearly operating costs

Fixed cost:		
interest and amortization	500,000	
other fixed costs	5,000	
Total fixed costs	**505,000**	**505,000**
Consumption costs:		
Energy:		
Pump	64,000	
Consumables:		
NaCl	121,545	
Resin	337,625	
Waste treatment	80,000	
Total consumption costs	**603,170**	**603,170**
Maintenance costs		**101,700**
Administrative costs		**146,818**
Specific operation costs		
operation	129,156	
quality control	129,156	
Total specific costs	**258,312**	**258,312**
Total yearly operating costs		**1,615,000**
Total operating costs per m^3 water	**5.4 cents/m^3**	

Calculating the operating cost the following percentages can be used:

- Other fixed costs: 1% of interest and amortisation
- Maintenance costs:
  * general: 2% of gross construction costs (0.5-4%)
  * furnishing cost: 10% of gross furnishing costs
- Administrative costs: 10% of the other operating costs
- Specific operation cost:
  * operation: 2% of the investment cost
  * quality control: 2% of the investment cost