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Proyecto Final de Carrera

Abastecimiento de agua de consumo en Rønde, Dinamarca.

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GROUP 3

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1. Abstract

**“Water can be without the company of humans but
we as humans can only be without water for a few days."**

This quotation shows the whole truth about the importance and meaning of water as the main source of nourishment. Its value cannot be overestimated. It is essential for all life on this planet. The water is our most wealthy treasure, our life depend on the quality of the water we use for drinking, and even for washing clothes, dishes etc.

Ground water can be a very important source of water. The problem is that is difficult and/or expensive to find where we can get water from. However, in a priory point of view this water is more likely to be cleaner or freer of pollutant than the surface water, and then its treatment is cheaper and/or easier. Therefore is important to know the characteristics of the water and of the aquifer the water is being taken from. Once this is known, a treatment process can be designed to improve the water status and get then, optimal conditions for its consumption.

Moreover, in this world where the dollars are the most important thing, it was impossible not to think about this factor. Then if a network is about to be built, ways of saving money and providing water have to be thought. The network modeling will be an essential part of this proyect.

Group 3

2. Preface

The project, and this report has been written by a group of 3 people, as part of the Spring International Semester on Environmental Engineering Studies at the University College of Aarhus for the subject B6PMI2 (20 ECTS credits). The project is based on knowledge obtained from the BTWSPL course.
As a part of a consulting company, we are asked to check the drinking water network status of a Danish village called Rønde, give solutions to the hypothetical problems which can appear and to get an accurate idea of the plant performance, aquifer conditions, the chemistry of the water and of the way the water is supplied to the city and to the new area which is about to be built.

We would like to thank the three supervisors, **Michael Rosenberg Pedersen, Peder Maribo** and **Rasmus Bundegaard Eriksen** who helped us whenever any doubt came up.

It is our desire to give special thanks to **Peder Maribo**, for all his help during the writing of the report, and especially during the optional part experiments. Thank you.

We would also like to thanks Hans Rixen, from the Waterworks, for allowing us to take samples in the sand filters.

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3. Introduction

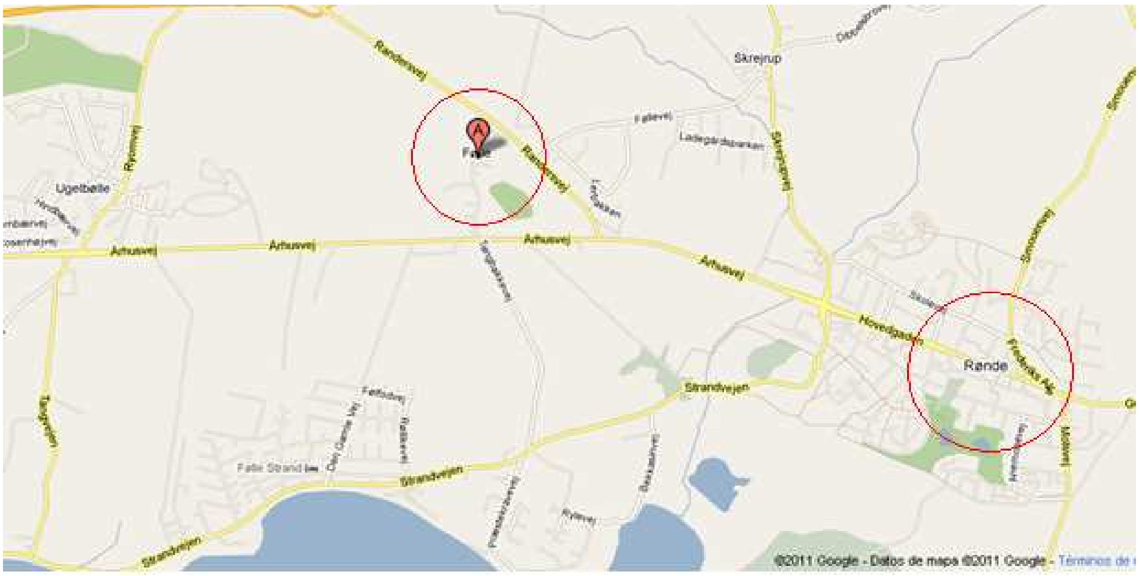
The drinking water for the village of Rønde comes from 2 well fields which are placed in the same region of the city.

Rønde is a city located 37 km from Aarhus in a northern direction. It is part of the municipality of Syddjurs. Its population is 2213 according to the GeoNames geographical database (09-08-2010).

The average elevation of the village is 57 meters.

The waterworks in charge of treating the water extracted from the wells only can clean the water by standard treatment, this is: Aeration and filtration. There is a storage tank right next to the water works and two more down in the town. These last two tanks are built in high.

The waterworks of Rønde has to provide, nowadays, water for approximately 1500 units consumers in the area but 500 units more are expected in short time with the expansion of the city close to Følle, an already existing city. The distance between them can be checked in the next map.



There have been different wells where Rønde were getting the water from. At the beginning, there was one well, really close to the facility, but it had to be closed because the ground started go move due to the extraction. Then nowadays, there are 4 open wells, but only 3 are working. The inoperative one doesn't work because the pump fell down and it is not worth it to fix it because the other three provide enough water.
The water quality of the aquifer, the process which take place in the waterworks, their key parameters, characteristics about the different aquifers and about the water extraction process are calculated to have a complete analysis of the situation in Rønde.

Furthermore, all the network of drinking water supply will be calibrated calculated, and the model of the new area in Følle will be built.

4. Intake Aquifer

To understand better the characteristics of the reservoir. It's necessary to know the geological characteristics and size of the area which water is taken from. To know it a geological profile and calculation of the abstraction area was made.

4.1.Geological profile

A geological profile is vertical cross section which shows the location of different layers in the ground, therefore is a very good source of information.

Geological profile can give some information about size of the aquifer and also explanation for question: Is the aquifer vulnerable to contamination?

Data from JUPITER (Denmark geological and hydrological database) give the information about position of different geological layers in the boreholes. Information gathered during the performance of wells: 80,321, 80,217, 80,272, 80,352, combined with distance between the wells (from Google Earth), are the base to made geological profile.

4.1.1. Analysis of geological profile of the Rønde aquifer

A Geological profile shows that, the water saturated sand layer is well isolated from surface by the clay layer. Minimum thickness of clay layer is 25 meters (well 80.321). Clay is almost impermeable to water. (Hydraulic conductivity for glacial clay is: $10^{-5} – 10^{-7}$ [m/sec]). It means that aquifer is invulnerable to antropogeneous contamination.

Well 80.217 and well 80.272 have screens in the same sand layer, to know if the well 80.321 is also connected to this sand layer, a pumping test should be made. The reason is because it looks like this water saturated sand layers aren't connected but by pumping test in one well the water level in other wells can be checked, if the water level also drops down it means that the aquifers are connected together. Well 80.352 has own aquifer. It's important information in connection with possibility of construction new wells in future, maybe it's possible to extract more water from this aquifer. All aquifers are confined.

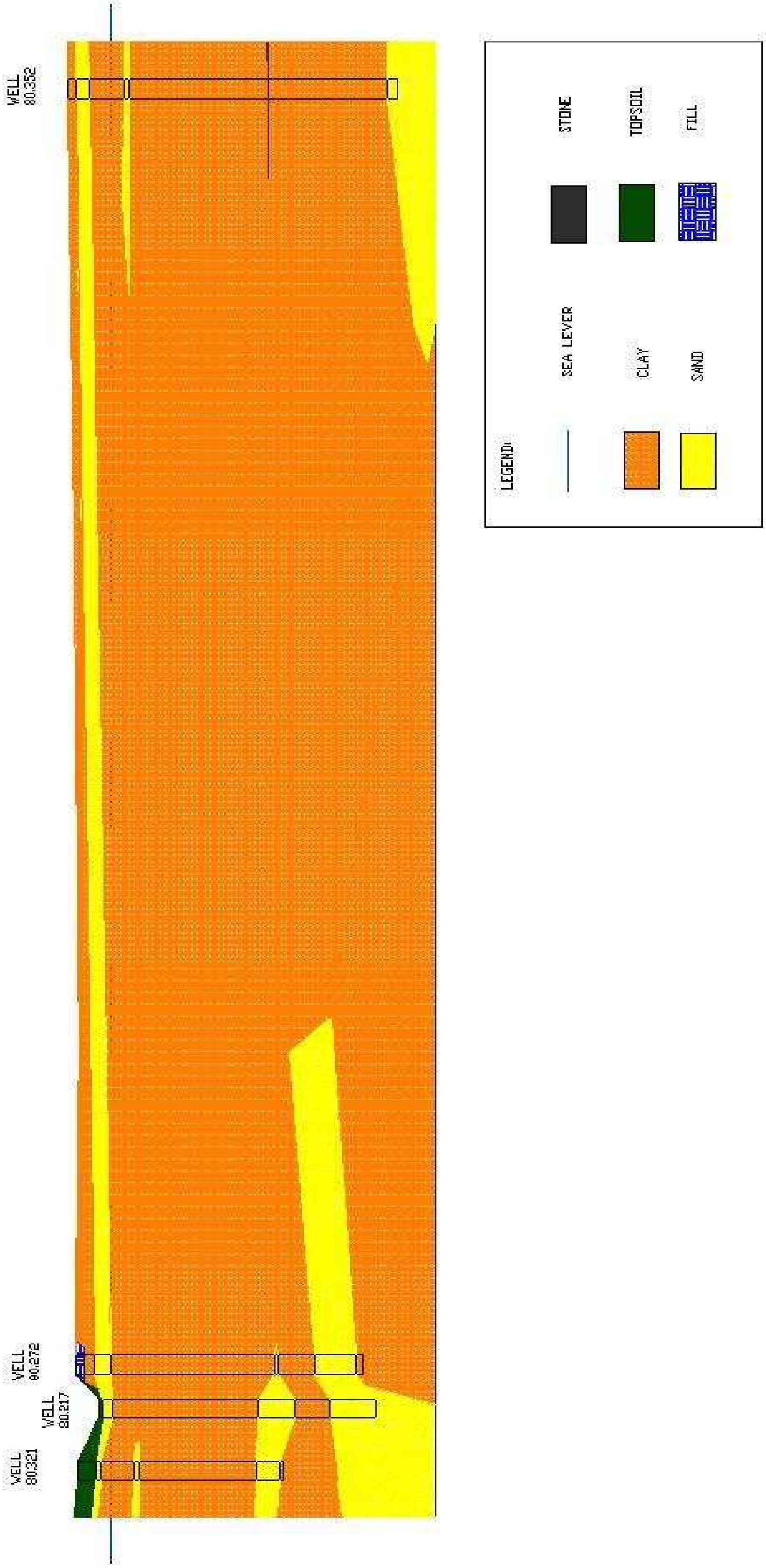


Figure 3.1 shows the geological profile of aquifer.

4.2.Abstraction area

The abstraction area is the field from which the water is taken. It depends on the amount of water extracted , shape of terrain, rainfall, the percentage of rainfall absorbed by the soil, and also transmissivity of the aquifer. Knowing this information is possible to calculate the size and shape of abstraction area.

4.2.1. Transmisivity

Hydraulic conductivity K or transmissivity T is the ability of aquifer to

Transmit water.

Hydraulic conductivity K is a parameter describing the ease with which flow takes place through a porous medium, and has units of velocity (m/s).

$$K = \frac{k \cdot \rho \cdot g}{\mu}$$

k = the permeability (m^2)

ρ = the density of the liquid (kg/m^3)

g = gravity acceleration (m/sec^2)

μ = the dynamic viscosity of the liquid (kg/m sec)

and ρ and μ are temperature-dependent.

In this formula, the viscosity of the groundwater is constant because temperature of soil does not change during the year. So the only variable in this formula is permeability. Permeability is a measure ability of a porous material to allow fluids to pass through it. This depends of type of soil, precisely from number and size of pores and connections between them.

The transmissivity is a measure of how much water can be transmitted horizontally. Transmissivity is directly proportional to horizontal hydraulic conductivity (Kh) and thickness of the water saturated layer (d).

$$T = \frac{Kh}{d}$$

The transmissivity of an aquifer can be determined by calculations in which the amount of intake water and water level drop are compared.

4.2.1.1. Calculation of transmissivity

Using the data of pumping test and the filter dimension, the calculation of transmissivity was made. All the data were found in JUPITER database.

Transmissivity was first calculated separately for each well:

$$T_{80.321} = 0{,}001317\ m^2/s$$

$$T_{80.217} = 0{,}002222\ m^2/s$$

$$T_{80.272} = 0{,}003750\ m^2/s$$

$$T_{80.352} = 0{,}000180\ m^2/s$$

The wells 80.272, 80.217, 80.321 have similar orders of magnitude of transmissivity.

However, the transmissivity in well 80.352 is much lower, the reason of that is the huge water level drop during water abstraction. The cause of so huge water level drop might be some problem with the screen in this well. Therefore the calculated transmissivity in this well, could be wrong, so transmissivity of well 80.352 was not used in further calculations.

Abstraction area will be calculated for all wells together, because of this, the transmissivity will be calculated again as the resultant of the three wells transmissivity.

The total volume of extracted water (Q) is a sum of water extracted in each well.

Water level drop is average of water level drop in well 80.321 and 80.217; the water lever drop in well 80.352 was not included because of strange high value.

Filter Diameter is average of dimension of all filters

$$T_{80.321+80.217+80.352} = 0{,}001080 \text{ m}^2/\text{s}$$

This value of transmissivity will be used in calculation of abstraction area.

4.2.2. Potentiometric map.

A Potentiometric map shows the elevation of a potentiometric surface which belongs to an aquifer by means of contour lines. It gives information about direction of groundwater flow, because water always flows from the higher potential point to point with lower potential.

Potentiometric map of Rønde will be used as a base to create abstraction area. The direction of the groundwater flow shows the place where the abstraction area is located. Gradient of terrain will be used in calculation of abstraction area.

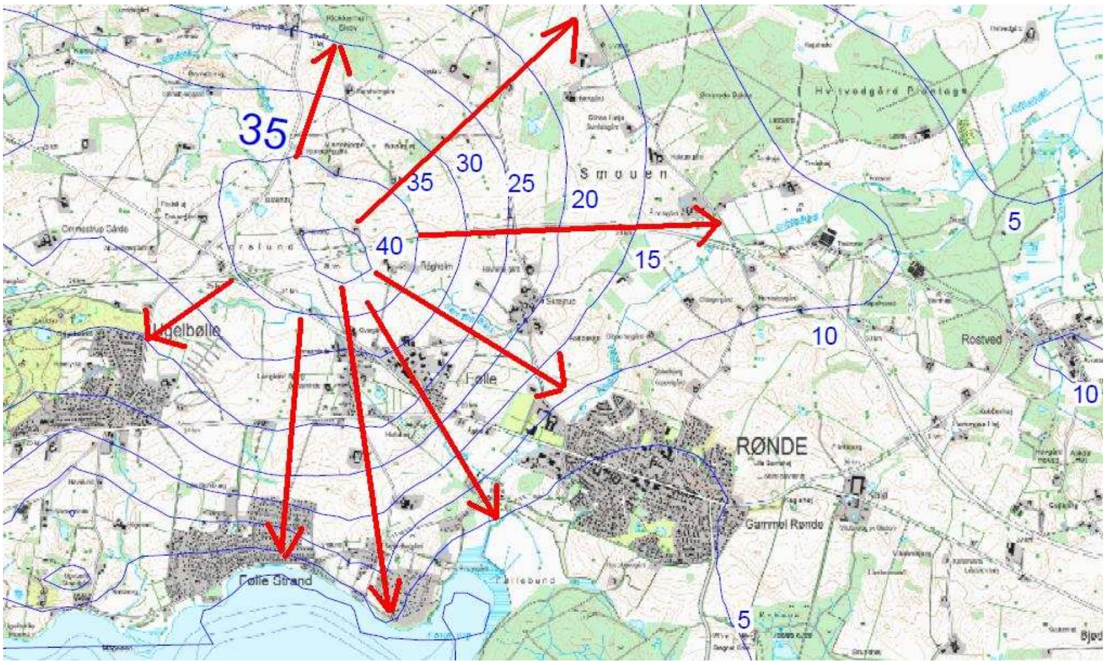


figure 3.2 shows the potentiometric map of Rønde and direction of water flow.

4.2.3. Precipitation and infiltration

The precipitation is a product of the condensation of atmospheric water vapor that falls under gravity. The Precipitation for Rønde is approximately 700 mm / year

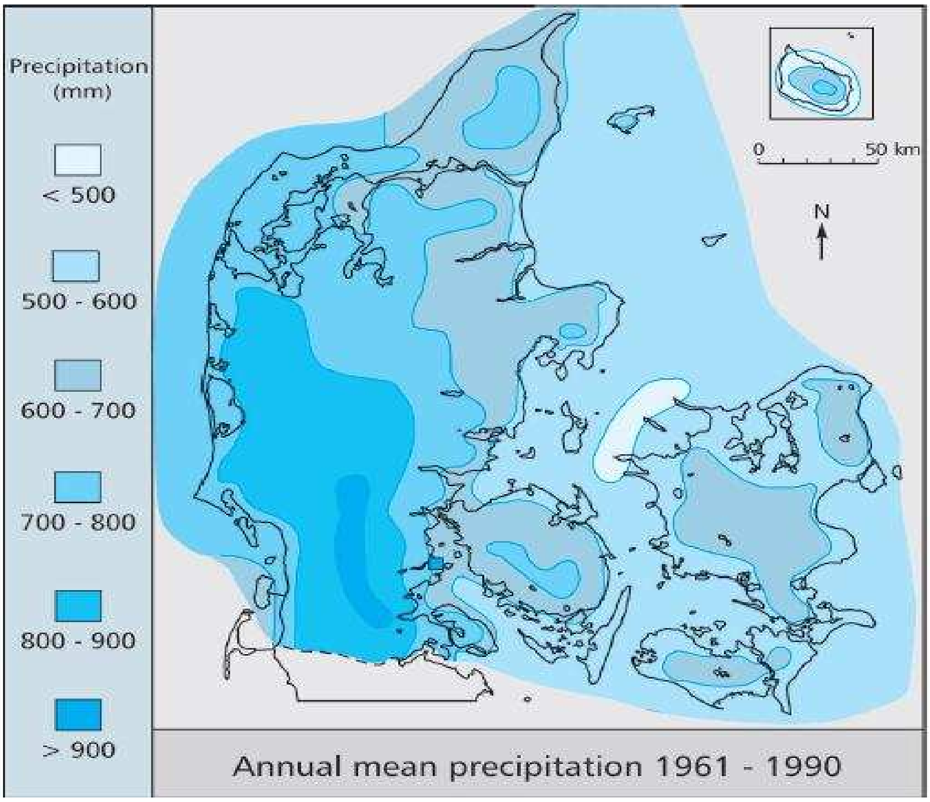


figure 3.3 shows the precipitation in Denmark.

The fraction of the precipitation, that does not evaporate or run off as surface water, is infiltration (other name: groundwater recharge). This gives information about the amount of water recharged per m^2 of ground. This parameter affects the size of abstraction area.

The infiltration is in Denmark typically 1/3 or 1/2 of precipitation. It depends on climatic and geological factors as well as land use and vegetation. To calculate the aquifer abstraction area were used infiltration of 1 / 3 of precipitation.

4.2.4. Calculations of Abstraction area

Danish law say: “only 35% of groundwater can be abstract from the aquifer”. If more water than 35% is abstracted, groundwater level will drop down, which will cause drying of lakes and streams. Therefore calculated two abstraction area, normal, and large for the water intake of about 35% from aquifer. In order to calculate a large area of water abstraction, amount of water intake was divided by 0,35.

Knowing the amount of abstraction water, transmissivity of aquifer and gradient of terrain is possible to calculate the dimensions of abstraction area.

Abstraction area for wells 80.321, 80,217, 80,352.

Point of stagnation	XL=	94,20500021m
Width of abstraction area by the well	YL=	295,8037006m
Width of the abstraction area up stream	YL,opl=	328,6707785m
Abstraction area	A=	800200m2

Abstraction area for wells 80.321, 80,217, 80,352. (for abstraction only 35% of water)

Point of stagnation	XL=	269,1571434m
Width of abstraction area by the well	YL=	845,1534304m
Width of the abstraction area up stream	YL,opl=	939,0593671m
Abstraction area	A=	2286285,714m2

The second abstraction area is almost 3 times bigger than first one.

Knowing XL,YL,YL,opl is possible to calculate X which is length of abstraction area:

$$X= 2503m$$

$$X_{0,35}= 2392m$$

In the result of calculation, length of "35%" abstraction area is shorter than the length of "100%" abstraction area. In reality it is impossible. Therefore length of “35%” abstraction area were increased to length of “100%” abstraction area.

Theoretical model of abstraction area were used to calculate size of real abstraction area.

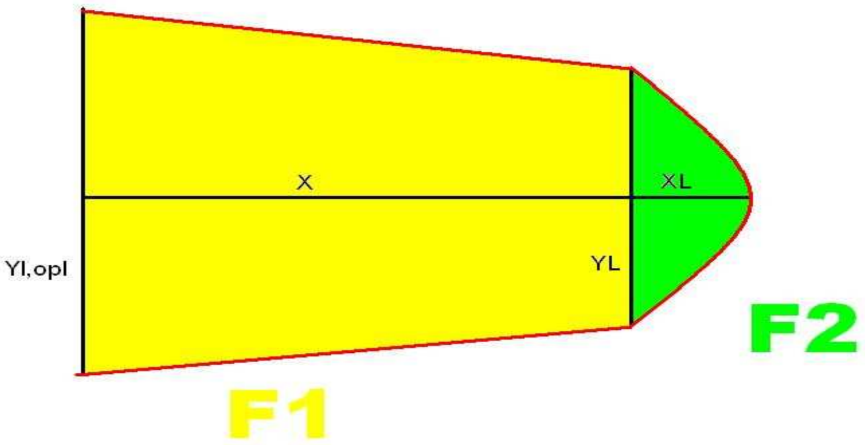


figure 3.4 shows the theoretical model of abstraction area.

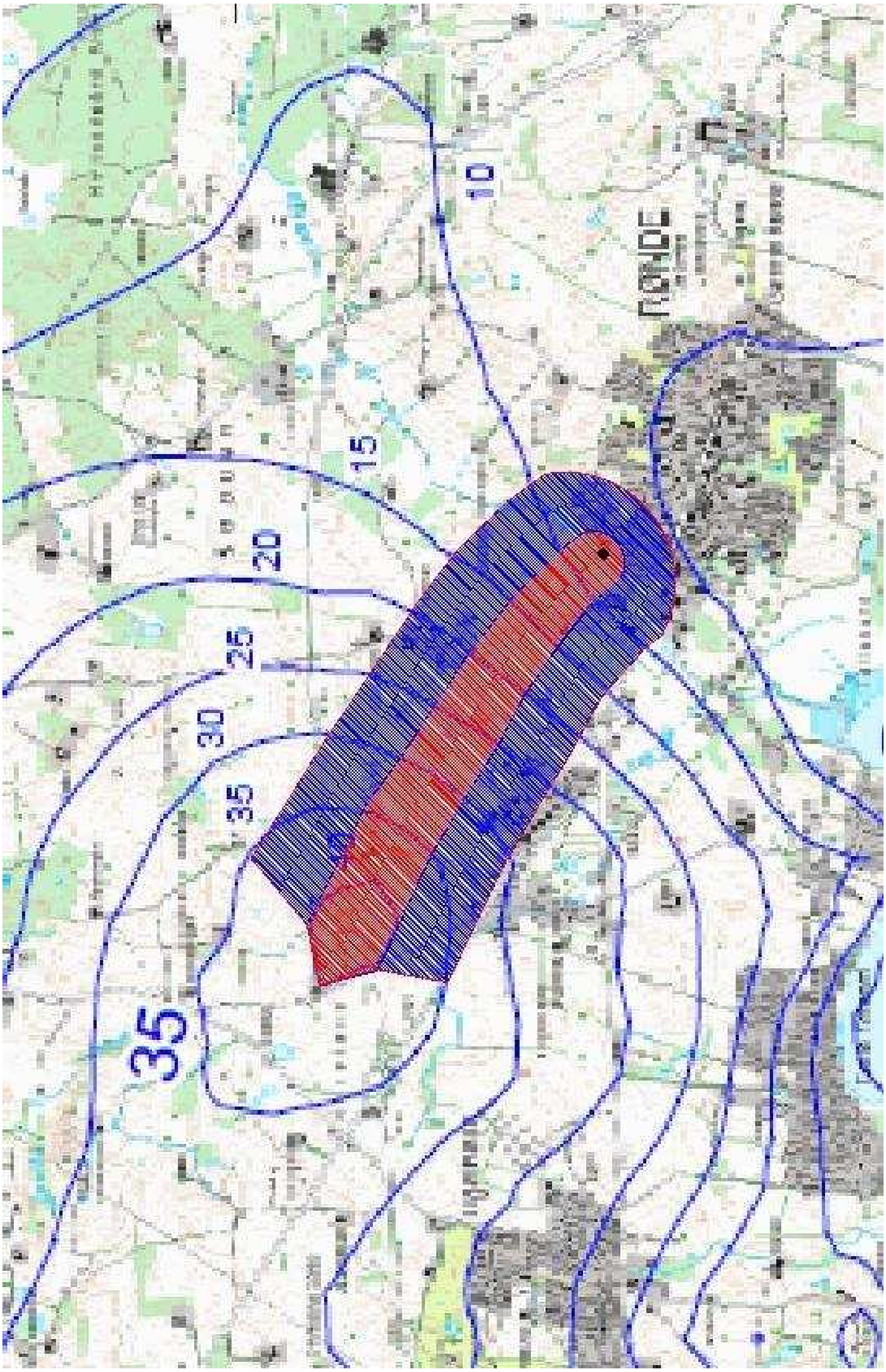
4.2.4.1. *Resultant of wells location*.

Abstraction area are made for three wells, therefore need to calculate the resultant point of wells location. Data of wells location were taken from JUPITER database. Calculation also takes into account volume of water extracted by each well.

figure 3.5 Shows the localization point of resultant of wells location.

4.2.5. Map of abstraction area

The performed Abstraction area shows places from which water is taken to Rønde waterworks. The area is located northwest from Rønde. This place should be protected from contamination, because it is risky, otherwise the contamination may get to groundwater, and later during abstraction to waterworks. In the area of abstraction, there are mostly fields. The biggest risk is connected with fertilizers. Some part of abstraction area is urbanized, therefore it should be looked for potential contamination e.g. gas station, old wells. Picture in the next page.



igure 3.6 Shows shape and location of abstraction area. Red color shows abstraction area for 100% use of

groundwater. Blue color shows abstraction area for only 35% use of groundwater.

4.3. Possible location of the new borings

To increase water intake capacity e.g. in reason of connects new homes to Rønde water mains, there are 3 possibilities:

a) Restore the well number 80.272

This well didn't work because of accident with pump which fell down in the bottom of well. Probably, there is some way to remove this pump, and resume water extraction even though this procees can be very expensive..

b) Make new boring near to well 80.352

Huge water level drop (33,7 m) suggests that well 80.352 don't work properly. Probably the problem is with the screen which is not enough deep in layer of sand and gravel. New boring with screen located more deep in aquifer, will help to extract more water from this aquifer.

c) Find new aquifer

To find new well protected aquifer it should be made geophysical surveys, like CVES to know upper layer of soil and TEM to know better deeper zones in ground .

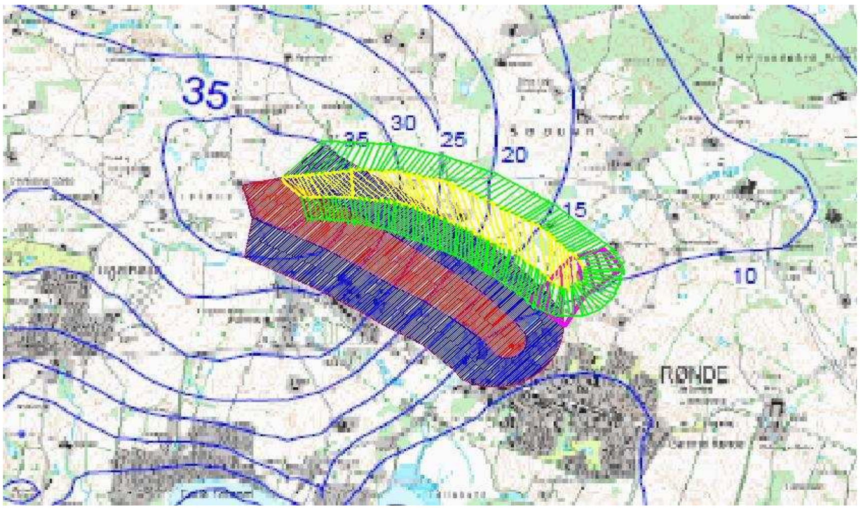


Figure 3.6.1 Possible new abstraction area

Figure 3.7Shows the suggested location of new borings.

Pipes which transport raw water to the waterworks are very expensive. Therefore the new wells should be located close to the waterworks.

Suggested area of new exploration is located north from well 80.352. This area keeps a distance from farms main buildings, houses, and surface water reservoirs, so the risk of contamination is lower. The problem can be pesticides. Additional problem can be get permission from landowners to make new well, so it is good that the searching area is located on several different fields. Moreover well located in this area will have different abstraction area than existing wells, some part of area can be the same but most of abstraction area will be different. Which means that the bigger amount of water can b

5. Intake Wells

Intake wells are used to collect water. The raw water is pumped to the waterworks, and after standard treatment it goes to individual and industrial customers. To understand better raw water quality and risk of contamination is important to know construction and location of the wells. Also the volume of water which we can abstract is related with sizes of the screen in well.

Rønde Vandvær currently uses 3 intake water wells to extraction of ground water, fourth well (80.272) is currently not used. Well 80.352 is about 360m away from water treatment station, other wells are located next to water treatment station building.

figure 2.1 shows the location of intake water wells in Rønde.

5.1. Wells technical specifications:

Information of each well will be presented below. This information will be used in calculations. Geological data collected during making boreholes will be used to made geological profile of the aquifer, and to evaluate aquifer vulnerability to contamination.

Information about wells was got from Jupiter databases and Google Earth.

5.1.1. Well 80.321

Date of made: 01/06-1973

Depth of well: 43,8m

Water intake: 21,6 m3/h

Water lever drop: 7m

Well capacity: 3,1 m2/h

This well is located next to waterworks. The water intake is protected by well house which looks quite new. The well house is used as protection from the weather, also it allows very easy access to the water intake equipment.

figure 2.2 shows the water intake and well house 80.321.

5.1.2. Well 80.217

Date of made: 01/01-1971

Depth of well: 58,8m

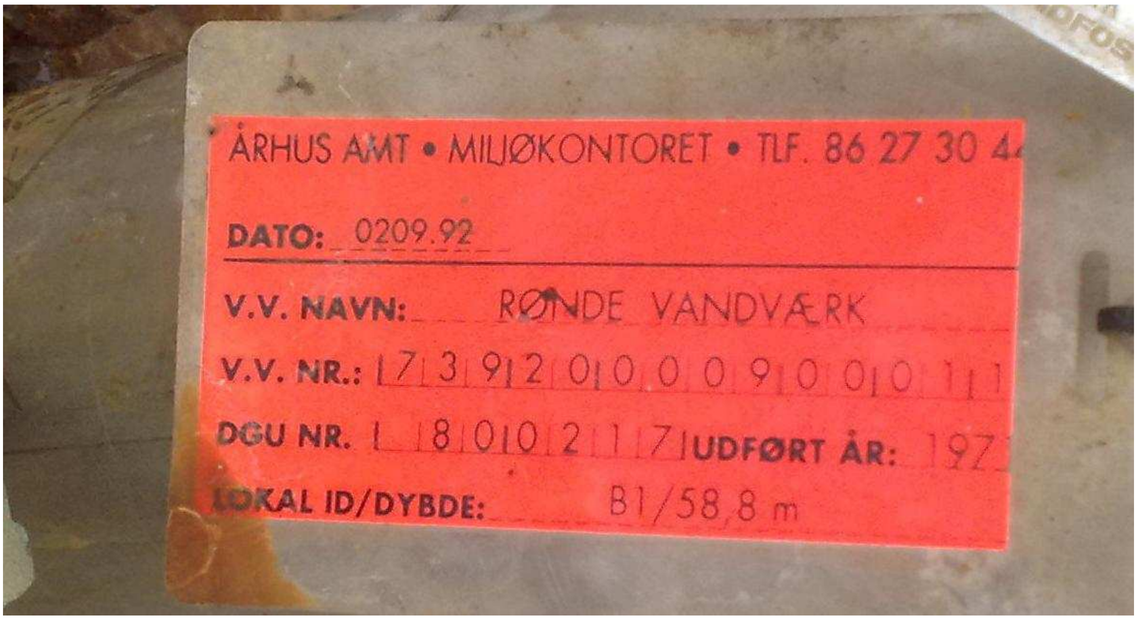
Water intake: 40 m3/h

Water lever drop: 8m

Well capacity: 5 m2/h

Well 80.217 has the largest water extraction of all wells. This water intake also is protected by a well house.

figure 2.4 shows the water intake and well house 80.217.



ÅRHUS AMT • MILJØKONTORET • TLF. 86 27 30 4

DATO: 0209.92

V.V. NAVN: RØNDE VANDVÆRK

V.V. NR.: 7 3 9 2 0 0 0 0 9 0 0 0 1 1

DGU NR. 8 0 0 2 1 7 UDFØRT ÅR: 197

LOKAL ID/DYBDE: B1/58,8 m

figure 2.5 shows the label of well 80.217.

From the label we can read that the well house was built in 02.09.1992, probably it replaced the previously existing well pit.

5.1.3. Well 80.352

Date of made: 01/05-1986

Depth of well: 70 m

Water intake: 16,3 m3/h

Water lever drop: 33,7 m

Well capacity: 0,5 m2/h

The newest well, located 360 m from waterworks. If we look at water drop level, and compare it with water intake, we can see that this well don't work properly. The problem is probably with screen, maybe is getting clogging, or the screen should be put more deep in the sand and gravel layer.

figure 2.7 shows location of well 80.352

5.1.4. Well 80.272

Date of made: 01/12-1973

Depth of well: 61 m

Water intake: 0

Water lever drop: 0

Well capacity: 0

"Well 80.272 is taken out of service because the pump has fallen off the tube, and there is no need for it, has not done more about it" – this information was obtained from the employee of Rønde waterworks. This well were close in 04.03.1996.

figure 2.9 shows the well pit of well 80.272.

6. Water Chemistry

(Water in relation to the geochemical conditions in the aquifer)

6.1.Description

In the following of this chapter, many important parameters compared for how to have a proper system of water. We will see that which parameter are not suitable for water supply and which needs to treatment processes, also their effects of the consumer's health.

In this chapter is included, review of well information ,comparing of drinking water criteria ,initial calculations, evaluation of general parameters, identification of important processes and critical compounds.

All information about groundwater was obtained from GEUS database and comparisons were performed according to Danish water criteria. When the parameters are checked it can be seen which well is the most appropriate, which one is promising for the future or if there is any need for new wells according to the results. Thus, the first impression is obtained for the present and future consumptions. We can find more details about consumption in the part of water consumption.

All wells were compared and there was appeared some critical points because of the high values which are very significance for follow-up and measuring them carefully. As examples, iron, manganese, ammonium and total-P, which were measured higher than criteria for all wells.

6.2. Comparison to drinking water criteria (Danish water criteria)

In this section, the parameters are compared and considering the values in excess. Comparison of the parameters can be found in the chart in the Water Chemistry Enclosure According to the results, generally water is stable, even when the pollutants exceed the Danish drinking water criteria, they are easy to remove..

According to past samples, changing is very low. It is possible to find time series of some substance in the Water Chemistry Enclosure.

6.3. Calculations

The following table parameters were calculated and it is possible to find formulas in the Water Chemistry Enclosure. Parameters were evaluated according to Danish water criteria.

		WELL NUMBERS				UNITS
PARAMETERS	**Symbol**	**80.217**	**80.272**	**80.321**	**80.352**	-
Date		2009	1996	2009	2009	-
Ion Exchange **(I)**	**I**	1,53	1,72	1,34	1,54	
		ION EXCHANGE	ION EXCHANGE	ION EXCHANGE	ION EXCHANGE	-
Degree of Weathering ***(F)***	**F**	0,85	0,73	0,83	0,36	-
Hardness ***(dH)*** ***Middle***	**dH**	12,54	10,8	12,82	11,65	-
Conductivity		84	83,2	110	95	mS/m
Organic Matter	**NVOC**	1,4	1,2	1,5	1,5	mg/L
Pyrite Oxidation		None	None	None	None	-
Calcite Saturation Index ***(logSI)***	**log SI**	0,65	0,46	0,59	0,54	-
Sulphate Reduction		Yes	Yes	Yes	Yes	-
Acid/Base Water Type		Buffered	Buffered	Buffered	Buffered	-
Redox Conditions		D	D	D	D	-
Ion Balance Ca,Mg,Na,K - HCO3,Cl,SO4,NO3	**CATIONS**	8,59	8,3	11,08	9,51	meq/l
	ANIONS	8,39	8,28	10,11	9,57	meq/l
Charge Balance Deviation	**%**	2,36	0,24	9,16	-0,63	meq/l

Figure: Comparing of Parameters

6.4. Parameters

Parameters were evaluated according to existing information which was given of the region of Rønde.

6.4.1. Ion Exchange (I)

Ion Exchange is occurring by ions that are loosely bound to aquifer solids exchange with ion dissolved in the groundwater. Groundwater becomes enriched in sodium and depleted in calcium by the way changing ions when is ion exchange, and it will be the opposite, when reverse ion exchange is found. This process is a key factor in evaluation groundwater age and vulnerability.

Aquifer solids with a high density of charges and wide surface areas have the largest ion exchange capacities.

All the wells present ION EXCHANGE, which means;

- ✓ Ion Exchange is still taking place and the system has not reached equilibrium yet
- ✓ Therefore, the groundwater is old and well protected from surface contamination
- ✓ High CEC (Cation Exchange Capacity): Clay minerals have large capacities and all the wells are surrounded by clay, meters of clay.
- ✓ There are limited groundwater flow
- ✓ Recent freshening
- ✓ Water is becoming softened because calcium is removed

6.4.2. Degree of Weathering (F)

Knowing this parameter is essential to guess if pyrite oxidation exists. It was found that this process is not taking place in any wells. This assumption was made analysing **F** (Degree of Weathering). Hence, it turned out that **F** is lower than 1, which is the lower limit to have pyrite oxidation.

But not only the pyrite oxidation can change F, some other processes might affect Degree of Weathering which are pyrite oxidation, sulphate reduction and ion exchange. As it can be checked in the Water Chemistry Enclosure F depends on Mg^{2+}, Ca^{2+} and HCO_3^- concentration. Then, any process that affects these concentrations will modify the F as well. It will increase because of pyrite oxidation, hydrolysis and it will decrease because of ion exchange, sulphate reduction.

6.4.3. Hardness (dHº)

The kind of hardness identified in all the wells is middle hardness, which matches with the interval of 8-18 dHº. As it can be checked in the Water Chemistry Enclosure hardness depends on the Mg^{2+}, Ca^{2+} , and some other divalent cations concentration.

The long chain is not soluble in water but adequate to dissolve in organic compounds. However, the carboxyl group is able to be dissolved in water.

Hardness assignments are used in the control of softening processes. Because, this processes is made with a certain amount of calcium and magnesium.

6.4.4. Conductivity

All results are above Danish water criterion for the all wells. In spite of exceeding this criteria, if the classification of different conductivities given by the Bibliography // is checked, all of them are type of typical. (30-130)

Conductivity measures the ability of the water to conduct the electricity, then the more ions we have in the water, the easier the electricity goes through the water and hence, the higher will be the conductivity.

High values can be caused by salt water intrusion or landfill leakage.

Low values can be found in many rock aquifers or sedimentary aquifers where salt have been leaching out since before last ice age.

6.4.5. Organic Matter (Non-volatile Organic Carbon)

The wells types are identified according with the Bibliography//, as typical. The highest value is 1.5 mg C/L which is in the typical range.

Dissolved organic matter is often measured as non-volatile organic carbon or NVOC, which may give the groundwater a colour ranging from weak tea to black coffee. Also, organic matter is most important parameter ion exchange in the top soil.

All of wells' values are between 1-4 so that, it is type of typical.

6.4.6. Pyrite Oxidation

As it was already said before, there is no pyrite oxidation in none of the 3 wells.

Pyrite oxidation has taken place by following these parameters:

- Sulphate increases to >30 mg/l or higher
- Hardness increases above background if carbonates are present
- pH may drop if no carbonates are present
- Nickel present in the pyrite may dissolve in the groundwater
- I value is usually low

6.4.7. Calcite Saturation Index (log SI)

By analysing the Calcite Saturation Index it is possible to know if the water is aggressive or not. To identify, if water is aggressive, laboratory measurements may be carried out by simply adding and excess of calcium carbonate to the sample and measuring if there is increasing in the water. If the water is not aggressive, the

CaCO3 won't dissolve and aqueous concentrations will remain same. The three Log SI were calculated instead of getting them experimentally.

To check how Log SI was calculated, please go to Water Chemistry Enclosure

The water extracted from the 3 wells is non-aggressive due to the Log SI > 0. It should be kept in mind that in order to use that formula, some assumptions were made and then the accurate of the equation is ±1. For more accurate results, a geochemical model must be done.

6.4.8. Sulphate Reduction

In order to determine if sulphate reduction has already taken place, knowing that the water type is D, it is assumed that the background sulphate concentration in the area is 30 mg/l.

The sulphate concentration in all the three wells is less than 30 mg/l. If it would decrease then it could be guessed that the sulphate reduction in fact,is taking place. However, this concentration decrease could be also because the sulphate reacts with the iron in water, and form FeS, so the reason of the decrease should be checked.

In order to be sure that this assumption is correct, other parameters such as, degree of weathering or HCO_3^- , H_2S concentration, which can be affected by the sulphate reduction should be checked. Then, If the concentration of hydrogen carbonate is higher than 300 mg/l, the Degree of weathering, F, decreases usually to below 1 values or there is hydrogen sulphide and methane in the water, then that will say there is sulphate reduction.

There is no data about methane or hydrogen sulphite concentration in water, so no presence of these gases in the water can be guessed. Nevertheless, hydrogen carbonate concentration is higher than 300 mg/l and F is in fact smaller than 1. The conclusion is there could be sulphate reduction in the three borings.

6.4.9. Acid/Base Water Types

In order to know the kind of water which is extracted from the wells, it is necessary to take a look at the water ph. The result is the water is Buffered which means that the pH is between7-8.5. (For more information about buffered in the Water Chemistry Enclosure). It is OK for each wells and it is proper for treatments.

Buffered water type is characterized by:

- ✓ Neural pH
- ✓ Saturated with calcite
- ✓ Medium to high hardness

They are buffered so that, groundwater used for drinking water typically has a near neutral pH. If there is calcite in the soil layers, the acid may be neutralized.

In time, the buffer may be used up, and the aquifer material loses it is buffer capacity.

6.4.10. Redox Conditions

To know the redox condition of the water, an algorithm was used. It is possible to find it in the Water Chemistry Enclosure. All of wells are type of **D** which means ‘’**strongly reduced**’’ which is correspond to sulphate reduction.

6.4.11. Ion Balance

If Ion Balance value (the charge balance deviation) is less than 5%, the sample is suitable and there is no ions problem. It is possible to find more information about this calculation in the Water Chemistry Enclosure.

Therefore, wells of **80.217, 80.272** and **80.352** have not ions problem, but well of **80.321** has ions problem. It means that here, the charge balance deviation more than <5. Thus, the calculation shows inaccurate results.

6.5. IDENTIFICATION OF CRITICAL PARAMETERS AND EFFECTS OF HEALTH

It is enough to take information about groundwater which is about stable or not, by looking at nitrate, sulphate as well as calculated parameters degree of ion exchange and degree of weathering. Depending on the severity of the contaminant, different treatment will be used. We can find the some critical parameters below in the Figure.

Advanced: Naturally-Occurring Parameters	**Advanced: man-made Contaminants**	**Standard Treatment**
Salt	Nitrate	Iron
Fluoride	Chlorinated Solvents	Manganese
NVOC	Pesticides	Hydrogen Sulphide
Arsenic		Methane

Figure: Potentially critical parameters

All categories are not equally serious. Critical parameters are categorized under 3 titles. One of them is naturally-occurring parameters, man-made contaminants and treatment. Naturally-occurring and contaminant parameters are very important because, it is very hard to remove it from water but, iron, manganese, hydrogen sulphide and methane, which are treated in standard treatment.

6.5.1. Salt

Salt problem is occurring by high values of sodium and chloride. It is one of the most common quality problems in groundwater. Danish criteria are set to avoid a salty taste. It is very important parameter for drinking water because consumers don't want to drink tasteless water. According to criteria , value of sodium has to be lower than 175 mg/l and chloride has to be lower than 250 mg /l. For the present water, all results are showing good quality about salt content.

Present water quality is not including bad property, but it is important to follow pressure between drinking water and salty water.

Additionally, it has caused to some important healthy problems like hypertension, cardiovascular, kidney disease. Also, using of salty water in industrial processes may result in corrosion. Because of this reasons, the amount of salt should be controlled.

6.5.2. Nitrate

It is very basic compound for nitrification processes so that control is necessary because it is the part of natural cycle. It is possible to find more information in the Enclosure of water chemistry

Exceeding of 50 mg/l Nitrate is undesirable, also our results are very low according to this criteria. According to results, nitrate level is below 0.05. It is possible to find information about contamination of nitrate in the section of 6.6. A possible explanation for such a low concentration is that the aquifers are quite well protected, and the intrusion of nitrates by filtration is very difficult.

6.5.3. Arsenic

Today, naturally-occurring arsenic is perhaps the most serious health threat found in groundwater. It is affecting to millions of people in the world. This compound is reasons of some significant diseases like heart problem, cancer, kidney disease and mental problems.

According to our results, one of the wells is above the criteria. It is not too much which is 5,7 and criteria is 5, but it should be checked for future. Actually, İt will be removed in standard treatment , therefore it is not occurring problem for now.

6.5.4. Fluoride

Fluoride has low values for all wells. It is available to find more information about fluoride in the Enclosure

According to results; all results are below the criteria but, for number of 80.352 which is very close to criteria. Amount of fluoride is about 1.4 for the well but criteria is 1.5. For preventing of some health problems in the future, we have to continue to control it carefully.

6.6. Four critical compounds of over the criteria

According to results of groundwater, **iron**, **manganese**, **ammonium** and **total-P** are higher than criteria for all wells. These are key compounds for various processes and treatments. So that control is necessary for substances.

WELLS **SUBSTANCES**	**80.217**	**80.321**	**80.352**	**DANISH CRITERIA**	**STANDARD TREATMENT**
IRON	2	2,1	1,1	0,02	Filtration
MANGANESE	0,12	0,11	0,061	0,05	Filtration
AMMONIUM	0,68	0,78	0,64	0,05	Filtration
TOTAL-P	0,18	0,19	0,054	0,15	Biological or Advanced

Figure: Comparing of 4 compounds according to Danish criteria

Total-P is over the Danish criteria, but it is very close to limit. So that it does not necessary to use Biological or Advanced Treatments only for these low upper-amounts. A standard filtration is enough to get rid of this phosphorous. If the concentration were increased, some advanced treatment would be necessary.

All of these compounds are removed in standard treatment. There is no need advanced treatment with present water values. Additionally, it is necessary to treat arsenic for wells of **80.321**. You can find more information in the part of Treatment.

6.7.Contamination of groundwater

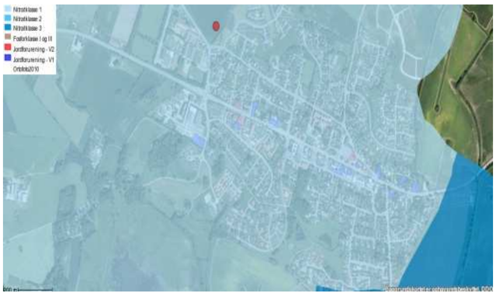
It is the one of the reasons to change quality of groundwater. Among the main causes of groundwater contaminations are: agriculture (nutrients and pesticides), industry (chlorinated solvents), the military (explosives), the energy sector (hydrocarbons and radioactive materials), municipalities (landfill organics) and even home owners (fuel oil from leaky underground Storage tanks)

Figure: Area of contamination around the wells

As shown in picture, there is available some buildings near the wells. Therefore, firstly their wastes should be kept under control. Secondly, area seems like suitable for agriculture so that a certain part of region’s water supply, agricultural activities are prohibited or allowed in part. For the animal effects, precautions should be taken with signboards and fences.

Finally, all the wells are well-protected which means, that is difficult to change their chemical properties by filtration of pollutants from the surface. Furthermore all the area was taken under control to prevent changing of water quality. It is possible to find more details in the Geography part of the project

Contamination of Nitrate:



It is available to see where, is nitrate density of contamination. We can see there are 3 kind of density of nitrate and red point is describing to Rønde Waterworks. There is exist of class of nitrate 1 around Rønde Waterworks, south-east is class of three and north-east is not including nitrate contamination. Class 1 means which requires about % 15 reduction in the flow. Also, class of three requires % 50.

Figure: Nitrate contamination regions

Contamination of Phosphorus:

Brown area is describing contamination but other regions do not show any contamination about phosphorus.

Figure: Contamination areas of phosphorus

Also, there is a central built which is for heating of Rønde and it may be depended on oil tank so that some problems can be occurred like leakage into the soil so that it is necessary to control it.

6.8.Conclusion

Generally, according to comparison of parameters, region is very useful area. Results are showing stable water with time series. Exactly, it is not enough to give decision stable or not. Also, for all the samples were checked for the other years. There was not a big change in the results.

Some parameters were above the Danish criteria. These parameters are iron, manganese, nitrate and total-P. They are not like naturally-occurring or man-made parameters. It is not hard to remove them water, they will be removed after standard treatment.

Contamination is very low around Rønde waterworks, but there is a field near waterworks and it has a potential risk for contamination about contamination of pesticides. Also, there is a factory which is central heating for Rønde. It is necessary to know what kind of production of heating available there. Additionally, area is well-protected with fences and aquifers. Additionally, because of the sand aquifer, there is low contamination.

As a result, result of water quality, abstraction area and region is fit for water supply. Denmark is an advanced country about groundwater in the world.

7. Water Treatment description

The water is pumped up from the well with a pump whose model is unknown. Once it is in the surface, it's driven to the aeration system through a pipe network. There, oxygen is added making the water to fall down through a cascade, which is composed of four steps, this way water is enriched with oxygen and gasses are stripped from it. Underneath, there is a small reaction basin, to give the water and its components time to react with the oxygen. From this basin the water goes through three filter beds by gravity. In this stage, iron, manganese, some phosphorous and other metals are removed.

This is the last step from all the circuit, after this process the water is taken by pumping to one storage tank in the plant, and from there to two others storage tanks located in down town.

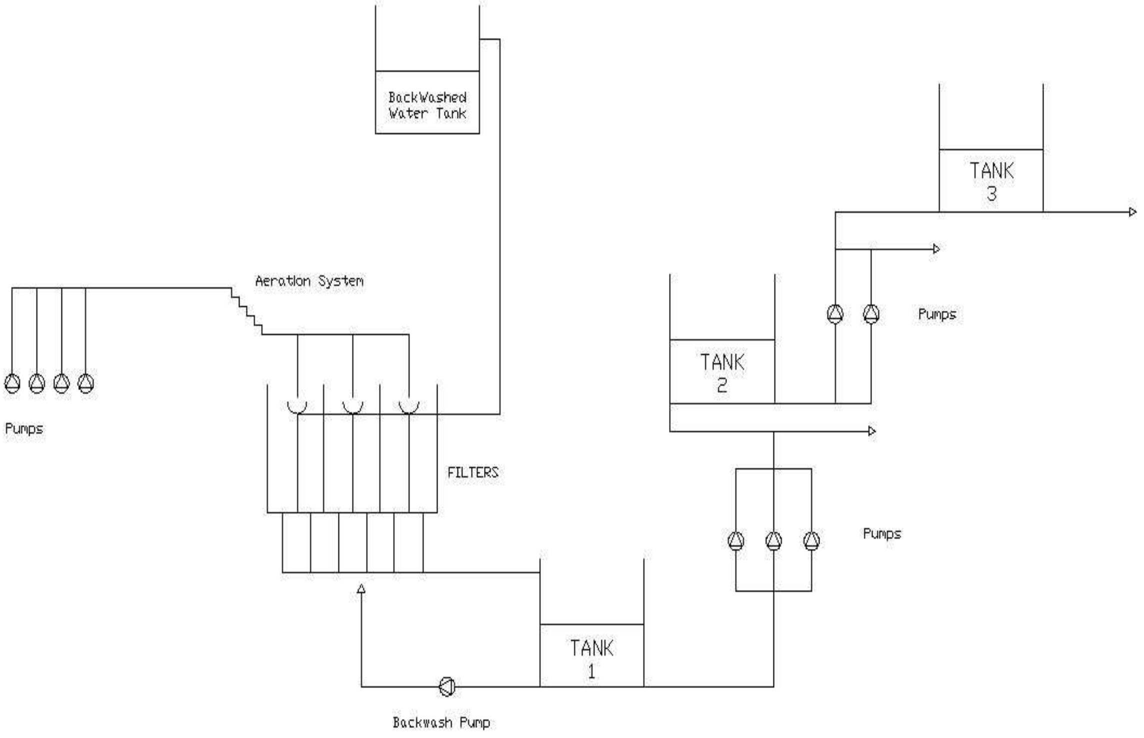


Figure 7.0 Flow Diagram of the waterworks

7.1.Aeration

In the aeration stage, oxygen is supplied to the water to ensure that it contains the minimum oxygen necessary for the bio-chemical and chemical reactions which take place in the sand filters. Furthermore, aeration has some other benefits for the water quality as improving the taste of the water, preventing the bacteria growth, stripping gases which are not desirable to have dissolved and it ensures aerobic conditions in the pipe lines.

The aeration process can be done in many different ways. In Rønde it is done by cascade and with air instead of pure oxygen. The water goes through the air due to the cascade model. This kind of aeration is called “water in air”.

The water falls down by three steps of 0,3 m high, a length of 3,25 m and 0,8 m wide each.

While the water is falling down the oxygen from the air gets dissolved in it, and the chemical reactions take place.

In order to know how much oxygen we need to provide to the water for an efficient removal of substances during filtration we need to calculate the Theoretical oxygen demand.
As the waterworks receives water from three different sources, there is a mixture of water quality and therefore, that water doesn’t present the quality of only one kind of water.

Maximum Theoretical oxygen demand: 8,14 mg O_2/L

Minimum Theoretical Oxygen demand: 7,47mg O_2/L

Average Theoretical Oxygen demand: 7,79 mg O_2/L

To see how it was calculated, please go to enclosure “Aireation”

For practical reasons the TOD will be set as 8 mg O2/L because it is the lowest requirement.

To strip the gases out from the water, it’s necessary to have a minimum flow or air. This flow is called “Minimum Air – Water Ratio” (MAWR)
The hardest gas to remove is the H_2S, so the highest amount of air will be needed for this gas. The concentrations of H_2S, CH_4 and some other gases are unknown to us, but as in the posterior analysis the concentration of these gases is below the criteria, it can be ensure that the volume of air in the room is enough for the stripping. There are four windows which provide the air and the ventilation needed. All of them are covered with a web or something which allows the air to enter, but stops animals, insects or other pollutants agents.

Fig.7.1 Cascade

To know how much oxygen is needed:

Qmax	805 m3/h
Theoretical oxygen Demand	8 mg O2 /l
Mass Flow of air	30666,7 mg Air/hour

Table 7.1 Oxygen needed for aireation

7.2.Reaction Basin

Right after the aeration cascade, the water is driven into a basin to ensure all the reactions which started in the steps are done before going through the sand filters.
The basin in Rønde is under the cascade, so all the water aerated falls into the basin and is kept there for a certain retention time.

The size of the basin in the waterworks is: 3,25 x 2,73 m = 8,8 m^2 .

The depth of reaction basin is 2,95 m. Then the volume= 8,8 m^2 x 2,95 m = 25,96 m^3.

7.2.1. Basin retention time:

As it was explained during the lecture period, a good assumption would be that 30-60 min are required for preparation of iron.

	Flow (m3/h)	T_{res} (min)
Q_{avg}	32,93	47,34347
Q_{ma}x	92	16,93043

Table 7.2 Retention time in reaction basin

As it can be seen, the average flow is within the tolerance required but at the maximum flow, the retention time is below the minimum residence time desired. The maximum acceptable flow (corresponding to a retention time of 30 minutes) is about 50 m^3/h.

As this time difference is not very high, it is likely that even with that small residence time; the process can be completed in time before leaving the waterworks.

During the 15th march 2010, there were 4 peaks which were above 50 m3/h, fortunately it only happens short periods of time, and as said before, 4 times in a day.

However, if the frequency of these peaks was higher, or during longer time, a bigger basin should be built.

Hypothetical scheme of the aeration stage in Rønde:

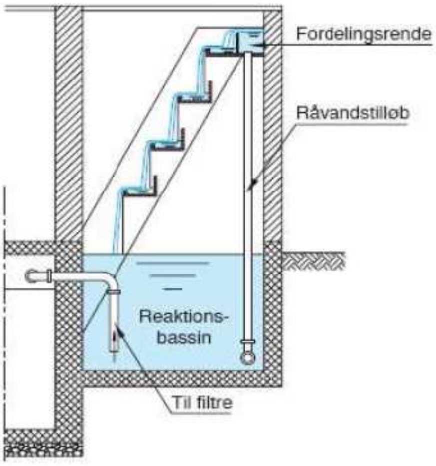
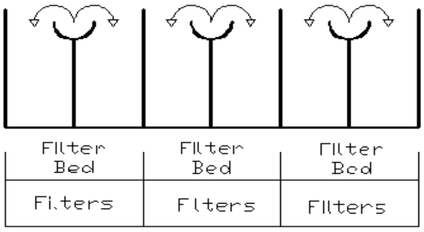


Fig. 7.2 Scheme aeration system

7.3.Filtration

It consists of making the water go through a medium which is typically a loose, porous filter material, in Rønde filters is sand. It only will be able to retain suspended matter comprising particles > 1 µm.
Iron, manganese and some other substances precipitate, besides the nitrification process which will take place in the surface of those particles.
During filtration physical action, physicochemical or biochemical reactions are to occur in contact with sand grains. Especially chemical oxidation and deposition of compounds iron, manganese and ammonium take place. Biochemical oxidation or other action takes places when passing water through a filter bed, due to the development of the necessary bacterial flora in organic impurities on the filter grains.
In an ideal filter, fine grains can be found at the bottom of the filters, and coarse ones at the top ensuring an even distribution of solids. However, due to the backwash effect this is impossible, making the fine particles go to the top and create a problem which is called “cake filtration”. Cake filtration is completely undesirable because it makes the process slower and we have a bursting risk. Furthermore, filter cake tends to get hard and that is the explanation for the efficiency loss.
Instead of this, a depth filtration is tried to be done, and hence, avoid the head loss.
The design and sizing of the filtration equipment is especially dependent on the raw water’s content of iron (Fe), manganese (Mn) and ammonium ($NH4+$).
In Rønde there are three gravity filter beds, which make 6 filters. The sizes of the filters are 2,7m x 1,8 m and it has a depth of 1,8 m. However, the filter bed depth is 1,0 m.
The water enters through three pipes which are in the middle of the filters, spreading the water to both sides. It is added in large area without turbulences and whirling up of filtration material. Then, it passes through the filters and goes to the clean water storage tank.
When one of the filter beds has to be cleaned, it is shut down so then, neither left nor right filter works. There are actually four filter beds but nowadays only three are used. The forth one is there just in case we need more capacity.



7.3 Filter Scheme

The filters are connected in parallel, so if one of them breaks down or must be cleaned the rest of them can go on working. The walls are made of concrete and they are paint with a protecting paint.

The $Fe(OH)_3$ and MnO_2 got attached to the particles of sand while the water goes through the sand. As said before, where the water get rid of a higher amount of iron and manganese will be at the beginning of the filter, reducing with depth the reaction rate.
These reactions are affected by many factors, such as pH, temperature, sand age, backwash…

If a more concise characterization of the filter is desired:

Filters	3 (6 in parallel)
Type	Rapid Open gravity
Material	Quartz sand
Porosity	0,4
Specific Density	2.4 – 2.7 Kg/m3
Dimensions (w.d.h)	1.8 x 2.7 x 1.8 m
Bed filter Depth	1 m

Table 7.3 Filters Characteristics

The hydraulics of the filter will be calculated to know the key parameter of it. They should be calculated for the Q_{max} and Q_{avg} in order to learn how they behave with different inlet flow.

It is known that the critical moments will be with high flow. When the filters are subjected to a high load of water, the retention time decreases and then it can't assure that there is enough time to reduce the concentration of iron, manganese, ammonium or even phosphorous and then accomplish the water criteria.

		FR (m/h)	EBCT (min)	T_{res} (min)
Q_{avg}	32,9	6,77	15,95	6,38
Q_{max}	92	18,93	5,70	2,28
Q_t	24,3	5		

Table 7.4 Hydraulics in filters

Where:

FR: Filtration rate → "Water flux in m^3 of water per hour per m^2 filter area (sometimes units are shortened to m/h)."

EBCT: Empty bed contact time → "The length of time that water would be in the filter bed, if it was empty."

T_{res}: Residence time → "The length of time that water is actually in the filter bed. The porosity (n) of the filter material must be considered."

In the literature about sand filters a recommended rate can be found. For gravity single media filtration bed the filtration velocity is supposed to be in a 3-5 m/h, and as it can be seen, the filtration rate calculated is higher than 5 m/h. As it can be checked in the table from last page, the filters are working in average, with 8 m^3/h higher flow than their theoretical maximum.

Furthermore, filtration rate higher than 15 m/h tends to deteriorate filtrate quality.

Using the information from three water analysis which was provided, it can be compared the concentration of some elements at the beginning and after all the treatment.

	Raw water (mg/l)	Criteria (mg/l)	Treated water (mg/l)
Iron	1,8	0,1	0,061
Ammonium	0,76	0,05	<0,006
Manganese	0,12	0,02	<0,005

Table 7.5 Concentratios in different stages

As it can be seen, these 3 pollutants of water when leaves the waterworks are in a concentration much lower than the criteria. Then, it could be said the filtration is effective.
Unfortunately information about flow during sampling or in which time sample was taken is missing.

To get rid of the iron, manganese, phosphates and some other elements which stay stuck in the particles of sand a backwash is needed.

Fig. 7.4 Sand filter

7.3.1. Backwash

Backwash takes place at Rønde at least every 5 days or 10000m^3 of treated water, whichever occurs first.

The process follows this order:

1 The inlet of water in the filter bed ready for backwashing is stopped and it is allowed to settle.
2 The two filters which composed the filter bed are separated.
3 The air is blown to the first area for three minutes.
4 Four minutes are waited.
5 Water is pumped to backwash the filter during five minutes and a speed of 40 m/h and is taking to a settling tank where the metals will be able to settle.
6 Water is passed twice through the filter instead of one for a period of time to make sure the filtration is effective after the backwash.
7 All this steps are followed by the other area of the filter.

Water used for backwash is stored in basin outside the building, where iron, manganese, and some other metals can settle and be discharged after an appropriate period.

A rule of thumb said during the lectures, the backwashing process should occur after 0.5kgFe/m^2 has passed through each filter.

With the actual amount of iron, backwash should occur every 5,3 days, so the estimated backwashing time is ok. However, if the other requirement is checked, the actual period should be if 4213,62 m^3 of treated water is reached. Calculations can be checked in Waterworks Enclosure

7.3.2. Settling tank

As it was said before, the water used for backwashing the filters is kept in a tank outside the main building. This tank has to be big enough to hold the sludge settled and the water. Volume of tank must be designed for acceptable retention time. During retention time deposits must be settled on the bottom of tank and separated water can be removed from tank into the water recipient. Settling tank should be invested with shut-off valve. Also washed out water can be filtrate and reused again.
Flow through the settling basin is not controlled and depends only on hydraulic properties of basin.

Fig. 7.6 Settling tank

7.4.Storage Tank

Clean water from water work can be delivered into the storage tank in the water work or into the reservoir (water tower) down in the city. There are many reason to install a Storage tank:

- Create 2 systems almost independent, the network before and after the storage tank. By doing this, a decrease of the fluctuating demand from consumers by reserving water for periods of high demand is got. When there is a low demand, water gets stored in the tank then, if there is a high demand the pumps from the wells don't need to work to its maximum power.
- Supply water for backwashing the filters.
- As a safety agent in case a treatment failure takes place. Then it could still supply water to the costumer for a period of time.
- Provide a supply of water during short periods of extreme demand, ie during a fire.

Then, a storage tank must include volume for water for fire fighting, for backwashing and to supply to the costumers always keeping in mind a security volume for leakage. Design of volume of drinking water depends on production of water work and numbers of consumers.

7.4.1. Storage Tank Design

STORAGE TANK		
Units	m^3	m^3
V_{com}	281,75	285,75
fire	150	150
BW	16,2	20
Tot	447,95	455

Table 7.6 Volumes of the storage tank

Then a storage tank with a volume of 455 m3 is needed. The calculation can be checked in the WaterWorks Enclosure.

It is known that the shape of the tank is in "L", however, the dimensions for a rectangular prism were guessed, and presented below:

Lenth: 9,7 m

Width: 9,7 m

High: 4,838 m

7.5.Conclusion

The plant works fine, and can remove all the pollutants in the water by standard treatment with a good efficiency.

Then, parameters such as iron, manganese, ammonium phosphorous are removed from the water, and the water which goes out of the waterworks is way below than the Danish criteria for drinking water.

However, if more consumers were added, then there would be more water consumption and it could create a problem basically in the filters. If the consumption is increased, the peaks would be higher, and the average flow would also be bigger making the residence time in the filters shorter. Therefore, the pollutants wouldn't be removed from the water and it wouldn't pass the drinking water control. Probably the fourth filter would be needed and even they might need a rebuilding to increase its capacity.

8. Water Consumption

8.1.Description

In the following of this chapter, we will see that how much water needs for consumption for the present and future in Rønde, Følle and for 500 new consumers. There is possible to find some basic information about water consumption in this section about consumption area, additionally more specific information in the Water Consumption enclosures.

There is no problem about available water consumption about current system, but have to be sure about future what it needs, which likes new borings, reservoirs, pipes or pumps. All of these consumption, Rønde waterworks will be used for treatment of groundwater and it is important to know its capacity enough or not.

There are 4 wells in Rønde, which are ensuring water for the consumption area**.** But, one of these wells was closed. So that, there are 3 wells as active. It is an important problem that 3 wells will be enough for future structuring.

8.2 Present Consumption

At the moment there is 1500 consumers, also they are consuming about 168.042 m^3 per year. Plus, we have to calculate for future consumption which is for new 500 consumers.

It is possible to calculate present and future consumption using by formulas which are below*:*

- *The Daily consumption*

$\mathbf{Q = Q_m \, x f_d}$(It is possible to find tables in the Water Consumption enclosures)

$\mathbf{Q}$ = daily consumption
$\mathbf{Q_m}$ = mean (average) daily consumption
$\mathbf{f_d}$= day factor (we can take between 1,5-2 also we took 1,75)

$Q_m = Q_y/d$

Q_y = yearly consumption
d = number of days/year

Q_m= 168.042 m^3 / 365 = 460,389m^3

Q=547,945 m^3 * 1.75 = 805.680 m^3

- The Hourly Consumption

$q = q_m * f_h$

q= hourly consumption

q_m= mean (average) hourly consumption

f_h = hour factor, we can choose between 1,5 and 2,5 .

q_m = Q/24

q_m= 805,680/24 = 33.670 m^3

q = 33,670 * 2 =67,140 m^3

The Daily consumption	460,389 m^3
The Hourly Consumption	33,670m^3

Figure: Present water consumption (Average)

The Daily consumption	805,608 m^3
The Hourly Consumption	67,140 m^3

Figure: Present water consumption (maximum)

8.3.Evaluation of Future Consumption

- **500 new consumers:**

There exists general information which are personal and general consumption from chart of Danish norm values. As we can see that for villages and small industries, person per house is 2,0 -2,7 and water consumption is 150 -180 Liters/person/day.

We can calculate two capacity which are minimum capacity and maximum capacity.

In the future,we will have 500 new consumers and we can reach minimum and maximum population. (Value to be added present population)

500 x 2 = 1000 person (minimum population)

500x2.7 = 1350 person (maximum population)

- The yearly consumption for future

Q_{min}=*155 Liters/person/day x 1000 person x 365day/year x 1*m^3*/1000 Liters*

=56.575 m^3

$Q_{max=}$180 Liters/person/day x 1350 person x 365day/year x 1m^3/1000 Liters
=88.695 m^3

The yearly water production is approximately 168.042 m3/y. This means that:

$Q_{min.future}$ = 168.042 + 56.575 =224.617 m^3/year
$Q_{max.future}$= 168.042 + 88.695 = 256.737 m^3/year

It was accepted average of results. About 70.000m^3/y

- **Følle:** Existing Waterwork and demand is 9000m^3/y for Følle

Totally, future water demand is about**70.000+9.000=79.000 ~ 80.000m^3/year**

Location of future consumption	**Capacity (m^3/year)**
500 new consumers	70.000
Følle	9.000
Total	80.000 (79.000)

Figure: Chart of future consumption

8.4. Assessment: Present and Future Consumption

In the future, it needs providing about 70.000m^3/year water more for new 500 consumers in Rønde and 9.000m^3/year for Følle.Totally, water demand will be about 168.042 m^3/year water. It is necessary to know there is enough capacity of borings.

8.5. Evaluation of Borings

According to chart below, total pumping of water is similar with calculation of hourly demand. It means that water consumption is proper for present demand.

Borings	**Pumping(m^3 /h)**
80.217	40
80.321	21,6
80.352	16,3
Total	77,9

Figure: Present pumping water capacity of wells

According to geology part, there is enough water capacity for future consumption. It is possible to find more information in the //Geology part.

8.6. Time-varying Demands

Water usage in distribution systems is unsteady because of the varying demands. The temporal variation in water usage for municipal watersystems typically follows a 24 hour cycle. However, it is not only changes with daily, also weekly and yearly.

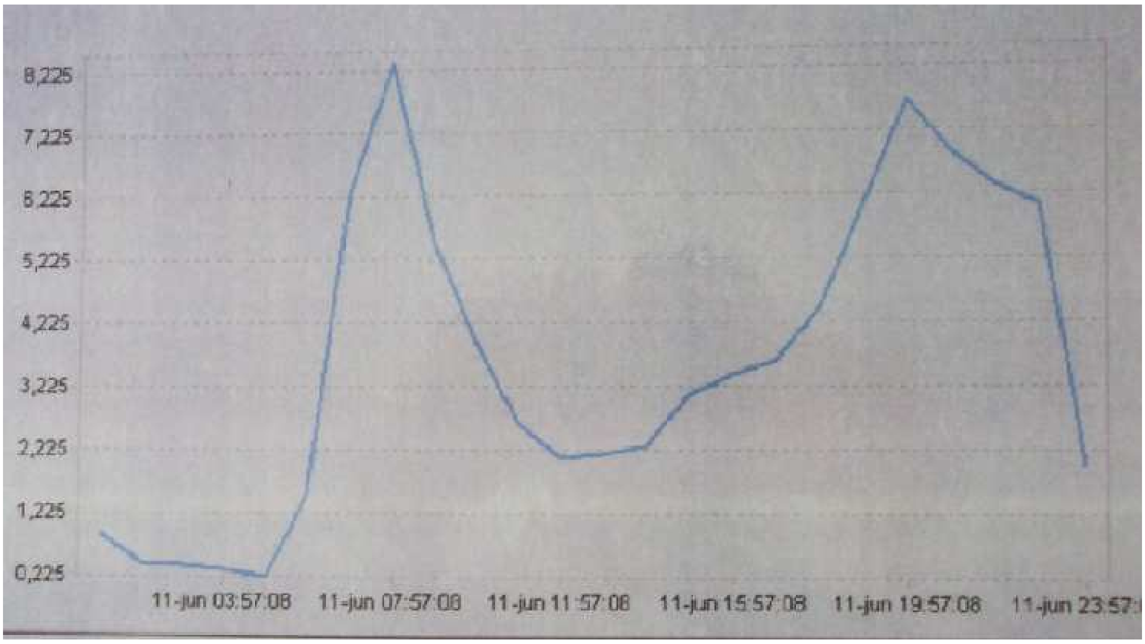


Figure: Fluctuation of Consumption in Rønde

According to diagram, we can see that what is the maximum consumption and what is the daily capacity of consumption.

In the picture, there is relatively low usage at night when most people sleep, increase usage during the early morning hours as people wake up and preparing for the day, decreased usage during the middle of day .Finally, increasing usage again in the early evening, because people return home from their works. Therefore, mean that there is two picks and water demand will be maximum in this 2 times.

8.7. Conclusion

As a result, there is no problem for ensuring of water to new structuring from wells. But, it is necessary to control wells and protecting them. It can be provided with a well water distribution modelling. In this project, Aquis was used for providing of water distribution.

9. Network

Network system delivers water from water station to customer. Water must be delivered at right pressure, and without any contamination. Network system consists of pipes, valves, pumps, reservoirs and control equipment. Combination of all these elements together in a well working network is no so easy, requires experience and big knowledge.

9.1. AQUIS model.

AQUIS program is used to simulate the waterworks network. With this program can design new networks and also check the operation of existing networks. The program is very complex therefore it's able to show potential problems with newly designed water network.

9.2. Water demands for Rønde.

Calculate water demand for Rønde is necessary to calibrate network system. Calculations were made using a database of water demand for each address in Rønde.

First step was to find the biggest water customers, then find the nearest node for each customer, and enter their demand into the node. Big customers were assumed to be costumers using more than 500 m3 of water per year. Afterwards the remaining amount of water was split equally between other nodes. Then offline simulation was begun.

9.3. Calibration

For the beginning the problem was with negative pressure in pipes 174 and 162. The reason was bad location of the pumps. The pumps were on higher level than the water reservoir, so there were a negative pressure between pumps and water reservoir. Problem was solved by making additional nodes, at the same lever like water reservoir and placing the pumps between new nodes.

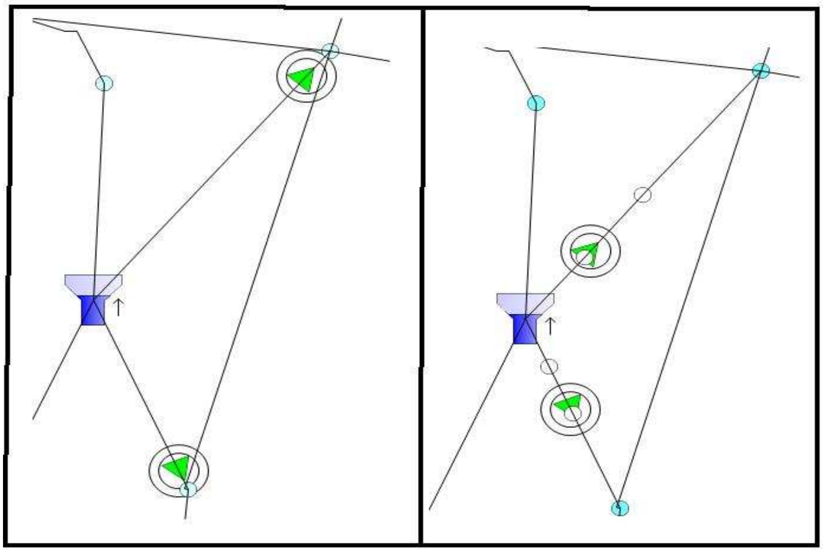


figure 9.1 shows change location of the pumps, new location on right.

This problem seems impossible to conceive out of the model, an explanation for this high difference was searched. The reason found was that in the reality both pumps are on top of the reservoir, and when the model was created whoever did it, made a mistake.

It was also necessary to connect pumps with water reservoirs, so pumping water will began when water lever in reservoirs will be to low. Third pump in waterworks station was switched off because in real world it was never used.

Next step was to close down the connection with old water station, and made new pipe to connect two networks in one system.

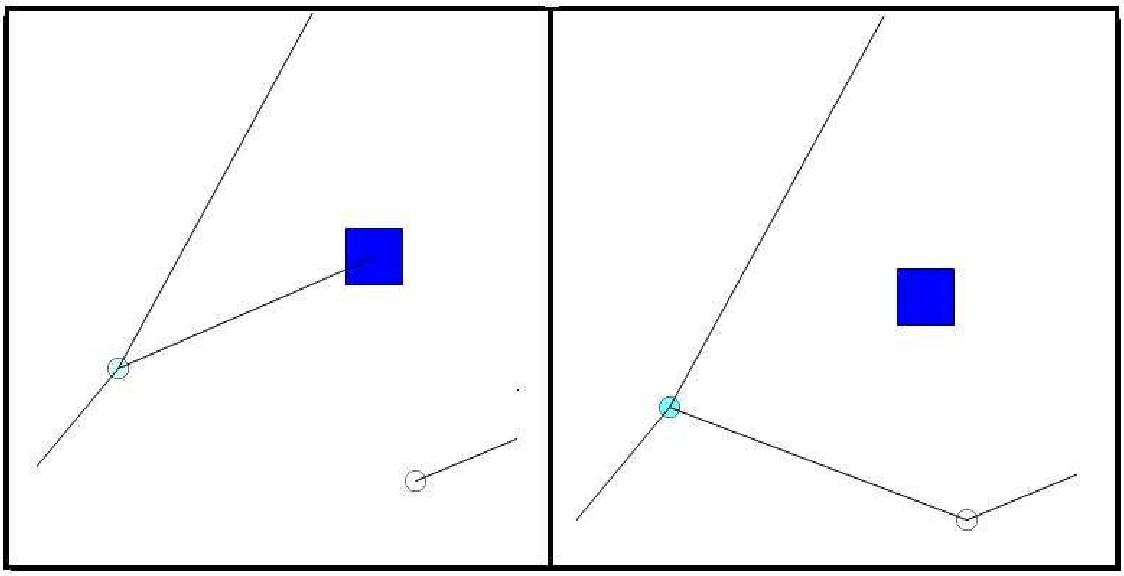


figure 9.2 shows new connection between the nodes which connects to networks in one.

9.3.1. Lack of water in reservoirs

Lack of water in reservoir caused low water pressure in network during peak hours.

This problem was solved by the calibration of the pumps. Pumps in waterworks station start working when the water level in reservoir 283 is lower than 1,8 m and stops when the water level is 2 meters. And pumps located in reservoir 284 start working when water lever in reservoir 83 is lower than 1m, and stop working when level is higher than 1,5m.

9.3.2. Too high pressure in nodes

In nodes 122,111,204,116 there was a problem with too high pressure. The problem was solved by adding PRV valve, which reduced pressure in the pipes.

Very interesting is that after the addition of several valve next to nodes with high pressure. The pressure increase in the whole network , even the new part in Følle. It suggests that the nodes with high pressure reduce the efficiency of the whole network.

9.3.3. Demand zone weighting factor

Calibration was made for demand zone weighting factor 1,0. For factor 1,2 (20% extra just in case) was a problem with negative pressure, because pumps in water station have not enough flow.

Problem solved changing the pumps but it was modification of network system. Therefore, decided use demand zone weighting factors 1,0 and don't change the network elements.

9.4. New water network in Følle

To make the project of a new network, first step is to look at location of roads and buildings to know were various networks elements can be located. Next step is to found a way to transport water to the network. In this project the main pipe will be located in or next to Aarhusvej, because it allows for easy connection to a Rønde network .

Følle is a village which used 9000 m3 of water in year. New water network will supply each house in Følle. The pipes and nodes are arranged in way as to be able to supply water to every customer. The dimension of pipes is changing from bigger in the main pipe, to smaller in the end of network branch. Følle will be supplied by Rønde waterworks.

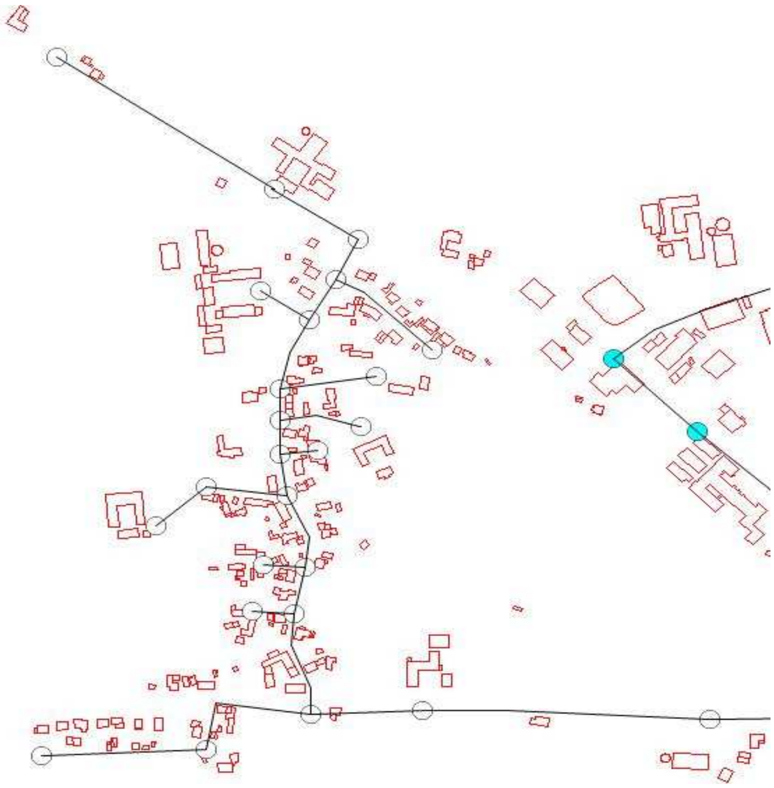


figure 9.3 shows new water network in Følle.

In the very first moment the new part was created, the pressure in some pipes was too low. It was lower than the minimum required by the Danish legislation. However, after placing the PRV valve in the nodes whose original pressure were too high, the pressure in the rest of the model was within the legal range.

From figure below it is able to see that there is no pipes with low pressure in Følle, which mean that the network was designed properly and works well.

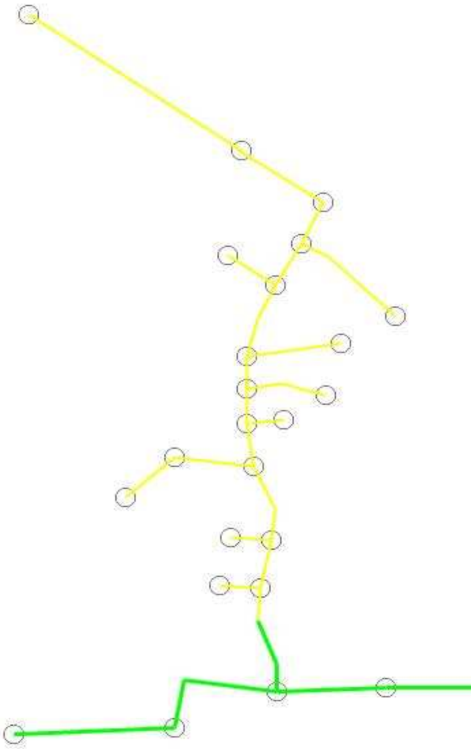


figure 9.4 shows the water pressure in network in Følle.

The minimum pressure in nodes and pipes was 12 mcw, and the minimum one established by the Danish criteria is 10 mcw. Furthermore the maximum pressure possible is not reached in anywhere.

1. Optional part

1.1.Main aim

As optional part of the project, it was decided that it would be interesting to study different aspects of the ammonia removal, such as variation of the nitrification rate with the depth in the filters, variation with time, determination of the order of reaction etc.

1.2.Introduction

Nitrification during filtration is currently used in drinking water production to remove ammonia, which is the source of several water quality problems during treatment and distribution.

As presented before, the objective of this investigation is to know how the nitrification rate, which is the velocity of ammonia conversion into nitrate, varies as the water goes deeper in the sand filter, and learn what kind of reaction is, the one which rules over this process varying with time. As it is known, the velocity of a reaction might be of different order, zero, first, second etc. The order of the nitrification reaction will be tried to know.

To accomplish this, several samples will be taken in the waterworks itself, in two different days. One day, right after the backwash process have taken place. Having done this, it will be able to know the effect of the backwash in the nitrification occurring in the filters. The second day will be a day when the cleaning of the filters hasn't happened yet and then, it will be possible to compare the different rates and get a conclusion.

Besides all this samples, a small portion of the sand from the filters will be taken to measure the nitrification rate in the laboratory. In this replica, $(NH_4)_2SO_4$ and oxygen will be supplied to the sand. By this, it will be easy to make a graph where the variation of the nitrification of the NH_4^+ with time.

After knowing this, possible solutions to improve the ammonia removal will be searched.

Unexpectedly, a kit to determine iron concentration in water was available, so iron was also measured during the two days. It could be interested to see how the backwash affects in the iron removal process.

Hypothesis

It is supposed that the day when the filter is just backwashed the nitrification will be lower because the particles are more loosen and some of biological film can be lost which helps to the nitrification can be lost. It is the aim of this part to prove if this is true or not.

Furthermore, it is also supposed that the concentration of ammonium will decrease as the water goes deeper in the filter because the deeper the water goes the more time the ammonium has been exposed to the bacteria which carry the reaction.

Nitrification Process

Nitrification is the biological oxidation of ammonia with oxygen into nitrite followed by the oxidation of these nitrites into nitrates.

It is called biological oxidation because it is carried by 2 different kinds of bacteria, one per step:

1. The Nitrosomonas. They oxidize the ammonium in an intermediate product, nitrite.
2. The Nitrobacter. They transform the nitrite created previously into the final status o the nitrogen, nitrate.

These nitrifying organisms use carbon dioxide as their carbon source for growth.

By oxidizing the ammonium, this harmful substance becomes less dangerous as it gets the nitrite status, and even less dangerous as it gets the most oxidized status, nitrates.

The degradation of ammonia to nitrite is usually the rate limiting step of nitrification.

The main problem is that the bacteria are sensitive to the environment and then the process can be inhibited by 4 reasons:

- Low pH
- Lack of oxygen
- High concentration of ammonia
- Low temperatures

The reactions of the nitrification are the followings:

1. $NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$
2. $NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$

Total: $NH_3 + O_2 + H_2O \rightarrow NO_3^- + 5H^+ + 4e^-$

As it can be seen, the reaction releases protons what makes the dissolution more acid.

1.3.First Experiment

1.3.1. Materials

In the list below, all the material used can be checked:

- 2 x Plastic glass 0,5 l
- VirKon S 1%
- Pipette
- Kit HACH LCK 304, for ammonium.
- Kit HACH LCK 304, for iron.
- Spectrophotometer DR3200
- 20 m plastic tube 5 mmø
- 4 m steel rod 4mm ø
- 4 m plastic tube 40 mmø
- Plastic gloves
- 4 x disposable suits
- Rubber cap
- Plastic 1 m x 4 m
- Syringe
- Pump
- 3 m steel rod 25 mm ø

1.3.2 The sampling device to take water:

To create the sampling tool, first of all it was necessary to know what material was available in the laboratory and in the store of the college. After having checked it, it came out there were enough material to build just one sampling device.

As it had been decided to take samples in 3 different levels inside of the filter, it was thought that the easiest solution would be to introduce in the filter 3 different tubes of 5 m; all of them tied to a 4 m metal rod (two 2 m steel bar) in order to make the set stiff and it could penetrate the sand. There was a problem during the design of this stiff bar; two rods of 2 m length each were chosen because it was easier to transport than having only one of 4 m length but, in the place where the two bars contacted, the tube could bend and it could cut the plastic making this spot a very critical point. To avoid this, an external shorter metal bar was added in order to the flexibility of this spot.

A tip made of a tough plastic full of epoxy was made for the end of the tube in which was the steel rod because the bar couldn’t get in contact with the water and this part was going to receive all the pressure of the set.

From this tip the three tubes with their screens were placed in different highs (20,50,80 cm from the tip).

To choose what screen would be the most appropriate, 3 different kinds of filters were made and tested:

1. Lineal cuts with a distance between cuts of 1,5 mm
2. Lineal cuts with a distance between cuts around 1 mm
3. Circular holes.

Fig. 1.1 Different Screens

These three filters were tested using a 2 m with the same diameter as the tube used in the waterworks, a test tube full of sand with a size of grain similar to the filter in the waterworks, water, and a syringe to pump up the water. In spite of doing this test, another parallel was carried out. This extra test was to check the capacity of the syringe to pump up water 2 m above the water.

Fig. 1.2 Tools during testing

The result was that effectively, it was possible to pump water with a syringe and a headloss of 2 m. The best screen was the pierced one. To know more details of these tests, please go to Optional Part 1 Enclosures.

In order to take samples (sand or water) in the waterworks, every component of the tool which is going to have contact with the water or sand had to be perfectly disinfected.

For disinfecting the tubes, a disinfecting agent was used. It is called Virkon S. Here it can be seen some of its properties:

- Powerful – independently proven effective against viral, bacterial and fungal disease causing organisms including the lethal H5N1 Avian Influenza Virus.
- Fast-acting – a one percent solution of Virkon® S is independently proven to kill bacteria with contact times as low as five minutes and the tough to kill parvovirus in ten minutes or less.
- Versatile – surface, equipment, vehicle, foot dip, water delivery system and aerial disinfection.

The dissolution had a concentration of 1% and the volume used was 3 liters in 2 days. To know more about this product, please go to the Optional Part 1 enclosures

For applying the disinfectant agent to the sampling tube, a bigger tube was designed to keep them inside for at least 10 min. This tube measured 4 m length and its diameter was around 4 cm. A pierced rubber cap must be place at the end of the tube. A epoxy stuffed plastic tube has to be put in the hole of the rubber cap.

Fig.1.3 Tools at waterworks

1.3.3The sampling device to take sand:

A tool to take the sand used in the experiment II was needed. Two 1,5 m length steel bars 1,5 m length and 25 mm ø each were used.

Using two pins in two holes it was possible to join them. In one of the extremes, a plastic glass was possible to join thank to 2 bridles.

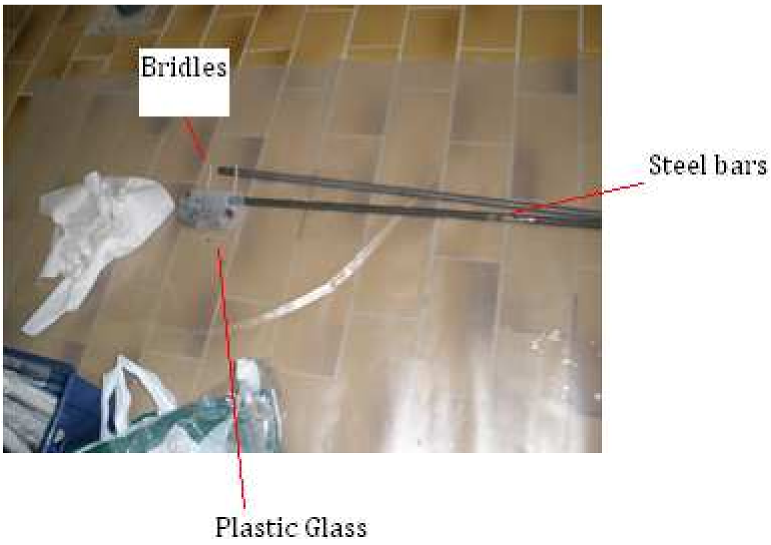


Fig. 1.4 Tools at waterworks II

As mentioned before, pumping the water from 2 m below was needed. To accomplish this, two pumping system were tested:

- Syringe
- Vacuum hand pump

Both of them worked, but it was much easier to use the vacuum hand pump because using the syringe the maximum volume was reached too soon. Furthermore, when flushing the syringe was necessary, many problems came out to keep the pressure in the tube; pressing a soft piece of plastic was needed and it was difficult to avoid the inlet of air inside.

Finally it was decide to use both of them thank to a plastic piece with one inlet and two outlets. So the vacuum hand pump was used at the beginning to pump the water to the syringe, and then the syringe was used to take 50 ml where the 5ml needed for the sample were taken from.

1.3.4.Method

The sizes of the filters are 2,7m x 1,8 m and it has a depth of 1,8 m. However, the filter bed depth is 1,0 m.

It would be desirable to take samples of water representatives of all the area of the tanks. Five sampling points would be chosen per layer. However, due to lack of material, only one point will be used. This spot should be at least 20 cm away from any wall to avoid any flow disturbance.

The temperature of the water is to be measured, because nitrification is highly dependent of it. However, this measurement wouldn’t change a lot from the temperature measurement done before the water enters in the waterworks. This will be chosen as the water temperature.

It would also be advisable to take samples every 10 cm of depth, but as it was said before, due to lack of material, samples will be taken in this way:

- Outlet (filtered water)

- 20 cm from bottom of the bed filter.

- 30 cm from the previous point.

-60 cm from first point.

-Inlet (raw water)

There will be 2 samplings day, the first one; right after backwashing the filters. The second one; the day after backwashing. The same amount of samples is to be taken in both days.

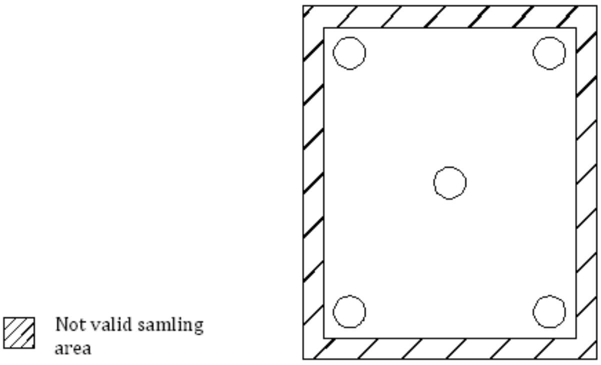


Fig.1.5 Sampling method I

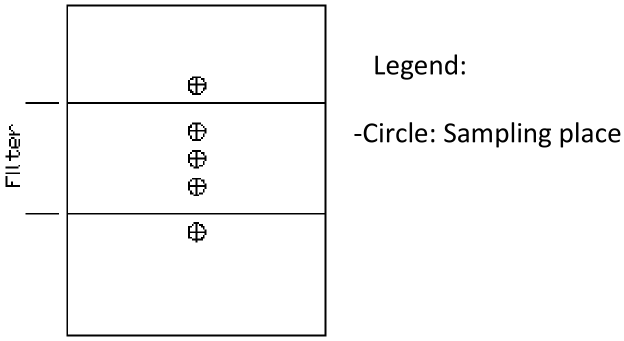


Fig.1.6 Sampling method, filter profile.

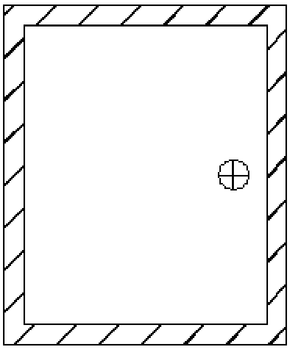


Fig 1.7 Sampling method II

Having the sample taken, there are two options:

1. Make the measurements in situ
2. Take the samples to a laboratory and make the measurements there.

it's highly recommended to make the measurements in situ because more reliable results are obtained on fresh samples, however, if no car is available it may be difficult to take all the equipment to the waterworks and then the best choice would be to make the measurements in the lab. If the measurement has to be postponed, the samples have to be treated.

This treatment consists of:

The first aim is to destroy residual chlorine to prevent its reaction with ammonia. To achieve this, 0.8 ml conc. H_2SO_4 /L sample should be added and then, keep it at 4ºC. The pH of the acid-preserved samples should be between 1,5 and 2. After this treatment the sample can last 28 days before getting spoiled. The recipient to keep the water can be plastic made, or glass.

If acid preservation is used, neutralize samples with NaOH or KOH immediately before making the determination. Reference

Finally despite of having to take all the equipment to the waterworks, the analysis will be carried out in situ, what makes it easier than treating the samples to take them to the laboratory.

It should be at least tested once the sampling and disinfecting procedure before going to the waterworks, in order to be fast and to know how to react for possible unforeseen events.

In the waterworks, the disposal suits are to be put on and then, prepare the working area.

Place the protective plastic on the floor. Having all the tools disinfected is the previous step to introduce them in the filter. The disinfection should get started as soon as possible because it takes some time to disinfect with the Vikron S and then it should be flushed several times with water to get rid of this agent.

1.3.4.1.The disinfection procedure

The second steel rod must be introduced into the tube where the first steel bar is. Once this is done, the whole set is to be introduced in the disinfecting tube with the rubber cap at the end. With a funnel, approximately 1,5 l of Vikron S are introduced in the tube and from 10 to 15 min are waited. The rubber cap should be watched, because if there is too much weight it will blow up flushing all the disinfecting agent without any control.

Once this time has passed by, the flushing is begun. The epoxy stuffed plastic is to be removed and aiming properly to the Vikron S bottle, all the disinfectant is flushed. The same steps must be repeated four times but using tap water to remove all the remaining Vikron S in the tube.

To disinfect the steel bars for taking the sand the same procedure is to be followed.

The plastic glass to take the sand and the pins are put in a plastic box full of disinfectant for the same time. Then, after 10-15 min tap water.

Fig.1.8 desinfectant recipients

1.3.4.2 **Placing the tubes**

After the disinfection, it is time to introduce the sampling device in the filter. As trying to introduce the tubes with the water going down is impossible because the sand is very compacted, the backwash in necessary.

The backwash in Rønde starts first with air going up and then water. During the air time, to introduce the tube is fairly easy, so then, the sample device should be placed in the appropriate spot before backwashing and when the air is going through the filter it has to be pushed down until reaching the bottom.

Fig.1.9 Placing the sampling tool

1.3.4.3.Taking Samples

At the same time than placing the tubes, the sample of sand will be taken. Once the bars and the plastic glass are disinfected, they should be mounting together using the bridles and the pins to join de three parts. After this, while the backwashing is taking place, the glass in the extreme of the steel bar is put in the filter and moved to catch the sand. Then the glass is lifted and the sand is kept in a clean plastic glass for posterior experiments.

After the backwash period, 10 min later than when the water starts to get filtered; the sampling of water can begin.

There can be two sampling directions, from bottom to top, and from top to bottom. The concentration of ammonia in the water is lower in the bottom than in the top. As only one syringe is used, to minimize its contamination due to some remaining water in the syringe, the sampling process is started from the bottom.

To homogenize the tubes, they need to be flushed once before taking the sample. The extraction rate cannot be too high, otherwise not only water from this level would be extracted but from many points around the screen. This is not good for the experiment, because it's desired to know the variation with the depth, then if water from many levels is extracted, a mistake would be made.

It was decided that create vacuum every 6 sec was enough fast.

For knowing the wanted extracting rate, the filtration speed should be checked. The pumping rate should never be higher than the filtration because a too high negative pressure would be created around the screen and the effect above explained would happen. However, it is impossible to know our extracting rate, then the pumping of the water is done slowly and carefully.

As explained before, the vacuum hand pump is used for flushing and pumping up the water and the syringe is used to take the sample.

Fig. 1.10 taking samples

From each sample 2 analysis are made; ammonium detecting and iron detecting.

These detections are made in situ with the Kit HACH LCK 304 for iron and ammonium.

- For ammonium, 5 ml of water are needed
- For iron, 2 ml of water are needed.

The concentration obtained by this method will be noted down. To know more about this method, please go to Optional Part 1 enclosures

All the samples must be marked properly right after being taken to avoid confusions.

The first day only 1 measurement was repeated to check the accurate of the method.

The second day, it was decided to start from the top to the bottom. In order to avoid contamination in the syringe, it was flushed once before taking the samples. Then, there were two flushing, one for the cleaning the tube and the other one to wash the syringe, before taking the sample.

The flow is to be checked to calculate the HRT of the filters those days.

1.3.4.4.Possible problems and risks

Before going to the waterworks, lists with possible problems, risks and solutions for these problems were made.

Sampling in the waterworks is not an easy job. There is a big responsibility when a sampling tool is introduced in the sand filter (or in any place inside the waterworks where there is a contact with the water) because many things can happen and there is a risk of polluting the water. This would affect many people due to a possible shut down of the water supply until the water accomplishes the drinking water criteria again or even due to some health problems.

Here below the lists can be found:

- Problems which may happen:

    1. Impossibility of putting the sampling tubes in the filter or to the end of the filter bed.
    2. Clogging of the small screen.
    3. Loss of some parts of the tool when introducing or taking out.
    4. Drop of some items (watch, rings, bracelets..) in the water.
    5. Rupture of some parts of the sampling tool.
    6. High variations in the ammonia analyzed.
    7. Analysis of the water carried out wrongly.
    8. Disassembling of different parts.
    9. Break down of the syringe/pump
    10. Entrance of air through the joints
    11. Contamination of the sample due to a bad cleaning of the syringe
    12. Holes along the tubes

- Possible solutions to the problems:

    1. The sampling tubes will be placed during the backwash, when the sand is being loosened. If it s still impossible to do, a screwing movement could make it easier
    2. Let go some of the water which is in the tube, this way there will be a loss of pressure and the particles in the screen can go out of the slots.
    3. Handle the tube very carefully, and having something ready to pick up the possible thing which can fall down nearby, just in case.
    4. All the personal items should be left in a bag before handling the tube.
    5. It will depend on what part is broken, it could be replaced, removed and go on without it and as the worst possible case, take out all the tube and renew it.
    6. Measure ammonia in more than 1 sample, so average can be calculated. It is also possible to take samples again.
    7. Take new samples and start the measurements over again.
    8. Make sure that all the parts are correctly assembled with clamps. Lift the tube slow and carefully. In case some part disassembles, if it occurs inside of the sand filters, wait to next backwash when it would come to the surface. If it's out of the filter, we would be in point 3.
    9. Renew it or just pump up the water using the other method. (only syringe or just vacuum hand pump)
    10. Make sure all the joints are properly well closed and isolated.
    11. The sampling should be started in the spot which is the deepest due to the lowest concentration of the 3 points. After every sampling the syringe should be shacked and flushed to try to get rid of all the water remaining inside of it.
    12. Patch it.

- Hypothetical risks during sampling.
    1. Contamination of the water.
    2. Bad filtration while the tubes are inside of the sand filters.
    3. Bad filtration due to the extraction speed used.
    4. Some part of the sampling tool stays stuck in the filter and cannot be floated.

With all these for risks a chart evaluating them was made:

Risk	Probability	Impact	Result
1	**Low**	**High**	**Medium**
2	**High**	**Very low**	**Low**
3	**Medium**	**Very low**	**Low**
4	**Very low**	**Medium**	**Low**

Table 1.1 Risk evaluation

As it can be seen, all the risk had a small importance. Please note that this evaluation was done since a subjective point of view, it can change with the person doing it.

1.3.5.Experimental Hydraulics in the filter

	Day 1	Day 2
Flow(m3/h)	34	32,4
FR (m/h)	6,99	6,67
Real Velocity (m/h)	17,49	16,67
EBCT (h)	0,143	0,15
T_{res} (min)	3,431	3,6

Table 1.2 Experimental hydraulics in filters

For checking the calculations, go to Optional Part 1 enclosures

The extraction speed should never be faster than the real velocity, because then water from everywhere next to the sampling place will be extracted and the result wouldn't be representative of that level. However, it was impossible to know if it was being pumped up faster or slower than this real velocity.

1.3.6.Conclusions

Water was taken from inlet, outlet and from three different levels in the filter.

The three levels were called I, II, III according to the sampling order. Therefore, (I) was used to call the lowest point, (II) middle point and (III) was the point the closest to the surface. Here below, the concentration obtained as results can be checked in the Optional Part 1 enclosures

As the flow in both days were different, in order to compare the capacity of the filter right after backwashing and one day later to remove ammonia and iron, all the concentration should be changed into mass flow:

- First Day:

Spot	Fe (g/h)	NH_4^+ (g/h)	Fe (g/h)	NH_4^+ (g/h)
Raw	64,26	17,612		
3	10,574	0,748		
2	17,068	4,59	14,178	4,046
1	11,016	0,306		
Outlet	4,012	0,51		

Table 1.3 first day concentrations

- Second Day:

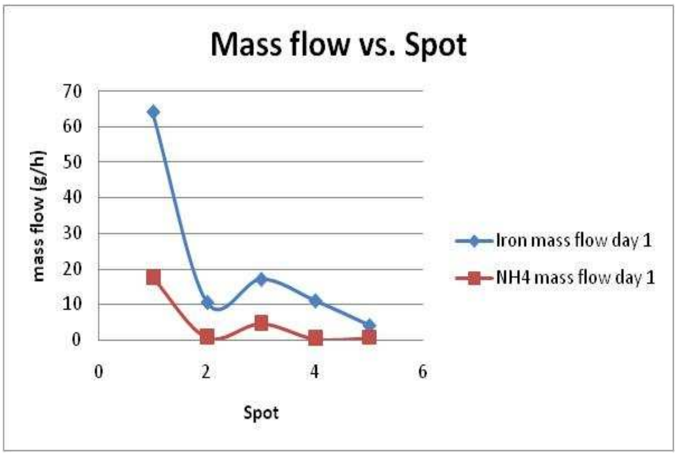
Spot	Fe (g/h)	NH_4^+ (g/h)	Fe (g/h)	NH_4^+ (g/h)
Raw	68,364	17,172		
3	27,3132	8,6184	16,9128	8,424
2	12,1824	3,8232	9,6228	3,1104
1	4,4064	0,0324	5,508	0,0324
Outlet	3,8556	0,0648		

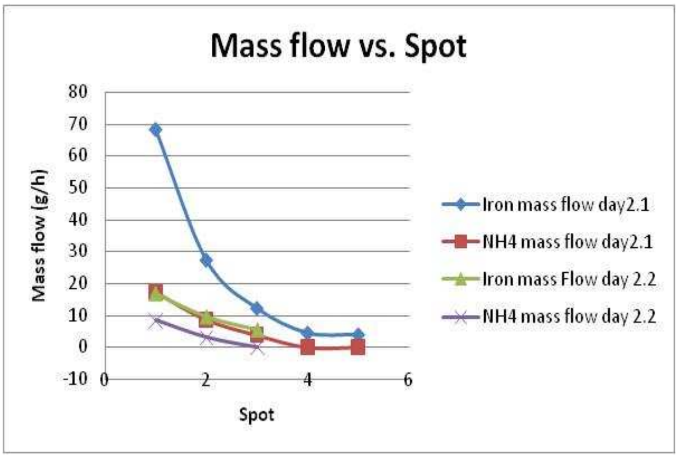
Table 1.4 second day concentratios

During the sampling the first day, only one sample could be taken twice and spot (II) was chosen as sampling point. The reason why this level was chosen is because it was in the middle of the filter and there would be less possible interferences there.

However, in the second day, a second sampling round was done to see how accurate the sampling system was.

The representation of these data can be seen right below.





Graph 1.1 Mass flos vs spot

Graph 1.2 Mass flow vs spot II

Day X.Y means in what day the samples were taken, and if it was the first or second time in that day.

As it can be seen in the graph, there is a reduction of ammonia and iron while the water goes deeper just as it was supposed theoretically at the beginning of the experiment. One of the things should be marked is the iron speed removal in the filters, it has a high iron removal speed at the beginning of the filter. From the raw water to the first point, which is only 20 cm under the surface, there are 40 g of iron less. However this velocity gets slower and slower. The graph could fit a exponential curve.

Despite of the fast change in the mass of iron, the variation of the mass of ammonium is not very big with depth, the concentration of ammonium doesn’t change fast, or at least not as fast as in iron removal. From the raw water to the Spot III around of 9 mg of ammonium is lost.

It gets proved then, that the concentration of either ammonium or iron gets reduced with the depth.

However, the nitrification rate variation is not very big with depth, the concentration of ammonium doesn’t change fast.

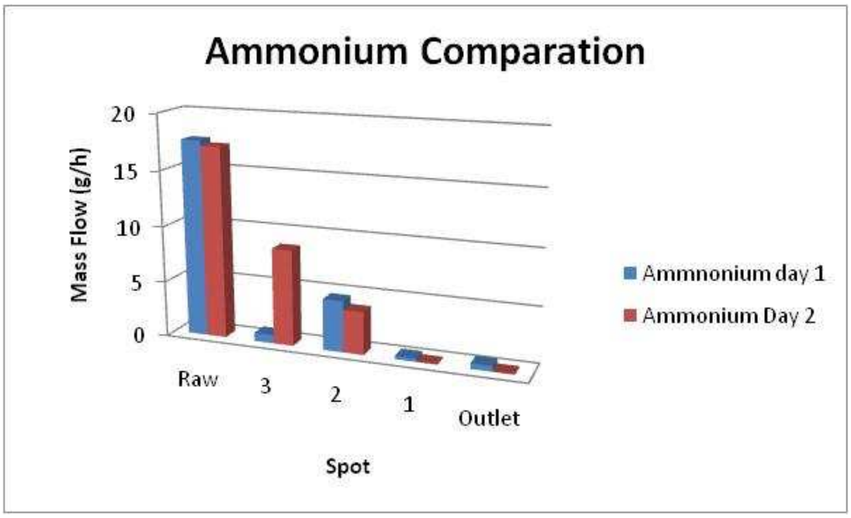
However in the spot III as it can be seen, some strange thing happens, the concentration of both, iron and ammonium, are very low. Some explanations for this effect were thought:

1. As all the sand particles were loosened the flow between particles doesn’t go straight, the paths where the water goes the easiest through are not done yet, then it could be that the water taken during sampling of Spot II was running around a bigger area than normally and that is why this sample has a less concentration of ammonium.
2. The extraction rate was too high, too much water was extracted in a short period of time during sampling, and due to a high negative pressure, water from much under the screen was taken, having this water less concentration as it should the water in this spot. That’s why the concentration is more similar to the next point.

3. It is known that the pumps stopped and resume working at least twice during sampling. This can affect the concentration of ammonium and iron because is straight related with the residence time. Then, it could happen that one of the pumps stopped working in some time before taking the samples in III (15 min earlier), so the residence time of the water taken in III was higher than for II or I.

As it was wanted to compare the nitrification two graphs were made to compare adequately the amount of ammonia and iron between days:

- For Ammonium:



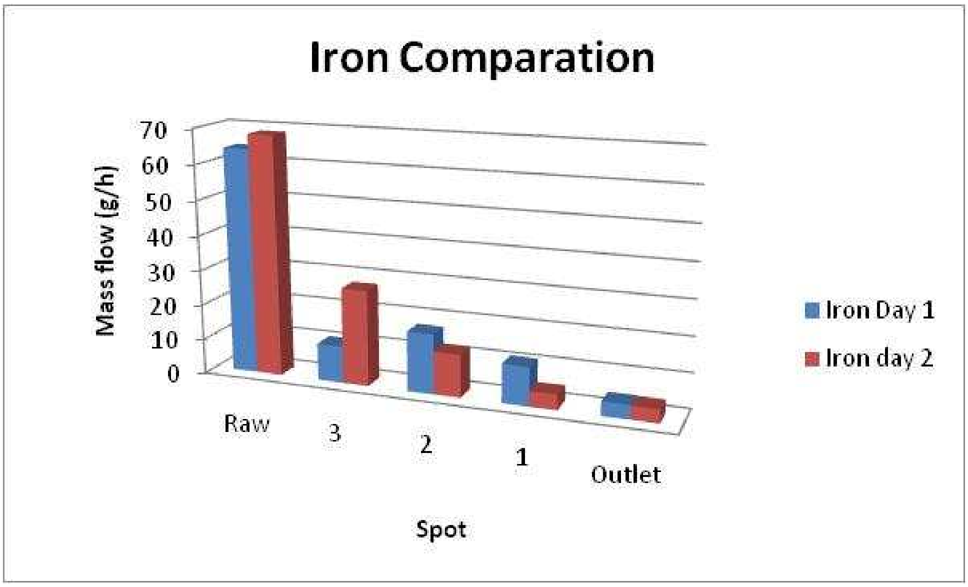
Graph 1.3 ammonium comparetion between days

Analysis of the graph:

If a one hour period is to be analyzed, then as it has been said before, is quite evident that the mass of ammonium obtained per level gets reduced going deeper in the filter.

It can be seen that in the first day, the day when the backwash took place, there is always more mass of ammonium than in the second day. Only one spot breaks this fact, the Sport III has more mass of ammonium in second day than in the first one. The possible explanation for this is explained in the previous page. However, the ammonium found in the raw water is also higher. Then it cannot be said 100% sure that the nitrification rate was higher the second day than the first one. The difference of mass is almost constant in all the spots, even the same in the raw water and treated water. Hence, the relation between backwash and nitrification is certainly not clear enough to get a conclusion.

- For Iron:



Graph 1.4 Iron comparation between days

Analysis of the graph:

Although it couldn't be concluded that the nitrification process depended on backwash, the effect of backwash in iron removal can be affirmed.

In the graph above, it can be seen that even having more initial iron in the raw water, the iron removal one day after backwashing is higher than the backwashing day. (Without taking into consideration the Spot III). It is evident that there is more iron in every spot the day one than the day 2.

Then it is right that the backwash affects the iron removal in sand filters, by loosening the particles and losing some of the biofilm which helps in the process.

1.3.7.Sampling Error.

Two measurements were made in order to calculate the error made during the sampling process.

There could be also an analyzing error made by the spectrophotometer, but this error would be/is minimal compared with the possible error made while taking the water out of the filter.

Many factors could affect the sampling procedure, and what is checked calculating this error is exactly to know how much these factors affected.

Theoretically more samples per level should have been taken, to make sure the sample taken is not bad, but due to lack of material only two per level were possible to take.

There are many ways of calculating the error, and different errors.

For this study, the relative error was chosen, being this its formula

$e = \frac{M1 - M2}{M1} \cdot 100$ Reference 2

Then applying this formula of its measurement and calculating the average, the average error will be obtained.

The relative error in the sampling process was: 10,471595 %

It is high, but knowing that for example the extracting speed couldn’t be checked, and it was done counting 5-6 secs between vacuum is quite acceptable.

1.4.SECOND EXPERIMENT

1.4.1.Introduction

As it was explained in the introduction of the first experiment, the nitrification process consists on the oxidation of the $NH4^+/NH_3$ to produce NO_3^{2-}. It gets oxidized by the oxygen in the water and by two different kinds of bacteria, Nitrosomonas and Nitrobacter which are hold in the sand used as filters at the waterworks.

Then, a plastic glass will be used as a batch reactor, a discontinuous tank, where the sand taken previously from the filters will be put in with the ammonium dissolution in order to check how the ammonium used in the nitrification process changes with the time, in other words, what is the nitrification rate in the reactor.

Knowing the concentration of ammonium, which is one of the reactive agents, in the time zero (t=0) and measuring the concentration of it while the time is passing will give an idea of the consumption of this reactive agent. Using this variation, the order of the process will be guessed.

1.4.2.Materials

This is the list of what was necessary to carry out the experiment.

- Plastic glass 0,5 l
- Pipette 1 ml
- $(NH_4)_2SO_4$ Molecular Weight= 132,1 g/mol
- Demineralized water
- Volumetric flask 1 l
- Sand from the filter kept in fridge.
- Kit HACH LCK 304, for ammonium
- Spectrophotometer DR3200
- Scale
- Ceramic plate
- Spatula

1.4.3.Process

20 cl of sand will be taken and put in a glass, which will be used as a reactor to measure the nitrification rate in that sampled sand.

After putting the sand in the glass, 20 cl of dissolution of ammonia in water of a known concentration will be added to the reactor. In the very first contact of the water with the sand, the time will be started to be measured.

The concentration of the dissolution was calculated, knowing the concentration of oxygen in water and the consumption of oxygen by the ammonia, obtaining:

10 mg O2/ l → 2,78 mg N/ l are needed.

To make this dissolution NH4)2SO4 will be used. Theoretically, it should be added 10,2 mg of sulfate and then add water until reaching 1000 ml in a graduated test-tube.

20 cl of this dissolution will be added to the reactor.

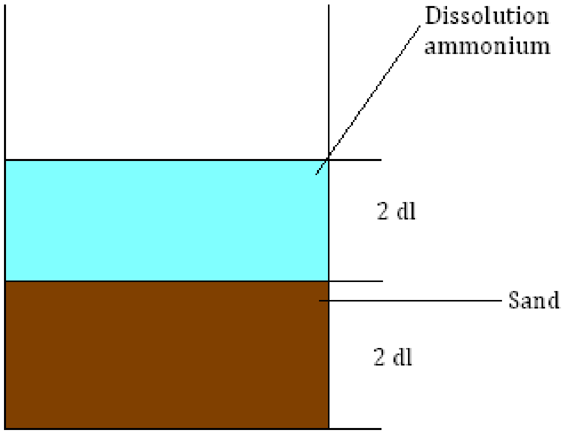


Fig. 1.11 Sand layout

Fig. 1.12 Some tools for the experiment

After 10 min the first sample is to be taken. A pipette will be introduced in the glass and 5 ml of the dissolution will be taken to measure the concentration of ammonia. To know how this time was calculated, please go to Optional Part 2 Enclosure.

One minute before sampling, the glass should be turned in back and forward so all its content is mixed and the water gets enriched of oxygen.

Then the sample of water has to be mixed with the reactive agents and after 15 min of continuous mixing it will be introduced in the spectrophotometer and the absorbance will be measured in order to know the concentration of ammonia. More information about this process in the Optional Part 2 Enclosure.

If after the first measurement the concentration is higher than the theoretical, which was calculated before, the second sample will be taken some later than 10 min. But if it is smaller it will be taken in a period of time smaller than 10 min.

After all samples have been taken, the graph Time vs. Ammonia concentration is to be drawn.

All the tools are supposed to be cleaned and homogenized with demineralized water. Furthermore, as we are taking samples from more concentrated dissolutions to lower level of ammonia, the pipette should be flashed at least twice.

Finally, eight samples were taken from the water in the glass, plush the raw water which was also analyzed, then, nine analyses were made.

1.4.4.Incidences

- The tools used were a bit inaccurate, so there might be some measurements mistakes.
- There was an error during the measurement of the $(NH_4)_2SO_4$ weight. 13 mg instead of 10,2 mg were taken. This makes a dissolution of 2,76 mg N/l, what is still correct because this concentration is smaller than the concentration of nitrogen for which the concentration in water is maximum.
- The sand taken from the filter was still wet, so there was a volume of water higher than the theoretical one. Despite of trying to remove this water, some of it still left in the glass. This water was dirty and could interfere during the measurement of the absorbance. To know how wet were the sand, the mass of water in sand was measured by gravimetric methods. The humidity of the sand is 24,9%. For knowing more about this, please go to Optional Part 2 Enclosure.
- A drastic reduction of the nitrification speed was thought as a reason why we were out of analyzing range of the spectrophotometer. After the results of the first sample, it was decided to wait 15 min instead of 10. The next result turned out to be again out of range from the barcode method, so the waiting time kept growing higher and higher trying to get inside of the measurement range. The last sample was taken almost three hours and a half later than its previous one.

  It was made a dilution of the samples whose concentration exceed.

- All the ammonia measurements were out of range for the spectrophotometer, the range which the barcode can measure Nitrogen in, is from 0,015 mg/l N to 2 mg/l N. As our initial concentration (2,7 mg/l) was higher than 2 mg /l, it could be understandable that the 2 or even 3 first measurement were out of range, but not all of them. Two possible explanations were thought:

- The turbidity in the liquid was really high due to the dirt in the sand. These small particles create an interference measuring the absorbance because they reflex too much light. Hence, the concentration got as a result, was much higher than the real one.
- The actual nitrification rate was extremely slower than expected, then, it took longer to go under 2 mg /l.
- After measuring the concentration of the ammonium sulfate dissolution, it was clear that a mistake making the dissolution was made, because its concentration was 12,08 mg N/l when it was supposed to be 2,76 mg N/l. Some possible explanation:
  - A mechanic failure in the scale. The scale didn't work properly.
  - 56,4 mg $(NH_4)_2SO_4$(necessary amount of solute to make that concentration) were taken instead of 13 mg(which is the weight the scale display showed and which was noted down)
- A mixed of the three previous points was thought as the explanation.
- The kit used is set to analyze de water in a 20°C, as the temperature wasn't checked there is a possibility that the water in the sample was in a different temperature.

Fig. 1.13 Difference of turbidity

To solve the problem where all the measurements were out of range, it was observed that all the sampling tube had different color, and actually, as it can be seen in the picture below, the first sample taking, had the darkest green of all of them, and the sample number 8 had the lightest green.

Then, if it is believed that the turbidity is a constant in the eight samples, the parameter which is changing is the concentration of ammonia what makes the color to change.

As it has been said before, to get inside of the range, all the samples were diluted. The volumes of the nine samples were taken to 20 ml what makes the samples four times more diluted than the original dissolution. Then, 5 ml of the new concentration were taken and measured in the spectrophotometer.

t(min)	C(mg/l)	C_{real} (mg/l)
0	3,02	12,08
12	2,81	11,24
20,5	2,52	10,08
37	2,03	8,12
57,7	1,85	7,4
88	1,65	6,6
128	1,52	6,08
193	1,43	5,72
380	1,41	5,64

Table 1.5 Concentratios and time

As it can be observed, the concentration which was measured is much higher than the original one, what doesn't make sense, unless the original dissolution had then a fake concentration. Then, a failure in the scale was more likely than in the spectrophotometer, hence, the original concentration was decided to be 12,08 mg N /l.

In the table from above, the increment of the waiting time between samples, which was described before, can be observed.

To know if it was made an error diluting the samples, it was decided to dilute one of the samples even more, and see if it made sense.

The sample of 12' was driven to a volume of 40 ml, what makes it to be 8 times more diluted than the original and twice more diluted than the first dilution. The result:

$C_{v=20}$ = 2,81 mgN/ l $C_{v=40}$ = 1,52 mg N/l

Theoretical concentration: $C1 \cdot V1 \cdot = C2 \cdot V2 = 20ml \cdot \frac{2{,}81mgN}{l} = C2 \cdot 40ml;$

C_2= 1,405 mgN/l

As it can be seen the real actual concentration is a bit higher than the theoretical one. But it was decided to say that the error wasn't too high to reject the method.

This problem is assigned to the error which is caused by the turbidity.

To check if there was any problem with the spectrophotometer, some pure water was introduced to analyze its ammonia. The result was 0 mg N/l, so a hypothetical failure in the machine was rejected.

Three days later, the tube samples were found with a light brown precipitate (iron and manganese loosened in the sand filters). This light brown precipitate is the agent which caused all the turbidity in the samples and made impossible to know the exact concentration of ammonia.

Fig1.15 Sand Settled

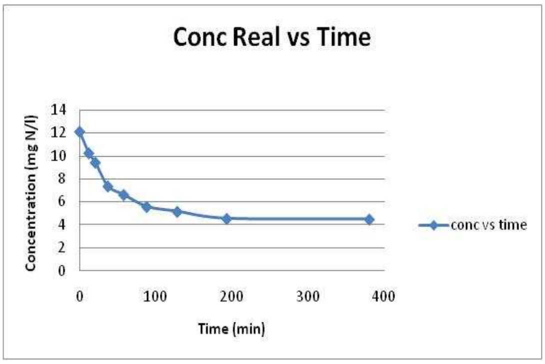
As the beam used in the spectrophotometer goes through the dissolution some higher than the precipitate, it was possible to determine in a more accurate way the concentration of ammonia. However, as three days had passed by, the concentration of nitrogen then was not the same as the beginning, but measuring the absorbance with the sand both settled and in suspension could give us an idea of how big was the error due to the turbidity and apply a corrector factor to the concentration obtained the first day, being the result:

t(min)	Creal (mgN/l)
0	12,08
12	10,2273874
20,5	9,408
37	7,35073684
57,7	6,61647059
88	5,57806452
128	5,15751724
193	4,54235294
380	4,48704425

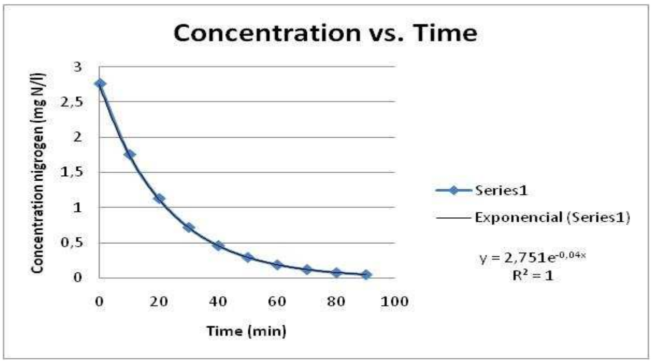
Table 1.7 time vs Real Concentration

1.4.5. Conclusions

Plotting all those results in a graph:



Graph 1.5 Concentration real vs time



Graph 1.6 Concentration vs time theoretical

As it can be seen, the graph has approximately the shape of an exponential curve, which is the kind of form that belongs to a 1st order kinetic equation. Then it could be assumed that the nitrification process which took place in the sand matches with a kinetic 1st order equation. However, as it can be checked in the Optional Part 2 Enclosure.many calculations assuming this 1st order were made, and none of them fitted the assumptions. Furthermore, the equation of the curve was calculated by approximation, and as it can be seen in the formula below, it is different than the typical formula of a 1st order. How this equation was got is explained in the Optional Part 2 Enclosure.

$$C = 0{,}23 \cdot e^{-0{,}023t} + 4{,}45$$ Formula 1.2

$$C = Co \cdot e^{-kt}$$ Formula 1.3

It should be kept in mind that the results aren't completely right. They are always approximated to the real ones.

A comparison between the graph obtained with the results and a graph extracted from another experiment, but with the same aim, was made.

In that experiment, the objective was to know the hydraulic characterization of the filters in a waterworks in Flanders, the northern part of Belgium. In order to accomplish this, a tracer test (Froment and Bishoff, 1990) performed on one of the biofilters was used to determine the hydraulic behavior of the biofilter. With this tracer test the number of (perfectly mixed) tanks in series that correspond to the actual reactors hydraulic behavior is determined.

For this tracer test a pulse of 4 mgN/ℓ ammonium was added to the influent of one of biofilters. Over a period of 2 h the effluent ammonium concentration was measured every 2.5 min.

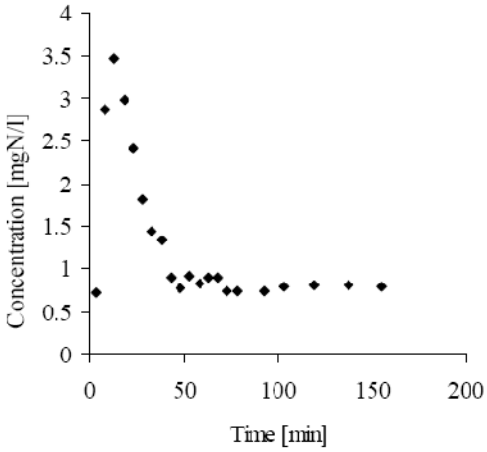
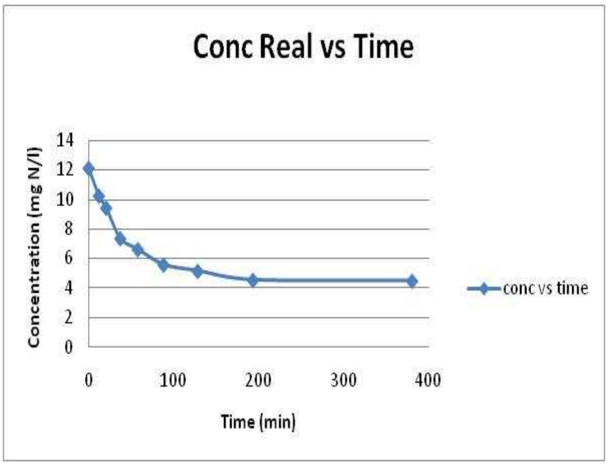
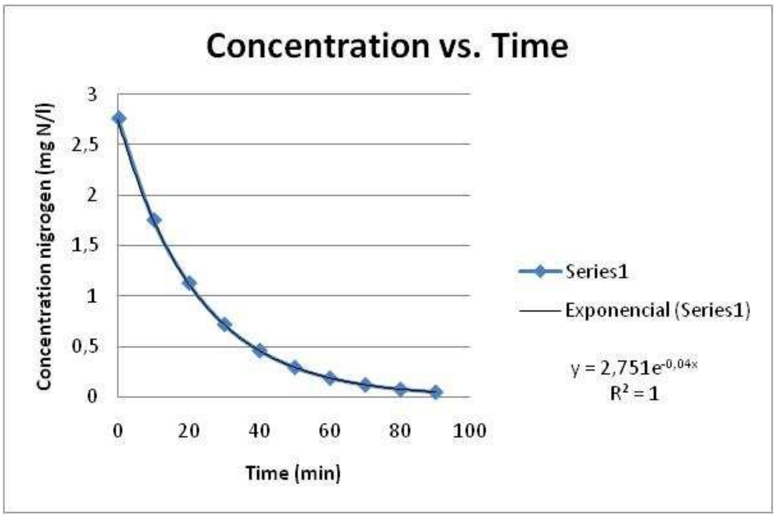


Figure 2
Measured effluent ammonium concentrations during the tracer test after injection of a pulse of 4 mgN/ℓ ammonium to the influent of one of biofilters at time 0



Graph 1.5 Concentration real vs time



Graph 1.6 Concentration vs time theoretical

If the nitrification process was first order equation, the half-life time, which is the time it takes to get the half of the original concentration of the reactive agent, would be the same, independent of the reactive agent original concentration.

However, it is not like this:

Half-life Time ($t_{1/2}$)		
Theoretical	Flanders	Experiment
15,47 min.	35 min	74,47 min

Table 1.8 Half life time

If the different $t_{(1/2)}$ were to be compared, the conclusion would be that the half life time from the experiment is higher, what means that the nitrification rate is slower.

If the formula for the 1st order of the half life time is used, the K of the process is easily calculated:

$T_{1/2} = \frac{Ln\ 2}{k} \rightarrow k = \frac{Ln\ 2}{t(1/2)} = 0,00931 \text{min}^{-1}$ Formula 1.4

It can be checked that the K calculated by this procedure, is different than the K calculated in the equation of the curve. This is another reason to say that it is not a first order kinetic equation.

Furthermore, the results from the experiment were tried to fit in a 2nd order equation, but neither had they fit. Hence, it can be concluded that the nitrification order reaction n, is $2 < n > 1$.

It easily appreciate that there is a big difference between the two practical graph and the theoretical one, while this last one tends to 0, the two firsts, tend to something less than their 50% concentration. This could be caused by the inhibition of the bacteria in charge of the nitrification either by a pH drop due to the oxidation of the ammonium and the consumption of the alkalinity of the water or because there was a high ammonium concentration.

It was calculated that in around 2 hours the ammonium in water should be in a very low concentration, but as it was seen in the experiment, the last sample was taken 6 hours later than the beginning and the concentration seemed still high.

One possible explanation for this effect could be that the ammonia concentration in the water from the wells is 10 times lower than the dissolution which was made, and too high concentrations of ammonium can inhibit the process. Another inhibitor can be the lack of oxygen, but it needs to be less than 1 mg/l of oxygen, and it is very unlikely that this could happen in the experiment.

Then, it can be said as a conclusion that the real nitrification rate in the sand is much slower than the theoretical calculated.

Despite all this, the main point would be that there was a fact which hadn't been taken into consideration, the iron and manganese rests which were in the sand and that interfered in all the measurements. The entire conclusion depends on this, what makes it a critical factor.

1.4.6.Possible improvements

If this experiment has to be done, there would be some things which are to be changed.

- In order to reduce the particles in suspension in the water, the mixing of the water in the last 4 samples was done 5 min before taking the sample. During the mixing of the water, all the particles which had settled in the sand are in suspension again. By giving them some time to settle again, it is possible to reduce the turbidity in the water which will go inside of the cuvette. It could be a good idea to increase the time between mixing the water and taking the sample, being always careful of not mixing it too much time ahead of the sampling moment because then the water wouldn't be representative of the concentration in the filter. If the time between samples is one hour, 10 min before sampling a mixing could be a good idea.
- One way to minimize the turbidity could be making the sampling water to go through a filter paper and therefore, holding the particles in the paper. To do this, it would be necessary then, to take more water.
- For trying to reduce the impact of the iron and manganese rests in the sand, more water could be used. Instead of using 0,2 l sand and 0,2 l water, it could be helpful to use 0,2 l sand and 0,4 l water. However, doing this the oxidation of all the ammonium would be even slower due to the increment of it. This can also be done by adding a dissolution more diluted than the original, but instead of just 0,2 l putting the volume needed to reach the total mass of ammonium which is in the original dissolution.
- Instead of using the kit LCK 304 whose capacity was a bit small, maybe it could be better to dispose of some other materials and for example use the Nessler reactive to analyze ions of ammonium. More details in Optional Part 2 Enclosure.
- In general, it would be great to have some more material to use, such as more testing tubes, glasses, and any tool used to measure volume.
- It would be a good idea to measure the pH of the dissolution over time.
- Measure the temperature should be done at least once during the experiment.

A compilation of pictures taken during the second part of the experiment can be found in the end of the enclosures or in the attached CD-ROM.

General conclusions

- Well protected aquifers. This was checked by 2 different ways, the geological profile and the analysis of the water.
- To provide more water:
  - Restore old well (80.272)
  - New wells next to the (80.352)
  - Investigate new abstraction area
- Water status: quite stable.
- Main contaminants: Fe, Mn, NH4, P, Ar.
- Waterworks work fine.
  - There might be possible bottlenecks in: reaction basin, sand filter and storage tank if the water demand increases (and it is expected to do so). To increase the capacity of the waterworks, a new reaction basin should be built, the 4th filter bed should be open and if the demand is too big, a new storage tank should be planned.
- The simulated network works properly. However the model creator did a quite bad work. There are many mistakes in the model provided.
- Adding extra costumers in the area of Folle doesn't have a negative influence in the whole network.

2. Enclosures

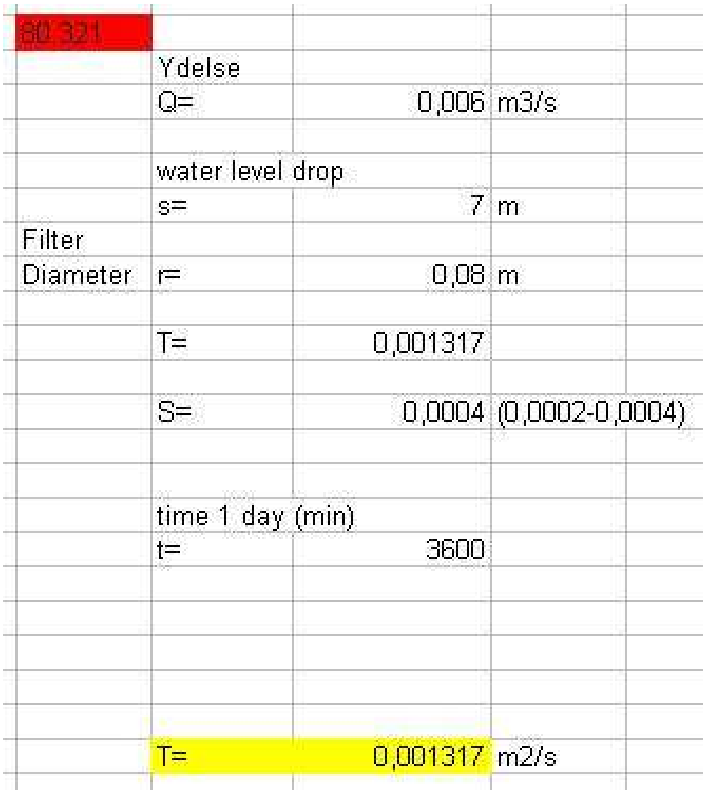
Geology

Transmisivity calculations

Transmissivity was calculated using following formula:

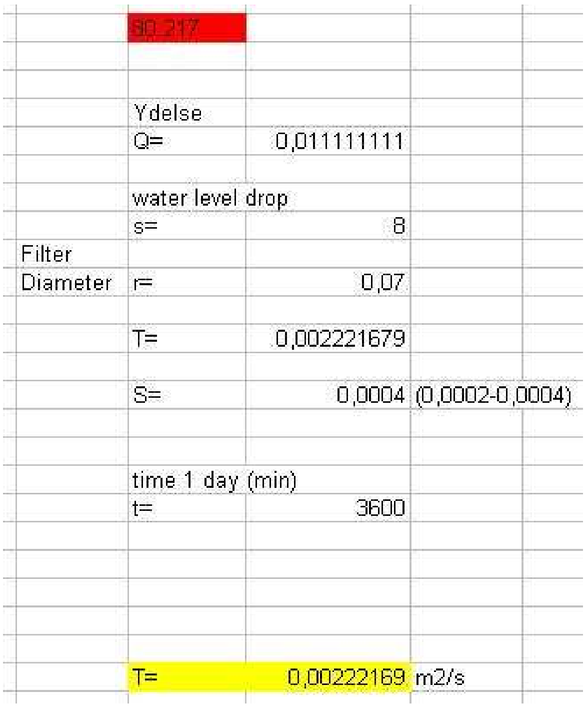
$$T = \frac{0{,}183Q}{s_W} \log \frac{135Tt}{r_W^2 S}$$

Calculation for wells:



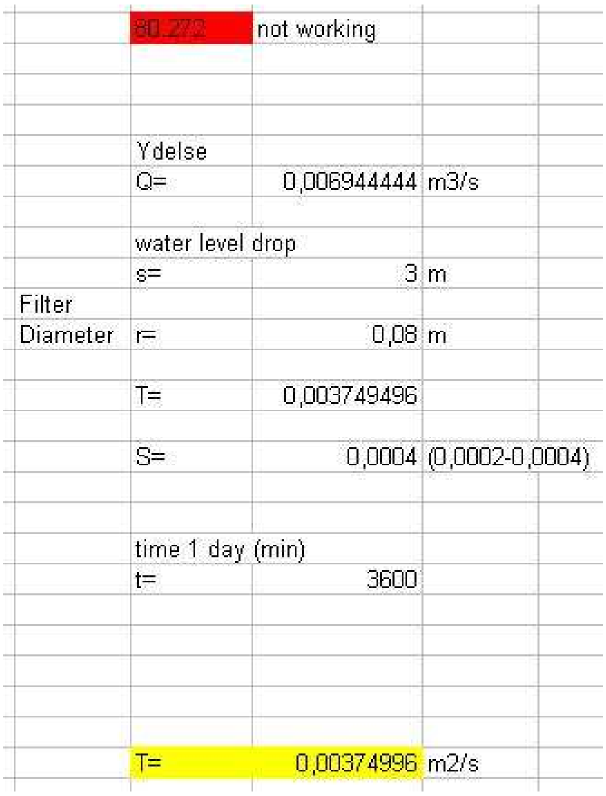
80.321			
	Ydelse		
	Q=	0,006	m3/s
	water level drop		
	s=	7	m
Filter			
Diameter	r=	0,08	m
	T=	0,001317	
	S=	0,0004	(0,0002-0,0004)
	time 1 day (min)		
	t=	3600	
	T=	0,001317	m2/s

figure 1.1 shows the calculation of transmissivity for well 80.321



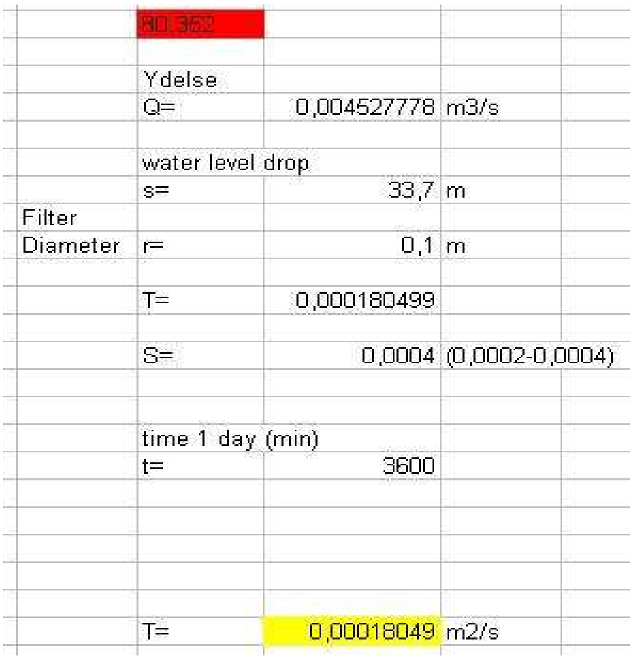
	80.217		
	Ydelse		
	Q=	0,011111111	
	water level drop		
	s=	8	
Filter			
Diameter	r=	0,07	
	T=	0,002221679	
	S=	0,0004	(0,0002-0,0004)
	time 1 day (min)		
	t=	3600	
	T=	0,00222169	m2/s

figure 1.2 shows the calculation of transmissivity for well 80.217



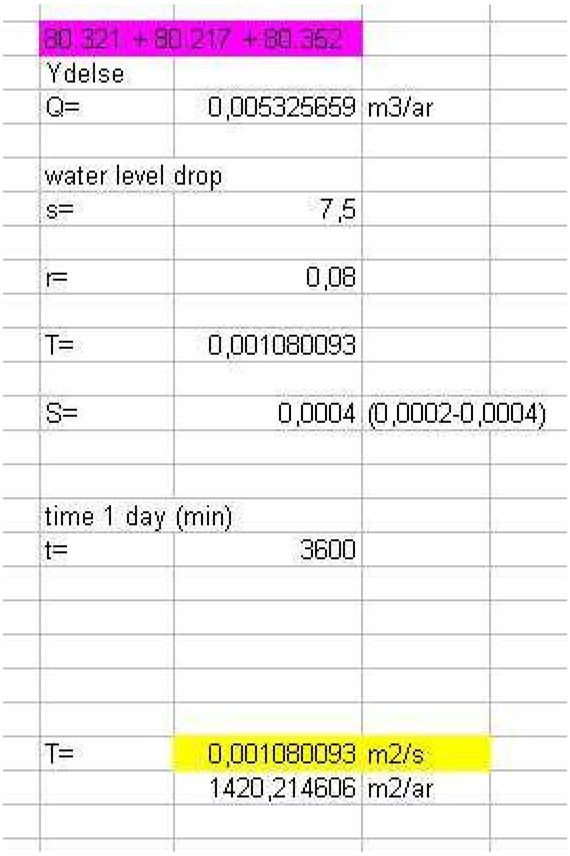
	80.272	not working		
	Ydelse			
	Q=	0,006944444	m3/s	
	water level drop			
	s=	3	m	
Filter				
Diameter	r=	0,08	m	
	T=	0,003749496		
	S=	0,0004	(0,0002-0,0004)	
	time 1 day (min)			
	t=	3600		
	T=	0,00374996	m2/s	

figure 1.3 shows the calculation of transmissivity for well 80.272



	80.352		
	Ydelse		
	Q=	0,004527778	m3/s
	water level drop		
	s=	33,7	m
Filter			
Diameter	r=	0,1	m
	T=	0,000180499	
	S=	0,0004	(0,0002-0,0004)
	time 1 day (min)		
	t=	3600	
	T=	0,00018049	m2/s

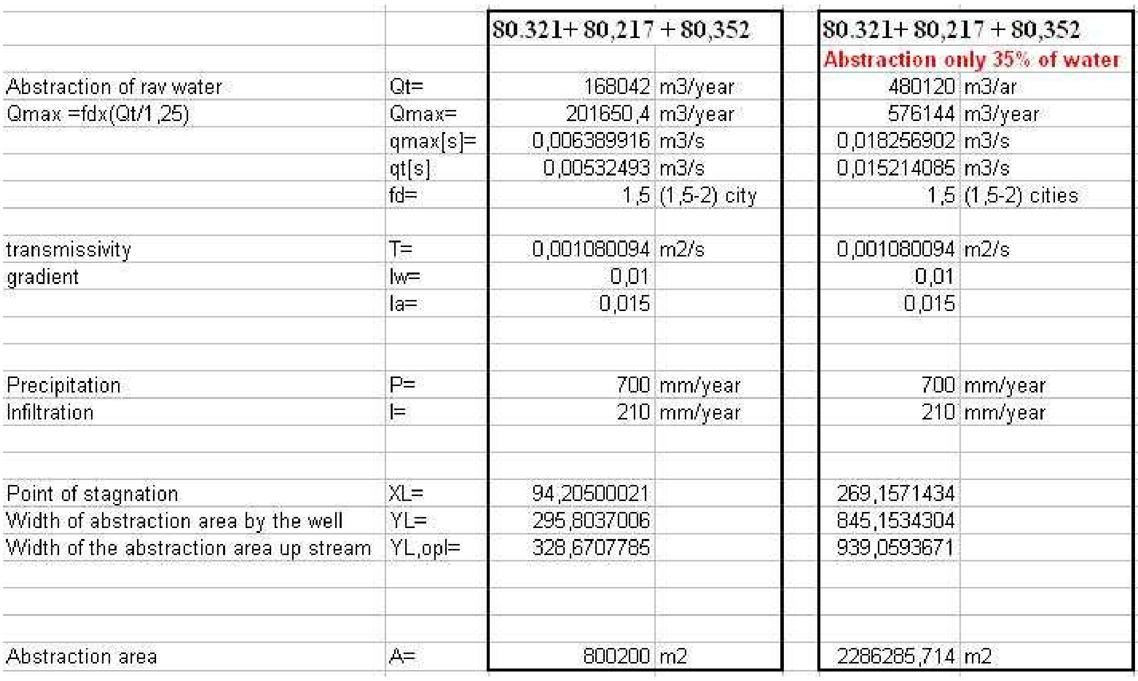
figure 1.4 shows the calculation of transmissivity for well 80.352



80.321 + 80.217 + 80.352		
Ydelse		
Q=	0,005325659	m3/ar
water level drop		
s=	7,5	
r=	0,08	
T=	0,001080093	
S=	0,0004	(0,0002-0,0004)
time 1 day (min)		
t=	3600	
T=	0,001080093	m2/s
	1420,214606	m2/ar

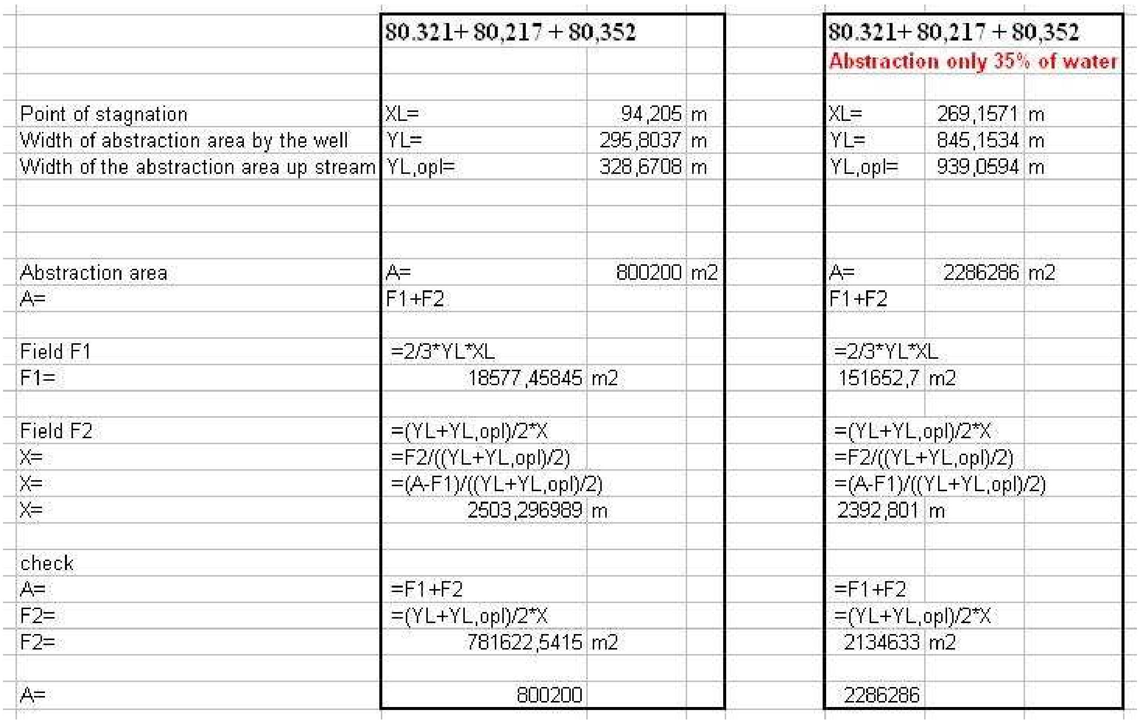
figure 1.5 shows the calculation of summary transmissivity for well 80.352; 80.217; 80.321.

Calculations of Abstraction area



		80.321+ 80,217 + 80,352		80.321+ 80,217 + 80,352	
				Abstraction only 35% of water	
Abstraction of rav water	Qt=	168042	m3/year	480120	m3/ar
Qmax =fdx(Qt/1,25)	Qmax=	201650,4	m3/year	576144	m3/year
	qmax[s]=	0,006389916	m3/s	0,018256902	m3/s
	qt[s]	0,00532493	m3/s	0,015214085	m3/s
	fd=	1,5	(1,5-2) city	1,5	(1,5-2) cities
transmissivity	T=	0,001080094	m2/s	0,001080094	m2/s
gradient	Iw=	0,01		0,01	
	Ia=	0,015		0,015	
Precipitation	P=	700	mm/year	700	mm/year
Infiltration	I=	210	mm/year	210	mm/year
Point of stagnation	XL=	94,20500021		269,1571434	
Width of abstraction area by the well	YL=	295,8037006		845,1534304	
Width of the abstraction area up stream	YL,opl=	328,6707785		939,0593671	
Abstraction area	A=	800200	m2	2286285,714	m2

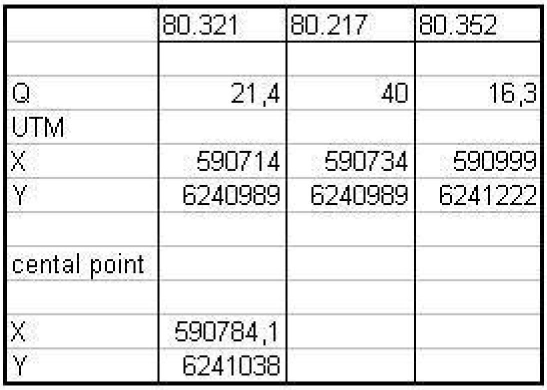
Figure 1.6 shows the calculations of dimensions of abstraction area.



	80.321+ 80,217 + 80,352			80.321+ 80,217 + 80,352 Abstraction only 35% of water		
Point of stagnation	XL=	94,205	m	XL=	269,1571	m
Width of abstraction area by the well	YL=	295,8037	m	YL=	845,1534	m
Width of the abstraction area up stream	YL,opl=	328,6708	m	YL,opl=	939,0594	m
Abstraction area	A=	800200	m2	A=	2286286	m2
A=	F1+F2			F1+F2		
Field F1	=2/3*YL*XL			=2/3*YL*XL		
F1=	18577,45845	m2		151652,7	m2	
Field F2	=(YL+YL,opl)/2*X			=(YL+YL,opl)/2*X		
X=	=F2/((YL+YL,opl)/2)			=F2/((YL+YL,opl)/2)		
X=	=(A-F1)/((YL+YL,opl)/2)			=(A-F1)/((YL+YL,opl)/2)		
X=	2503,296989	m		2392,801	m	
check						
A=	=F1+F2			=F1+F2		
F2=	=(YL+YL,opl)/2*X			=(YL+YL,opl)/2*X		
F2=	781622,5415	m2		2134633	m2	
A=	800200			2286286		

Figure 1.7 shows the calculation of length of abstraction area.

Resultant of wells location.



	80.321	80.217	80.352
Q	21,4	40	16,3
UTM			
X	590714	590734	590999
Y	6240989	6240989	6241222
cental point			
X	590784,1		
Y	6241038		

Figure 1.8 shows the calculation of resultant point of wells location.

Intake wells enclosure

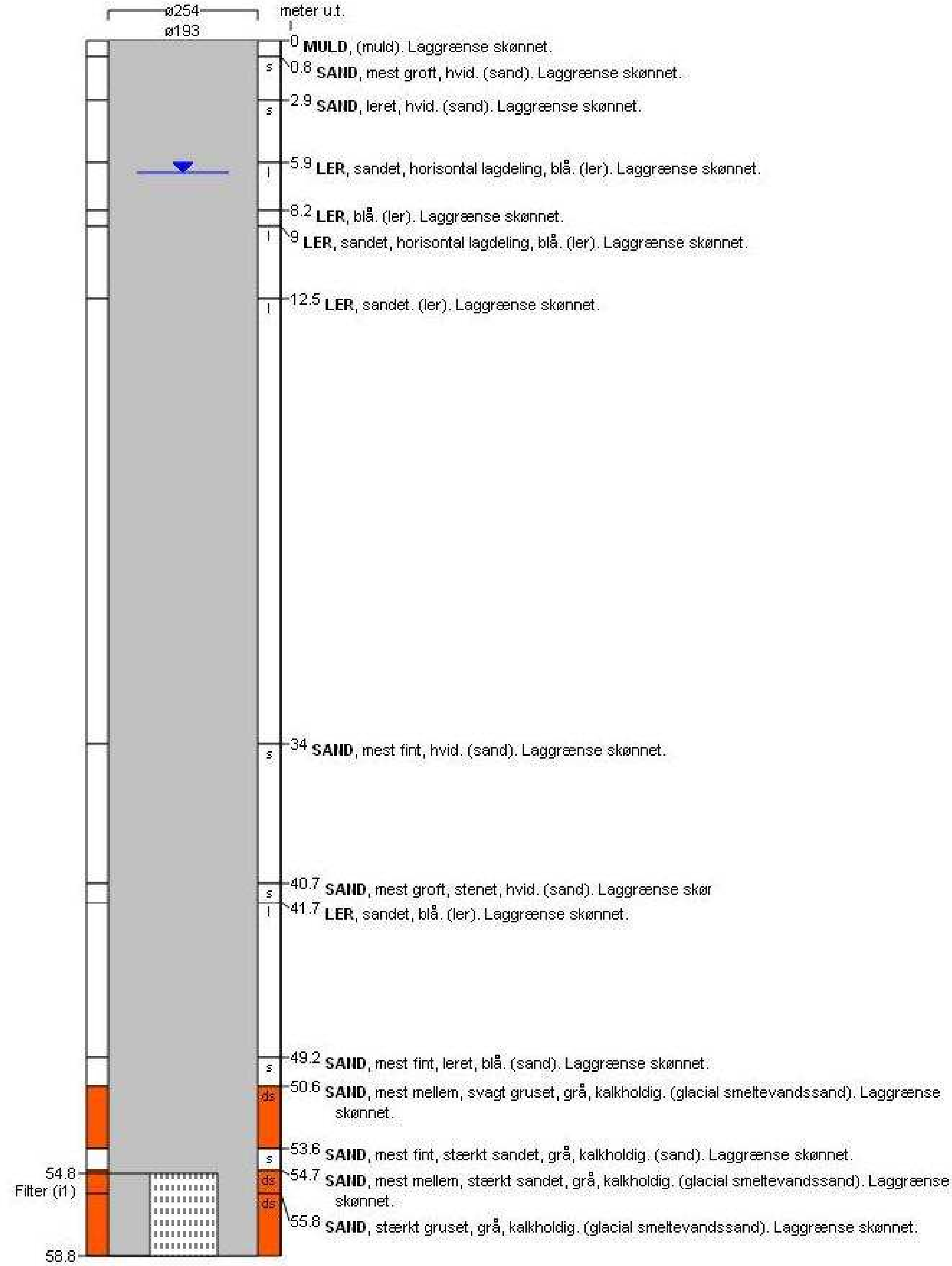


figure 2.6 shows the construction of the well 80.217, and geological profile.

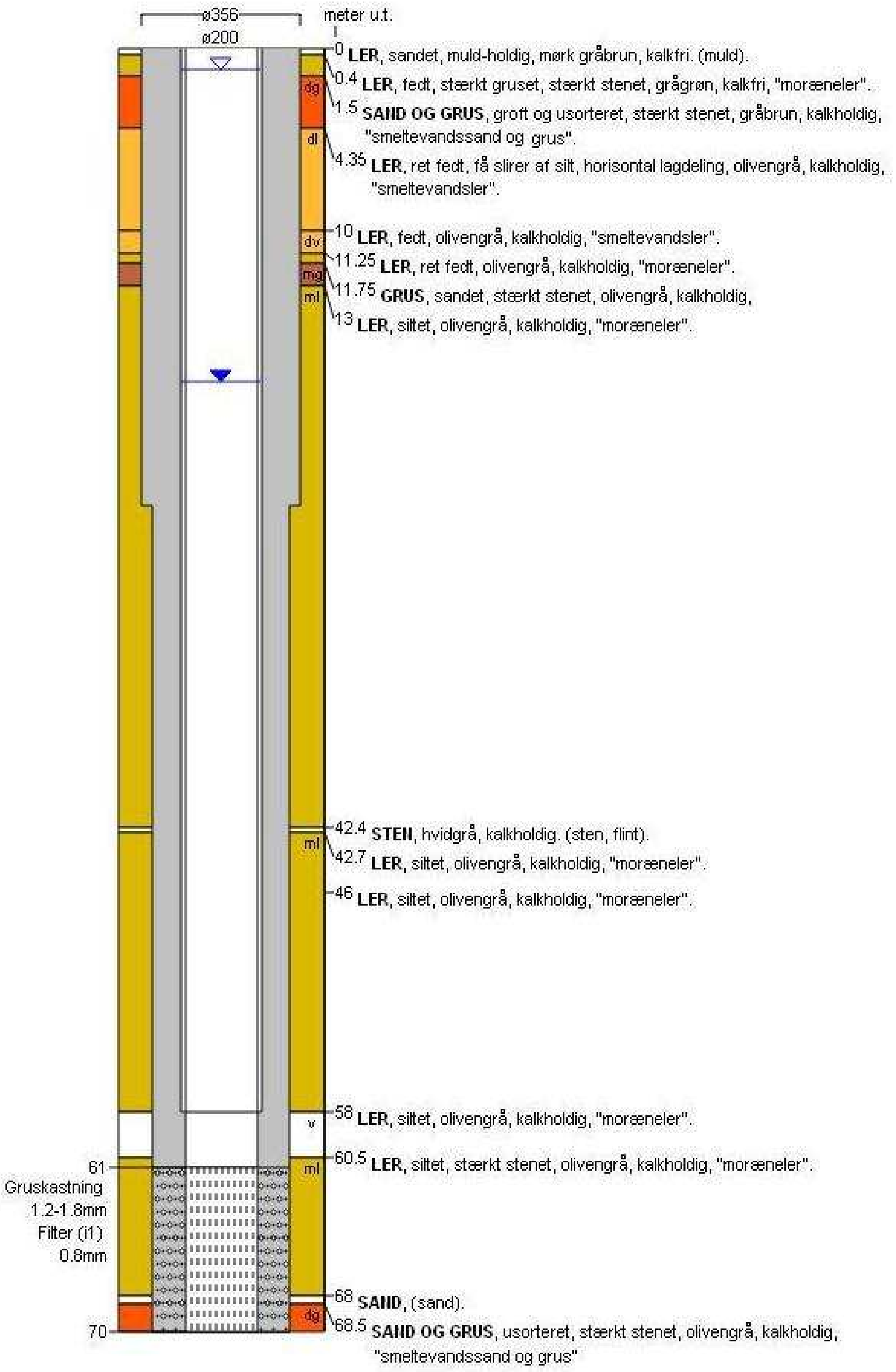


figure 2.8 shows the construction of the well 80.352, and geological profile

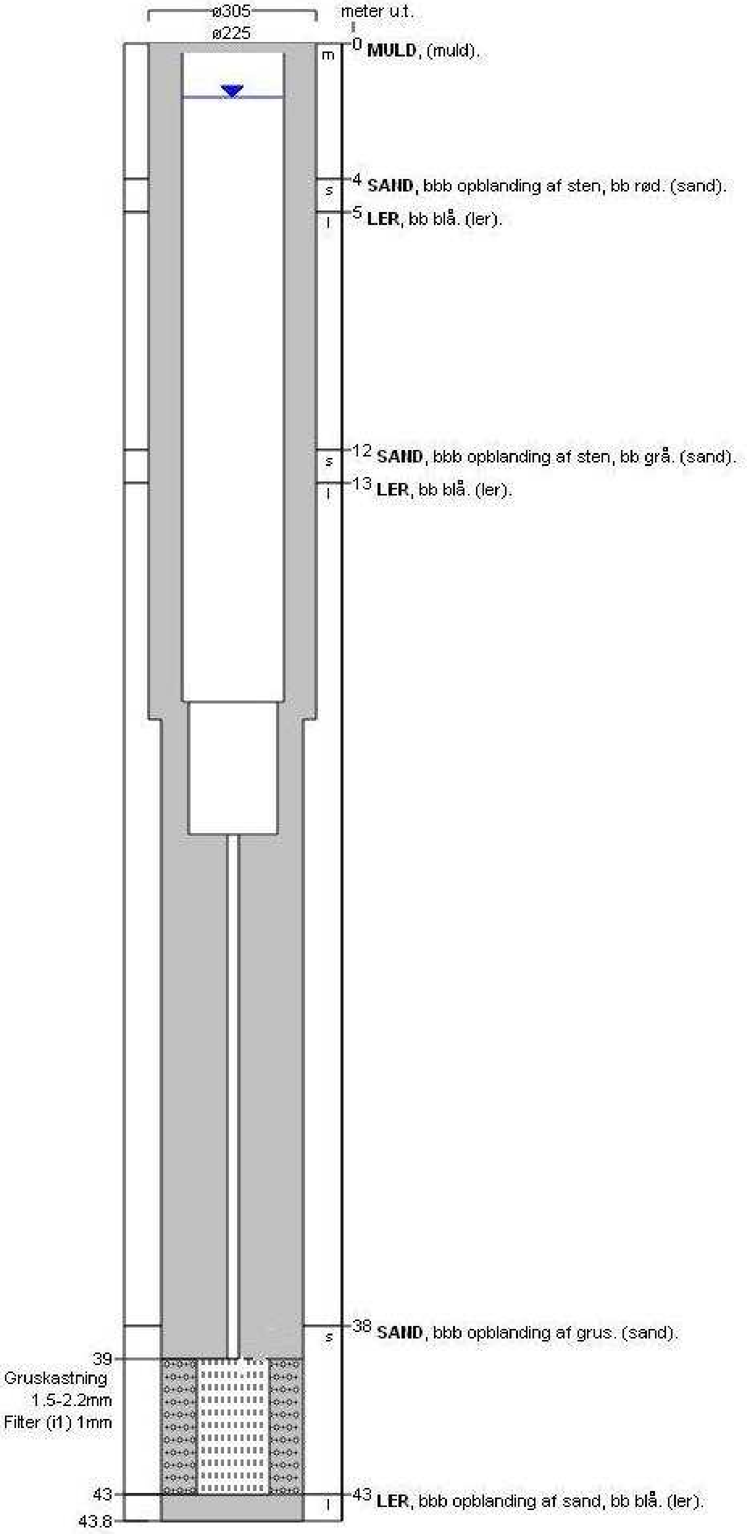


figure 2.10 shows the construction of the well 80.321, and geological profile.

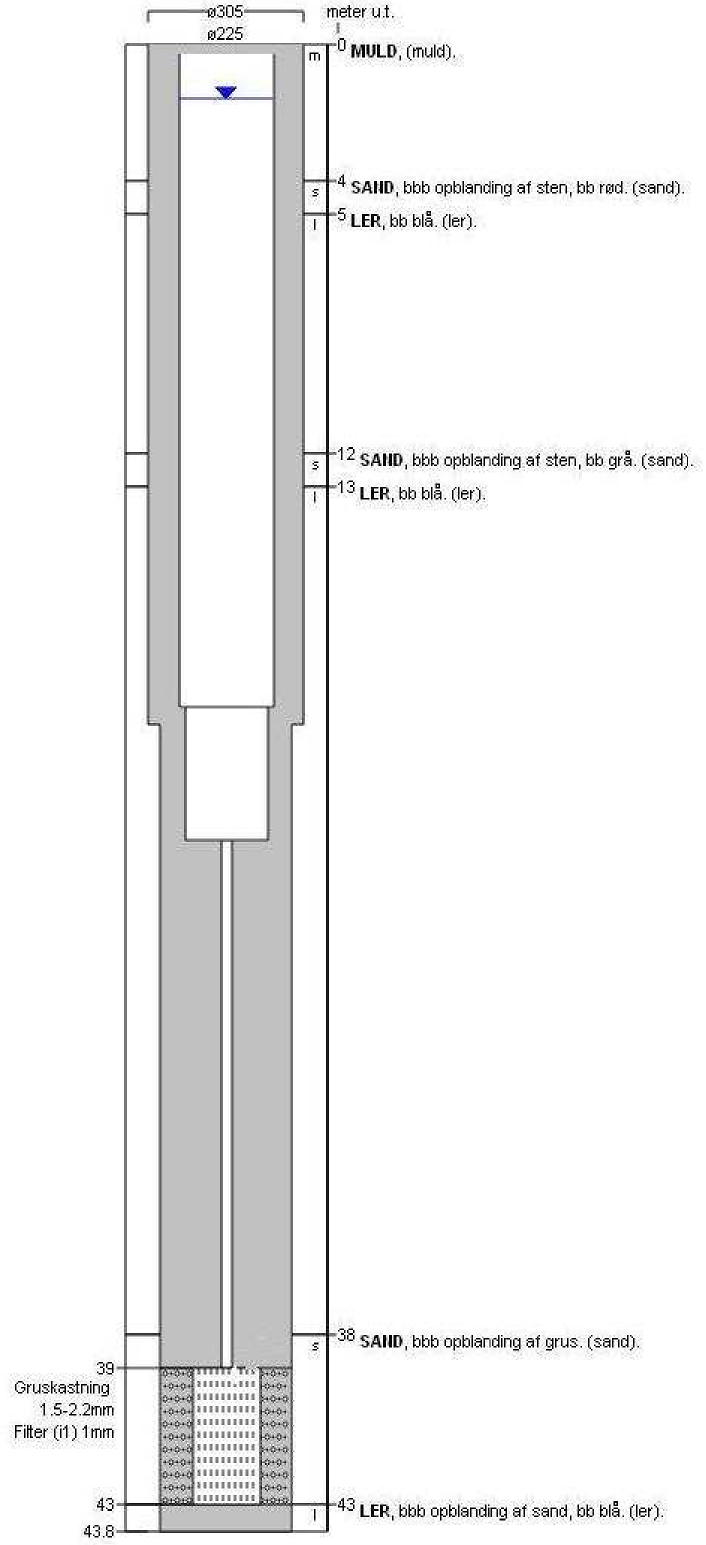


figure 2.3 shows the construction of the well 80.321, and geological profile .

Water chemistry

Evaluation of Water Quality

1. Comparison of Parameters

WATER QUALITY PARAMETERS

		WELL FIELD 1			***WELL FIELD 2***	***Units***	***Danish Water***
WELL NO.		**80.217**	**80.272**	**80.321**	**80.352**		**Criteria**
	DATE	**2009**	**1996**	**2009**	**2009**		
CONDITION PARAMETERS	**Symbol**						
Conductivity		84	83,2	110	95	mS/m	30
pH		7 ,7	7,6	7, 6	7 ,6	pH units	-
Temperature	**T**	9 ,3	---	9.1	9, 8	ºC	-
CHEMICAL MAIN COMPONENTS							
Ammonium	**NH3+NH4**	0,68	0,73	0,78	0,64	mg/l	0,05
Calcium	**Ca**	70	57	72	62	mg/l	-
Carbondioxid,Aggr.	**CO2**	< 2	<2	< 2	< 2	mg/l	2,00
Carbon,org. NVOC	**NVOC**	1,2	1,2	1,5	1,5	mg C/l	4,00
Chloride	**Cl**	93	90	150	120	mg/l	250,00
Fluoride	**F**	0,9	1	1,1	1,4	mg/l	1,50
Hydrogen Carbonate	**HCO3**	323	320	344	352	mg/l	-
Evaporation	**E**	480	490	610	540	mg/l	-
Iron	**Fe**	2	1,7	2,1	1,1	mg/l	0,20
Potassium	**K**	4,2	4,7	4,8	5	mg/l	10,00
Magnesium	**Mg**	12	12	13	13	mg/l	50,00
Manganese	**Mn**	0,12	0,1	0,11	0,061	mg/l	0,05
Sodium	**Na**	92	100	130	120	mg/l	175,00
Nitrate	**NO3**	<0.5	< 0,5	< 0,5	< 0,5	mg/l	50,00
Nitrite	**NO2**	<.005	0.012	< 0.005	< 0.005	mg/l	0,10
Oxygen Content	**O2**	< 0,1	1,10	< 0,1	< 0,1	mg/l	5,00
Total-P	**P**	0,18	0,12	0,19	0,054	mg/l	0,15
Sulphate	**SO4**	23	24	23	20	mg/l	250,00
INORGANIC TRACE ELEMENTS							
Arsenic	**Ar**	0,4	---	5,7	2,50	µg/l	5,00

Barium	**Ba**	74	---	110	58	µg/l	700,00
Bor	**B**	430	---	590	610	µg/l	1000,00
Nickel	**Ni**	1,6	< 2	0,18	0,36	µg/l	20,00
PARAMETERS							
Ion Exchange **(I)**	I	1,53	1,72	1,34	1,54	-	
Degree of Weathering ***(F)***	F	0,85	0,73	0,83	0,36	-	
Hardness ***(dH)*** ***Middle***	dH	12,54	10,8	12,82	11,65		
Conductivity		84	83,2	110	95	mS/m	
Organic Matter	NVOC	1,4	1,2	1,5	1,5	mg/l	
Pyrite Oxidation		None	None	None	None	-	
Calcite Saturation Index ***(logSI)***	log SI	0,65	0,46	0,59	0,54	-	
Sulphate Reduction		Yes	Yes	Yes	Yes	-	
Acid/Base Water Type		Buffered	Buffered	Buffered	Buffered	-	
Redox Conditions		D	D	D	D	-	
Ion Balance	**CATIONS**	8,59	8,3	11,08	9,51	meq/l	
	ANIONS	8,39	8,28	10,11	9,57	meq/l	
	%	2,36	0,24	9,16	-0,63	meq/l	

Theoretical Oxygen Demand			**80.217**	**80.272**	**80.321**	**80.352**
PARAMETERS (SUBTANCES)	**Concentration**	**ThOD**	**Oxygen Requirement**	**Oxygen Requirement**	**Oxygen Requirement**	**Oxygen Requirement**
Units	*mg/L*	*mg O2*	*mg O2/L*	*mg O2/L*	mg O2/L	*mg O2/L*
Iron	2	0,14	0,28	0,238	0,294	0,154
Manganese	0,12	0,29	0,0348	0,029	0,0319	0,01769
Ammonium	0,68	3,60	2,448	2,628	2,808	2,304
Methane	0	4	0	0	0	0
Hydrogen Sulphide	0	0,51	0	0	0	0
Oxygen (Residual)	---	---	5,50	5,50	5,5	5,5
Total Oxygen Reguirement	---	---	**8,26**	**8,40**	**8,6339**	**7,97569**

Figure: Chart of the comparison of Parameters

Variations of Elements

NH_4 (Ammonium)

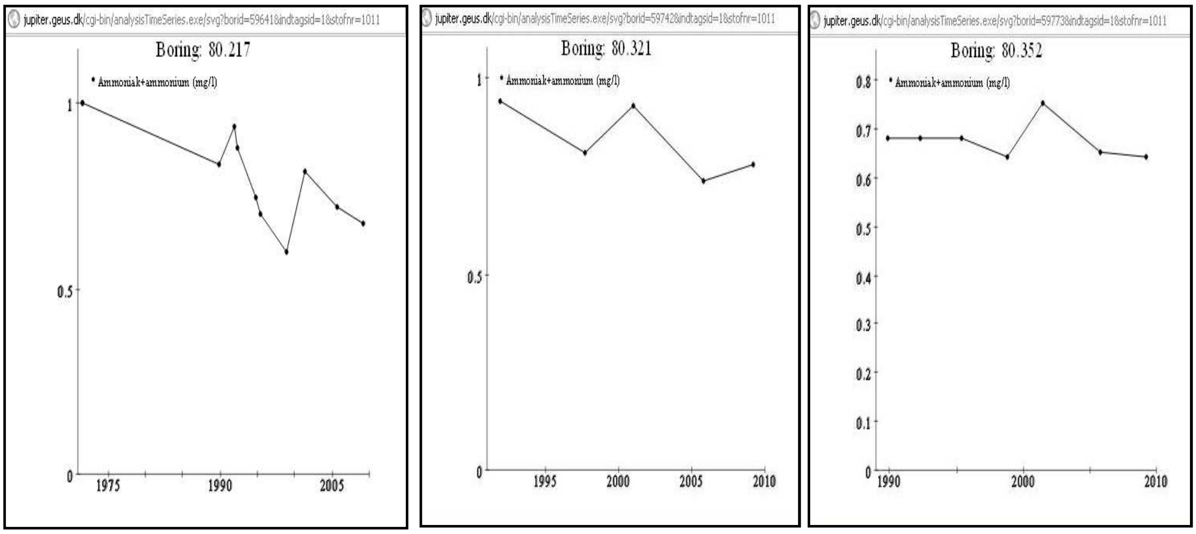


Figure: Variation of Ammonium

Generally, changings are resembling each other. They are making pick at the same time.

Fe (Iron)

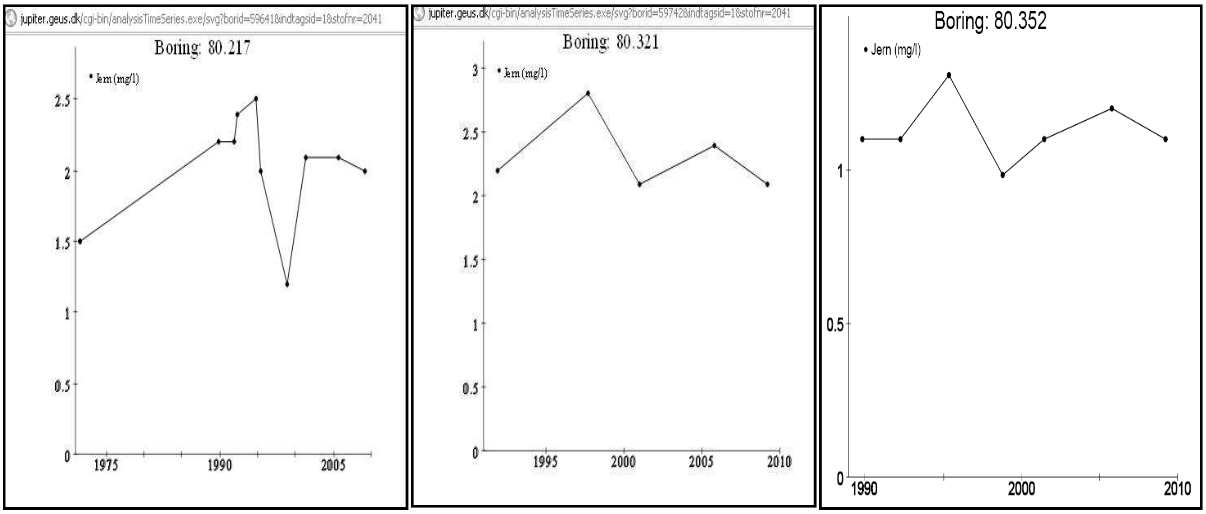


Figure: Variation of Iron

Results are unstable for 80.217 but it is not too high. For other wells, variations are watching same way but values are different.

P (phosphorus)

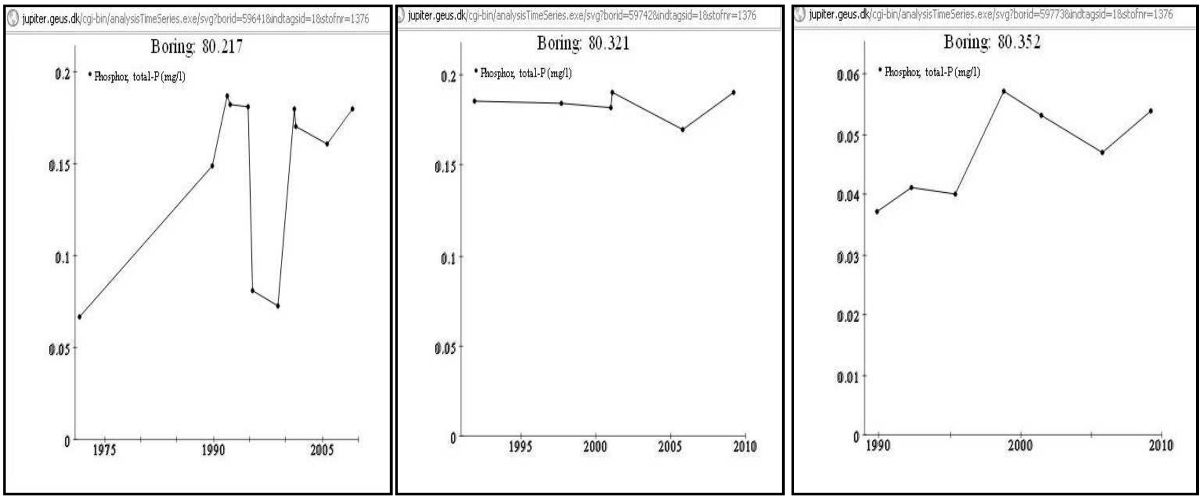


Figure: Variation of phosphorus

For phosphorus, wells of 80.217 and 80.352 results are very close to the limit. (0,2- Danish water criteria). Also, for 80.321, results are low and stable.

Mn (Manganese)

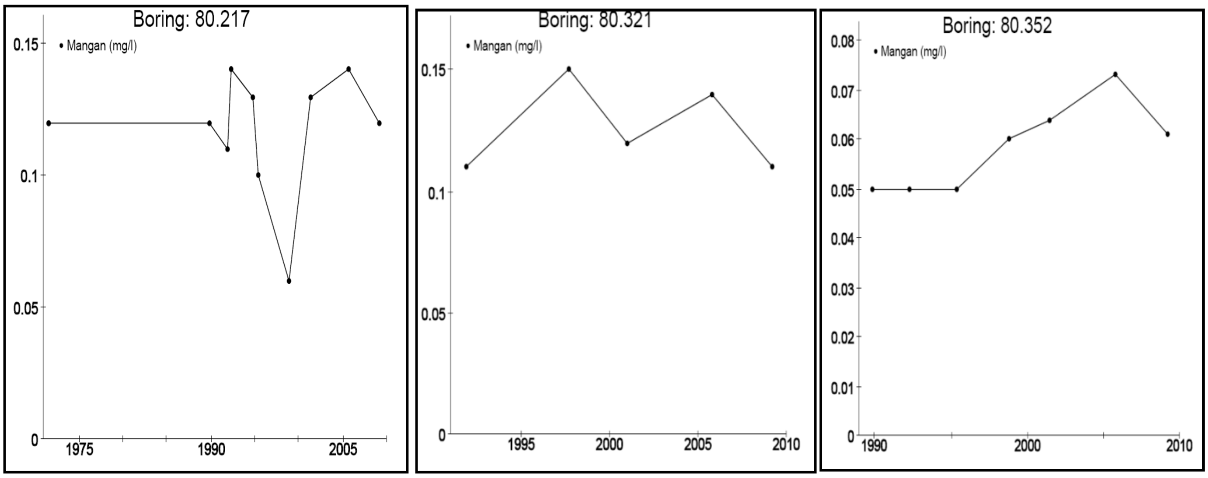


Figure: Variation of Manganese

80.217 and 80.321 are close to limit also little above criteria.

80.352 is under the limits.

Ar (Arsenic)

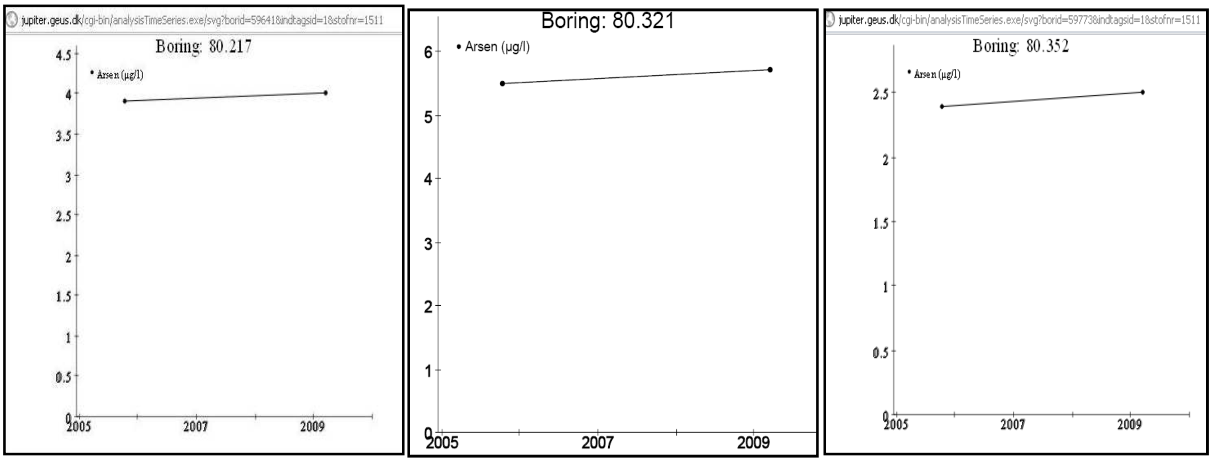


Figure: Variation of Arsenic

For arsenic, limit is 5 for Danish drinking criteria. 80.217 and 80.352 are under the limit but they are almost increasing year to year. Also, 80.321 is over limit and it is increasing. It is necessary to know that why it is increasing.

This element is occurring very important health disease so that it has be controlled. Additionally, it is mentioned in the mandatory part.

Conclusion

Generally, results are showing a stable case, but some section increases requires control.

2. Processes in Groundwater

The quality of groundwater is the result of processes in which gasses, dissolved constituents and solids react with one another. Some of groundwater processes:

1. Ion Exchange
2. Pyrite Oxidation
3. Dissolution of Minerals
4. Sulphate Reduction

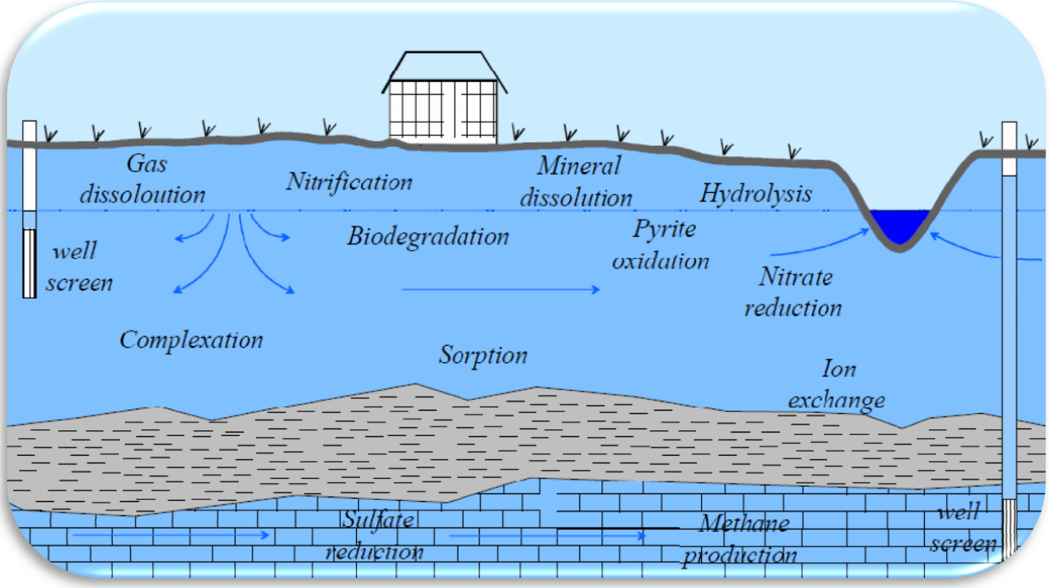


Figure: Processes in groundwater

2.1 Ion Exchange Process

This process depends on changing of ions with occurring softer water. It means that ,it is very useful treatment method for removing very hard water in areas.

Principle:

Water is passed through the column with an exchanger, which is including salt (sodium ions) and calcium ions are changing with sodium. Finally, calcium is removed from the water and water is becoming soften. (Figure)

Ion exchange is a reversible process, so that water softeners can be recharged with sodium ions as a result of saltwater intrusion Especially, this case may occur near a coastline.

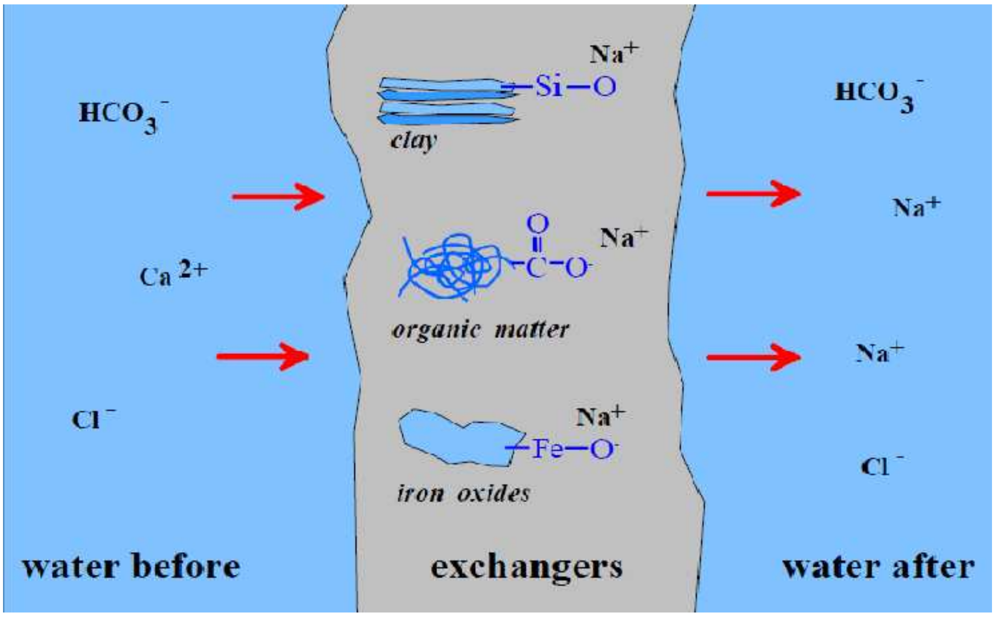


Figure: Visualisation of ion exchange process

Aquifer solids are changeable in their cation exchange capacities (**CEC**). This capacity is caused by negative charges on the surface of the solids. Aquifers has largest area capacity and high density of charges for this reason, they have the largest ion capacities. Clay minerals have large capacities, but most other aquifer solids have a very low CEC. Organic matter is a very important ion exchanger in top soil and for deeper levels, clay mineral solids are significant.

As we can see that the affinity rankings below. It is about that which compound is easily replaced. For example, according to ranking, sodium is replaced by calcium easily.

$$Al^{3+} > Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$$

Ion exchange ratio, **I**, is the another way for determining of ion exchange in aquifers. It can be related with hardness.

2.2 Pyrite Oxidation

Pyrite is an iron sulphate mineral with formula FeS_2. Pyrite oxidation is a process in which the mineral pyrite is oxidized usually by oxygen or by nitrate. This changing is happening in groundwater.

A great advantage of pyrite oxidation is removing of nitrate to nitrogen gas and it is perfect way for removing it from aquifer. Even, a small amount of pyrite is sufficient to protect an aquifer from many years of nitrate draining from agriculture practices.

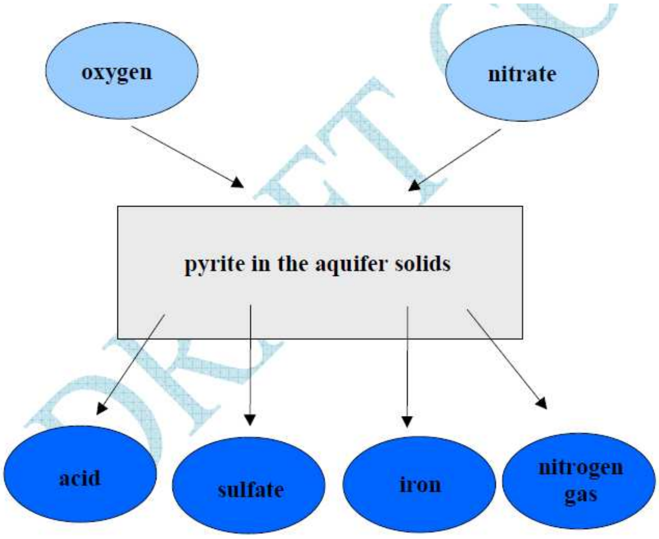


Figure: Processing of Pyrite Oxidation

3. Parameters

3.1 Hardness

Hardness consist of divalent ions ,like Ca ,Mg , Sr ,Fe , Mn … and some anions must be present corresponds to cations in water. Anions are HCO_3, Cl, NO_3 and SiO_3. Generally, hardness is occured due to contact with rock and soil.

To the consumer, hardness is one of the easiest water parameters to perceive. It can be checked by the amount of foam created once the soap is added to the water or by the quantity of detergent needed to wash cloths. In soft water, it is difficult to rinse off soap completely when bathing or washing. In hard water, there won't be a big quantity of foam, more laundry detergent must be used when washing clothes to get the clothes clean. The explanation for all this is that the detergent and soap is a chemical composed of a long chain made of hydrocarbons and a carboxyl group which is electric charged.

The divalent cations such as Mg^{+2}, Ca^{+2} react with the long chain making salts which are insoluble in water, this way, soaps and detergents precipitate as insoluble salts without producing foam and losing some of washing power.

Besides this problem, a soft water has other advantages like:

- Hair and skin softer after having a shower
- Less detergent is needed to do the laundry
- Less settling of minerals in pipes, water heaters, pots, pans etc.
- No water spots in plates, glasses using air drying.

False (pseudo) Hardness: Known that salt waters are not bubbling like hard waters. So that, we think a salt water as a hard water. This case is taken place because of the common ion effect of sodium.

3.2 Acid/Base Water Types

This type is depending on pH, groundwater may be considered acidified, aggressive, buffered or alkaline. All the wells are showing type of buffered.

Buffered: In this type, pH is nearly neutral and is buffered by minerals such as calcite against any acids that may be present in the filtrating water. If there is calcite in the soil layers, the acid may be neutralized. . This prevents the lowering of the pH and increases the concentration of calcium and hydrogen carbonate in the water, since the calcium carbonate dissolves. In time, the buffer may be used up, and the aquifer material loses its buffer capacity.

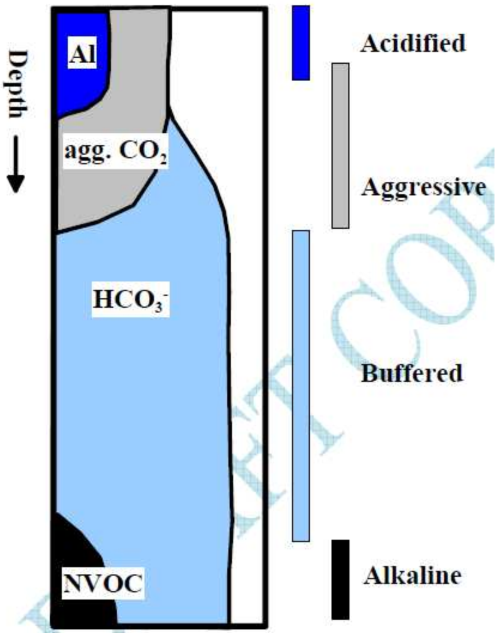


Figure: Depth profile of Acid/Base parameters in groundwate

3.3 Redox Water Types

Groundwater is divided into 4 categories which are strongly oxidized, weakly oxidized, weakly reduced and strongly reduced .This types are depending on which redox-active parameters are present. We can see these parameters in the figure**.**

Rain water drains into the ground and takes part in redox reactions. Oxygen is the first oxidant to be depleted. Secondly, NO_3^- is the one of the parameters. The other parameters are sulphate, iron, manganese, ammonium, hydrogen sulphate and methane.

If any groundwater process including the conversion of one or more of these redox-active parameters may be considered a redox reaction.

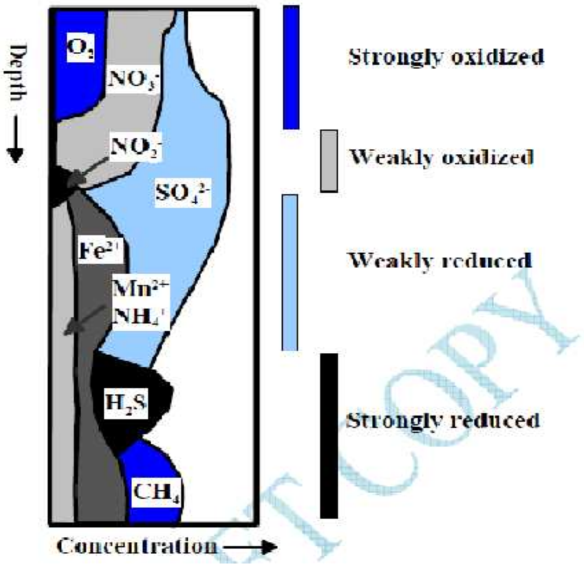


Figure: Depth profile of redox active parameters

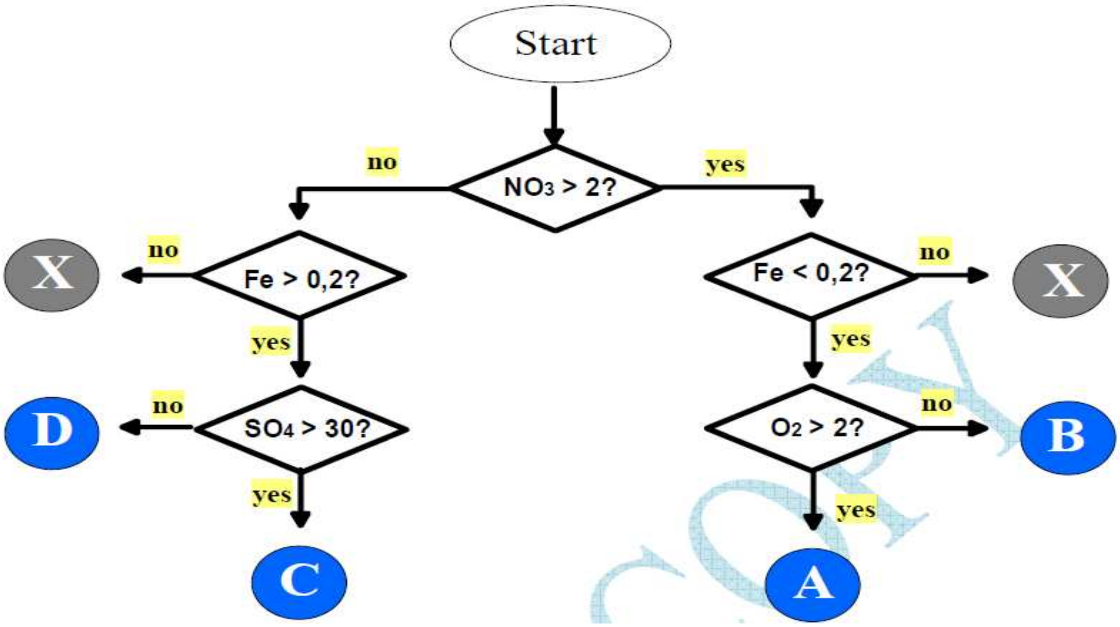


Figure: Algorithm for redox water type determination (conc. in mg/l).

According to results, all the wells' type of **D** (Strongly Reduced) this correspond to sulphate reduction. Also, we can understand from depth profile that hydrogen sulphate and methane may be present.

3.4 Conductivity

It is measured for learning ability of the ions in water to transport electrical charge. Therefore, It is very useful parameter for giving a first impression of how salty the water is

4. CALCULATIONS

- **DEGREE OF ION EXCHANGE**

$$\boxed{I = \frac{\frac{Na}{23.0}}{\frac{Cl}{35.5}} = 1.54 \cdot \frac{Na}{Cl}}$$

- **Results:**

WELL NO.	**80.217**	**80.272**	**80.321**	**80.352**
Ion Exchange	1,53	1,72	1,34	1,54
Type	Ion Exchange	Ion Exchange	Ion Exchange	Ion Exchange

Interval	**Category**
<0.6	Reversed ion exchange
0.6-0.9	No ion exchange
0.9-2.0	Ion exchange
>2.0	Strong ion exchange

Figure: Category of ion exchange

- **DEGREE OF WEATHERING**

$$\boxed{F = \frac{2 \cdot \left(\frac{Ca}{40.1} + \frac{Mg}{24.3}\right)}{\frac{HCO_3}{61.0}}}$$

- **Results**

WELL NO.	**80.217**	**80.272**	**80.321**	**80.352**
Weathering	0,85	0,73	0,83	0,36

Interval	**Category**
< 1.0	None
1.0 – 1.3	Typical
1.3 – 3.5	Pyrite oxidation
>3.5	Extreme pyrite oxidation

Figure: Pyrite oxidation according to value of F

HARDNESS

$$dH = \frac{1dH}{10mg/l\_CaO} \cdot \frac{56mgCaO}{mmolCa} \cdot \left(\frac{Ca}{40,1mg/mmol} + \frac{Mg}{24,3mg/mmol}\right)$$

- **Results:**

WELL NO.	**80.217**	**80.272**	**80.321**	**80.352**
Hardness	12,54	10,8	12,82	11,65

Interval	Category
0-8	**Soft**
8-18	**Middle**
18-32	**Hard**
>32	**Very hard**

Figure: Categories of hardness

CALCITE SATURATION INDEX

$$LogSI = pH - 11.4 + \log(Ca^{2+} \cdot HCO_3^-)$$

- **Results**

WELL NO.	**80.217**	**80.272**	**80.321**	**80.352**
Log SI	0,65	0,46	0,59	0,54

- **ION BALANCE**

The charge balance deviation =

$$\frac{\text{cations} - \Sigma\text{anions}}{½*(\Sigma\text{cations} + \Sigma\text{anions})} * 100\%$$

According to formula, if result is lower than 5, it means that the calculation indicates somewhat inaccurate results.

- **Results:**

%	2,36	0,24	9,16	-0,63	meq/l

***** % = The charge balance deviation

- **Conductivity**

Interval	Value (mS/m)
Low salt content	< 30
Typical	30-130
Elevated salt content	>130

Figure: Categories of conductivity

- **Organic Matter**

Interval	Value (mg C/L)
low	**<1**
Typical	**1-4**
Elevated	**4-10**
Brown water	**>10**

Figure: Categories of organic matter

- **pH Conditions**

Acid/Base Water Type	Value (pH Units)
Acidic	<4.5
Aggressive	4.5-7.0
Buffered	7.0-8.5
Alkaline	>8.5

Figure: Categories of pH conditions

Fluoride (F)

Chemistry

Fluoride is a halogen, defined as corrosive, pale greenish-yellow gaseous chemical element, the most reactive non-metallic element known, forming fluorides with almost all the know elements, organic and inorganic.

Health Effects

Dental fluorosis appears in a very small percentage when fluoride in drinking water is in the range of 1 -2 mg/l

Long term intake of fluoride in concentrations higher than 4 mg/l may cause asymptomatic osteosclerosis in a small percentage of persons.

Crippling fluorosis has been detected in individuals exposed to fluoride levels from 10-40 mg/L

No carcinogenicity or other adverse effects have been detected.

WATER CONSUMPTION

1. Description

Water consumption is basically the use of water in any form for any reason. It used in irrigation, cleaning, cooking and some cases...etc.

There is two ways for consumption. One of them is in-stream use; this includes hydroelectric power, boating and swimming like that. For example; if there is no in-stream activities don't use up the water. It is possible to degrade the water quality through pollution.

The second one is the withdrawal of water, which is valid for us in this project. Also, it is including:

- *Household Use*
- *Industry Use*
- *Consumption in institutions*
- *Additional consumption (backwash, leakage/pipe burst, fire fighting, pipe flushing ,cleaning)*
- *Irrigation*
- *Nuclear Power*

The amount of water that is taken (or withdrawn) from the source is called the water intake, and the amount that is returned is called the water discharge. The difference between the water intake and the water discharge is the amount consumed.

- ***Consumption*** *= Water intake – Water discharge*

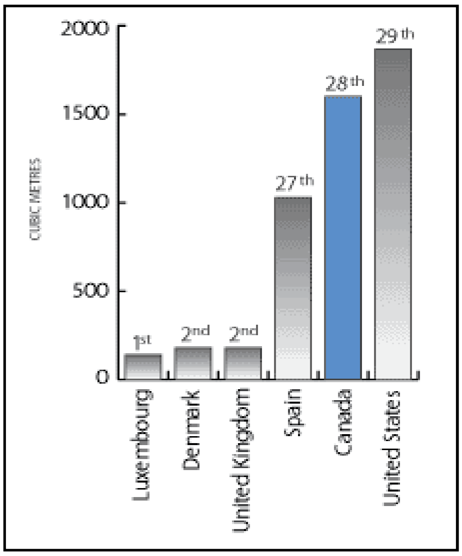
The total amount of water that is used is called the gross water use. The difference between the gross water use and the water intake is equal to the amount of water that is recirculated. The recirculated amount is expressed as a recycling rate and is a good indicator of water efficiency.

- ***Amount recirculated*** = Gross water use – Water intake

What is the cause of high level of water consumption?

That is why environmental and economic problems. About environmental, which is occurring because of high consumption places stress on rivers, lakes and groundwater aquifers and may require dams and flooding with serious ecological impacts. On the economic side, high-level of consumption requires increasing expensive systems.

These systems are like dams, reservoirs, water treatment facilities, distribution networks and sewage treatment.



According to chart, Denmark uses very less water than other countries per person. Also, other information is that water use is increasing some other OECD countries (Canada25.7 %, United States, Japan and Mexico) but, Denmark was able to decrease overall water use since 1980. (these researches from // environmentalindicators.com)

Figure: Freshwater abstractions per

Capita in cubic meters

2. Type of Consumptions and Charts

2.1 Data, Households

It means that water consumption in buildings primarily used for housing. Also, minor industries or minor institutions can be accepted in this group.

There is 2 types of household consumption is available**:** **1. Personal Consumption**

2.

General Consumption

1. Personal Consumption: It is including drinking, cooking, hygiene, cleaning, watering)

2. General Consumption: It is including in offices, shops, minor industries)

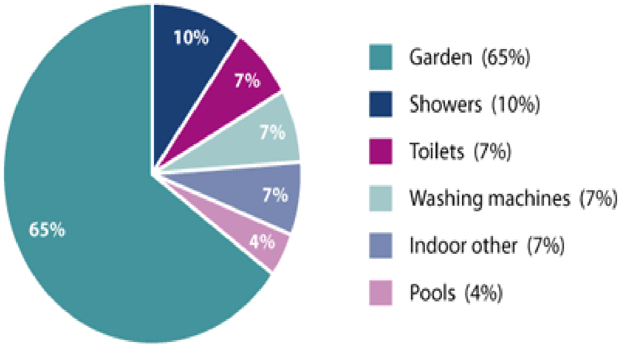
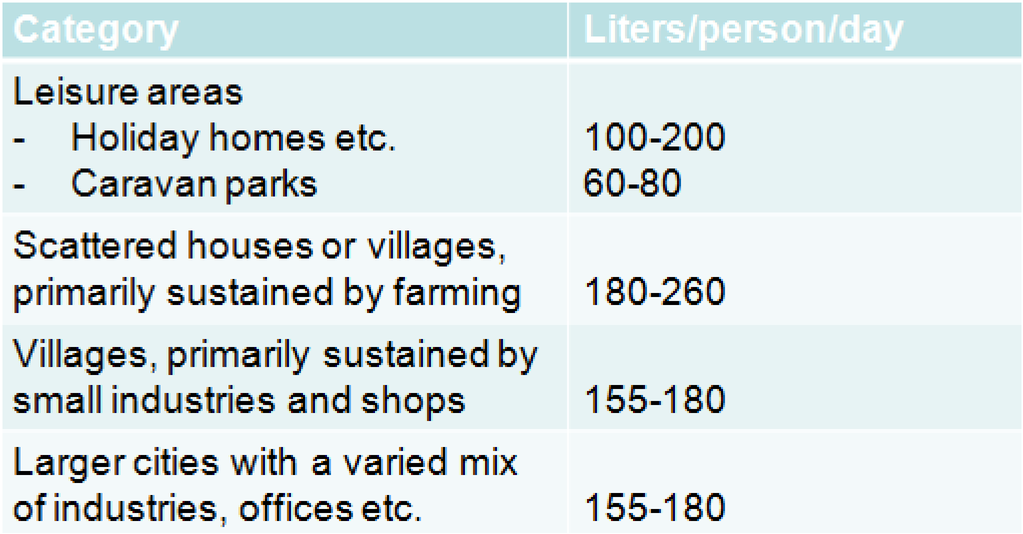


Figure: An example of single household

Personal and general consumption between 2.0 – 2.7 person per house (Danish Norm Values)



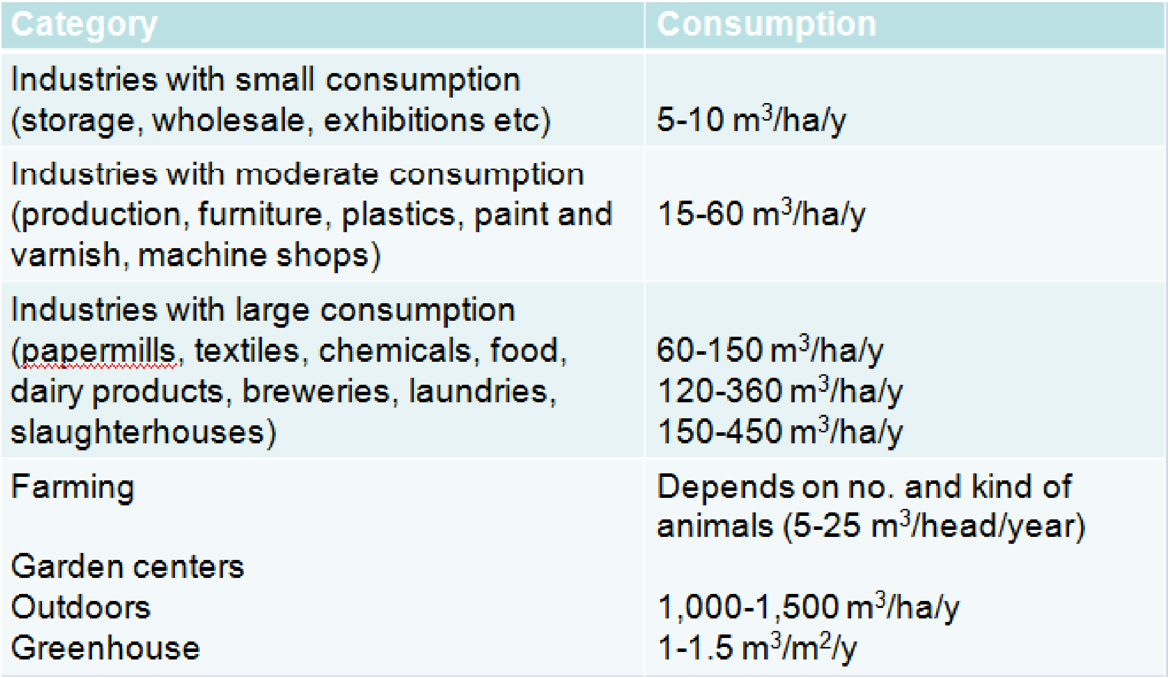
Category	Liters/person/day
Leisure areas - Holiday homes etc. - Caravan parks	 100-200 60-80
Scattered houses or villages, primarily sustained by farming	180-260
Villages, primarily sustained by small industries and shops	155-180
Larger cities with a varied mix of industries, offices etc.	155-180

Figure: Data for Household

2.2 Data, industries (norm values)

In this type, water consumption in buildings that primarily is used for business and industry.

Consumption may be changeable business to business, even though in the same line of production. Single households in an industry building may therefore count as industry consumption.

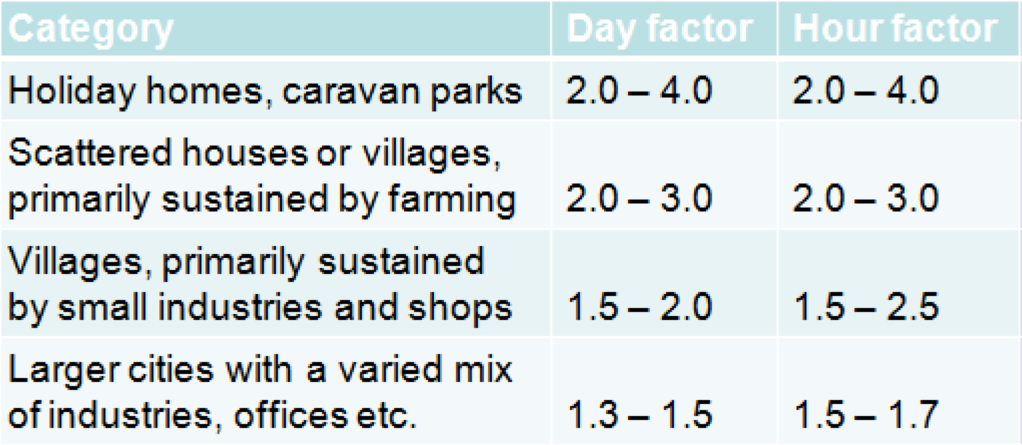


Category	Consumption
Industries with small consumption (storage, wholesale, exhibitions etc)	5-10 m^3/ha/y
Industries with moderate consumption (production, furniture, plastics, paint and varnish, machine shops)	15-60 m^3/ha/y
Industries with large consumption (papermills, textiles, chemicals, food, dairy products, breweries, laundries, slaughterhouses)	60-150 m^3/ha/y 120-360 m^3/ha/y 150-450 m^3/ha/y
Farming	Depends on no. and kind of animals (5-25 m^3/head/year)
Garden centers	
Outdoors	1,000-1,500 m^3/ha/y
Greenhouse	1-1.5 m^3/m^2/y

Figure: Data for industries

2.3 Variation in Consumption

*I*f there is no available data about consumption, the following day factor and hour factors can be used: $\mathbf{f_d}$



Category	Day factor	Hour factor
Holiday homes, caravan parks	2.0 – 4.0	2.0 – 4.0
Scattered houses or villages, primarily sustained by farming	2.0 – 3.0	2.0 – 3.0
Villages, primarily sustained by small industries and shops	1.5 – 2.0	1.5 – 2.5
Larger cities with a varied mix of industries, offices etc.	1.3 – 1.5	1.5 – 1.7

Figure: Day and hourly factors according to category of consumption

Note: These factors are generally too high!

2.4 Additional Consumption

Consumption in waterworks for backwash, pipe flushing and cleaning of fire fire-fighting.

Leaks and pipe bursts:

Waste measured as %, if waste of water is over %10 then a penalty tax is imposed.

3. Demand Types

Baseline demands during a steady-state simulation do not change over time. But, in reality water demand varies continuously over time according to time scale. This scale is occurring of daily, weekly, seasonal and long-term time series.

- ✓ **Daily** - Water use varies depends on course of a day.
- ✓ **Weekly -** Weekend patterns are different from weekdays.
- ✓ **Seasonal –** It depends on seasonal changes, such as tourism, consumption is very changeable season to season.
- ✓ **Long-term –** Depends on changing in population and area.

Some examples of demand types:

- **Average Day Demand:** The average rate of demand for an average day.
- **Maximum Day Demand:** The average rate of use on the maximum usage day.
- **Peak Hour Demand:** It depends on maximum rate of usage.
- **Maximum Day of Record:** The highest average rate of demand for the historical demand.

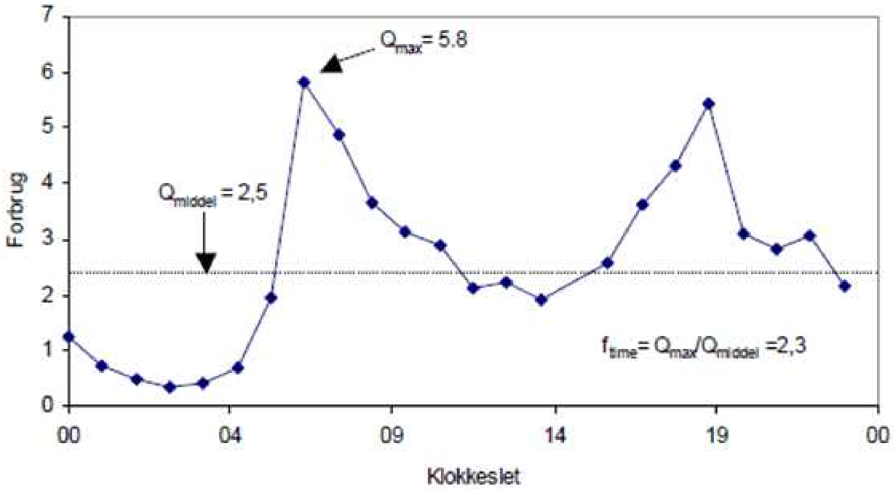


Figure: An example of variation for consumption

We can see the pick point which means that point is rate of maximum consumption in a day. ($Q_{max.}$= 5.8 m^3/y). Also, a line is dividing variation which is giving us average demand. (Q_{middle}= 2.5 m^3/y)

NETWORK – WATER DISTRIBUTION MODELLING

1. Description

Model-based simulation is a method for mathematically approximating the behavior of water distribution systems. Water distribution models have many different types of nodal elements, including junction where pipe connect, storage tank and reservoir nodes, pump nodes and control valve nodes. Also, it is possible to create a chart below about elements of network.

Element	**Primary Modelling Purpose**
Reservoir	Provides water to the system
Tank	Stores excess water within the system, and release that water at times of high usage
Junction	Removes (demand) or adds (inflow) water from/to the system
Pipe	Conveys water from one node to another
Pump	Raises the hydraulic grade to overcome elevation differences and friction losses
Control Valve	Controls flow or pressure in the system based on specified criteria

Figure: Common network modelling elements

The goal of Modelling

- A common database structure to ensure data can be correlated and cross referenced.
- One database to contain all data

- Well defined structure and outline
- Easy to expand
- No information is to be registered twice (or thrice..)
- Easy update and use of data
- Reduced need for conversion of data

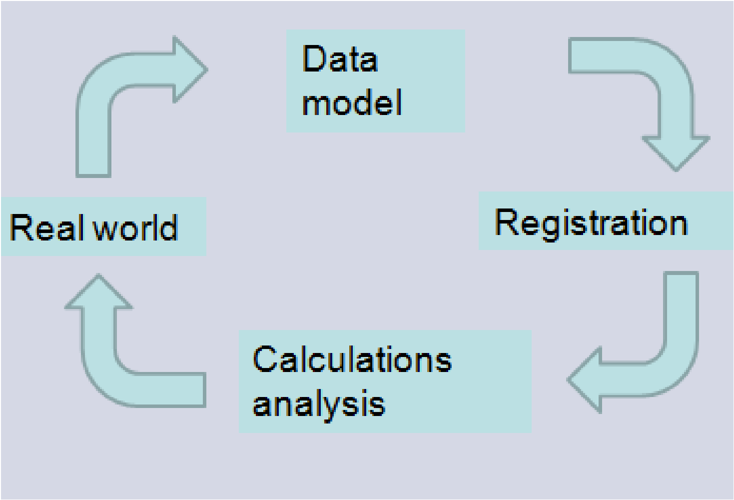
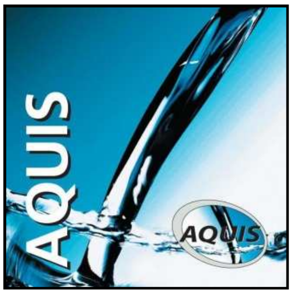


Figure: Cycle of Network Modelling

To give an example of the network model:

- **AQUIS**
- **EPANET**



Differences between them, AQUIS is more up to date. Also, project was carried out according to AQUIS**.**

2. Definitions of Common Network Elements

2.1 Reservoir

Reservoir can supply or accept water with such a large capacity that the hydraulic grade of the reservoir is unaffected and remains constant.

Reservoirs are used to model any source of water where the hydraulic grade is controlled by factors other than the water usage rate.

For a reservoir, two things are required;

1. Hydraulic grade line

2. Water quality

2.2 Tanks

Figure: Storage Tank

Tanks have a finite storage volume, and it is possible to completely fill or completely empty. Storage tanks are present in distribution systems, and the relationship between an actual tank.

Water storage tanks can be classified by construction material;

Cylindrical, spherical, rectangular), style ; elevated, standpipe, ground, buried) and ownership (utility, private).

In the network modelling system, the most important thing is ‘’floats on the system’’. Tanks are used for storage of drinking water. They are filled when production is larger than demand or emptied when demand is larger than production.

Tanks equalizes the variations in demand. Also, they can be at the waterworks, on hilltops or water towers**.**

2.3 Junctions

Junctions are providing a location for two or more pipes to meet. They do not need to be elemental intersections, as a junction node may exist at the end of a single pipe, which called dead-end. Additionally, junction node is providing a location to withdraw water demanded from the system.

Figure: Junctions

2.4 Pipes

Pipe conveys flow as it moves from one junction node to another in a network. In the real world, pipes are usually around 6 meters, which are then assembled in series as a pipeline.

Pipe lines may also have various fittings, such as elbows, to handle abrupt changes in direction, or isolation valves to close off flow through a particular section of pipe. For modelling purposes, pipes and fittings can all be combined into a single pipe element. Model pipe should have the same characteristic (size, material, etc.)

Pipe Materials

Cast Iron	Asbestos Cement	PVC	PE
• Grey • Ductile		• White • Grey	• PEL,PEM,PEH • PE80,PE100 (PE40, PE63)

Figure: Chart of the pipe materials

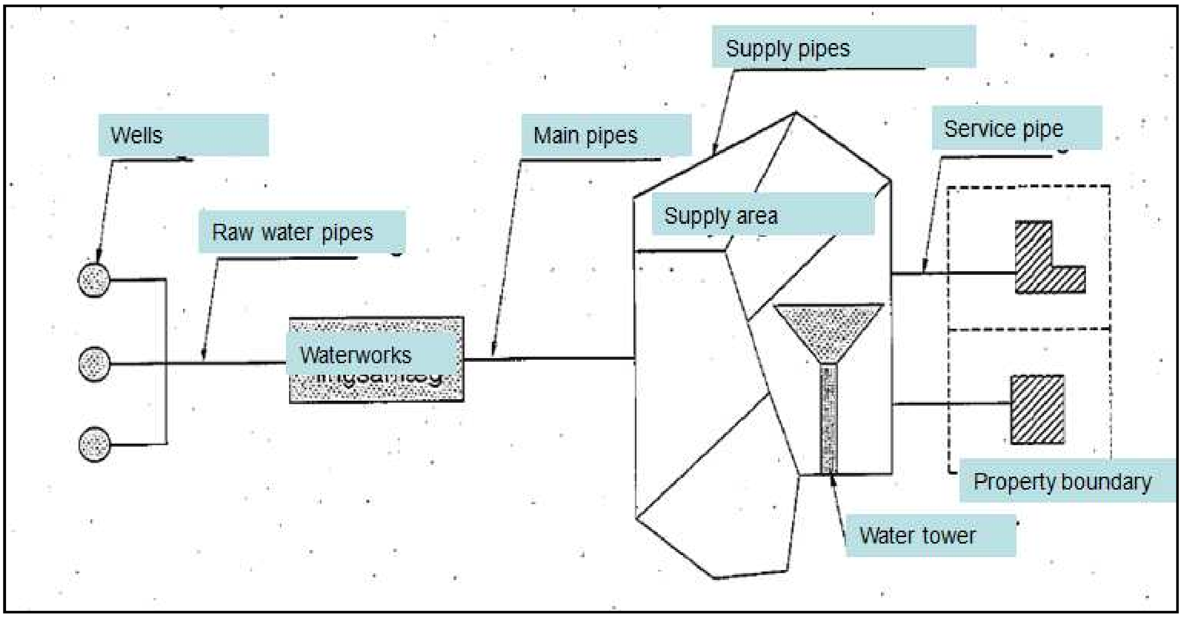
Commonly used pipe dimensions

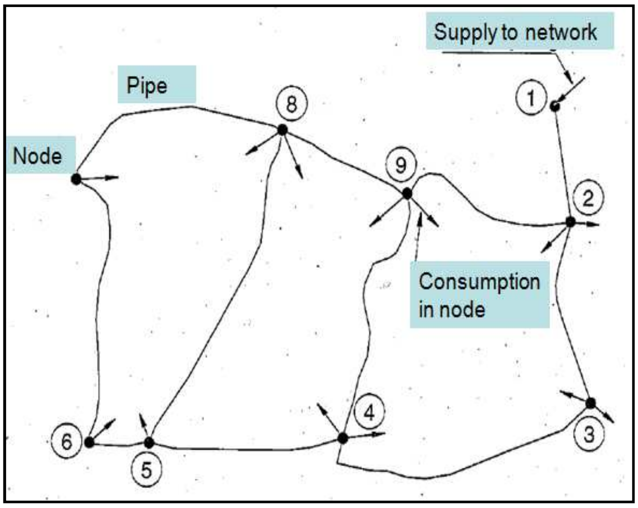
PE and PVC pipes	**50 mm, 63 mm, 90 mm, 110 mm, 160 mm, 225 mm, 250 mm, 315 mm, 400 mm**

Figure: Dimensions of pipes

Pipe Network

It is including of dead-end networks, gridiron networks, sectioning of pipe network, types of pipes (Main pipes, Supply pipes, Branch pipes) and firefighting.





Figures: Pipe Network

2.5 Pumps

Pump adds energy to the system in the form an increased hydraulic grade.

Methods of changing pump performance

- Throttle control
- Bypass control
- Speed control

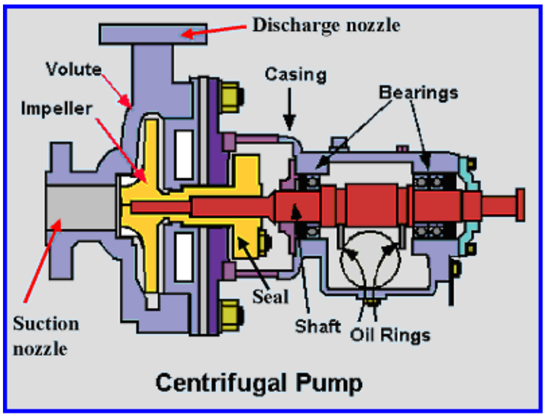


Figure: Cenrifugal Pump

2.6 Valves

Valve can be opened and closed to different extents to vary its resistance to flow, therefore controlling the movement of water through a pipeline. Valves can be classified into the following five categories:

- Isolation valves
- Directional valves
- Altitude valves
- Air release and vacuum breaking valves
- Contol valves

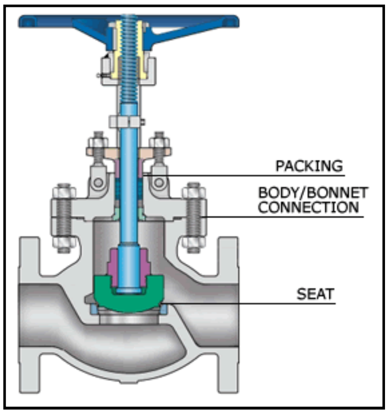
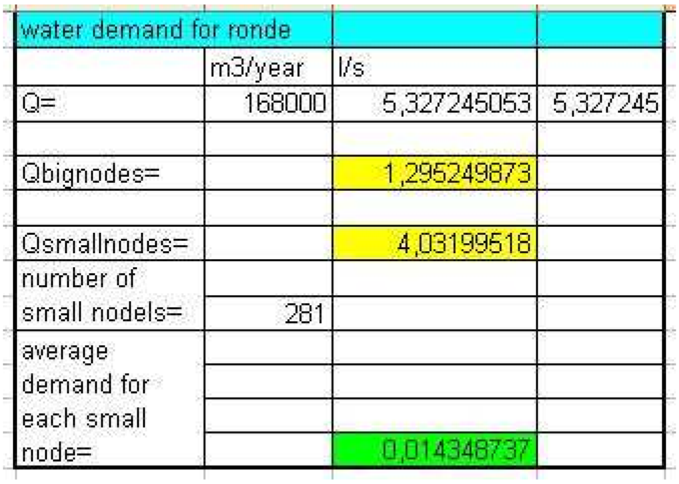


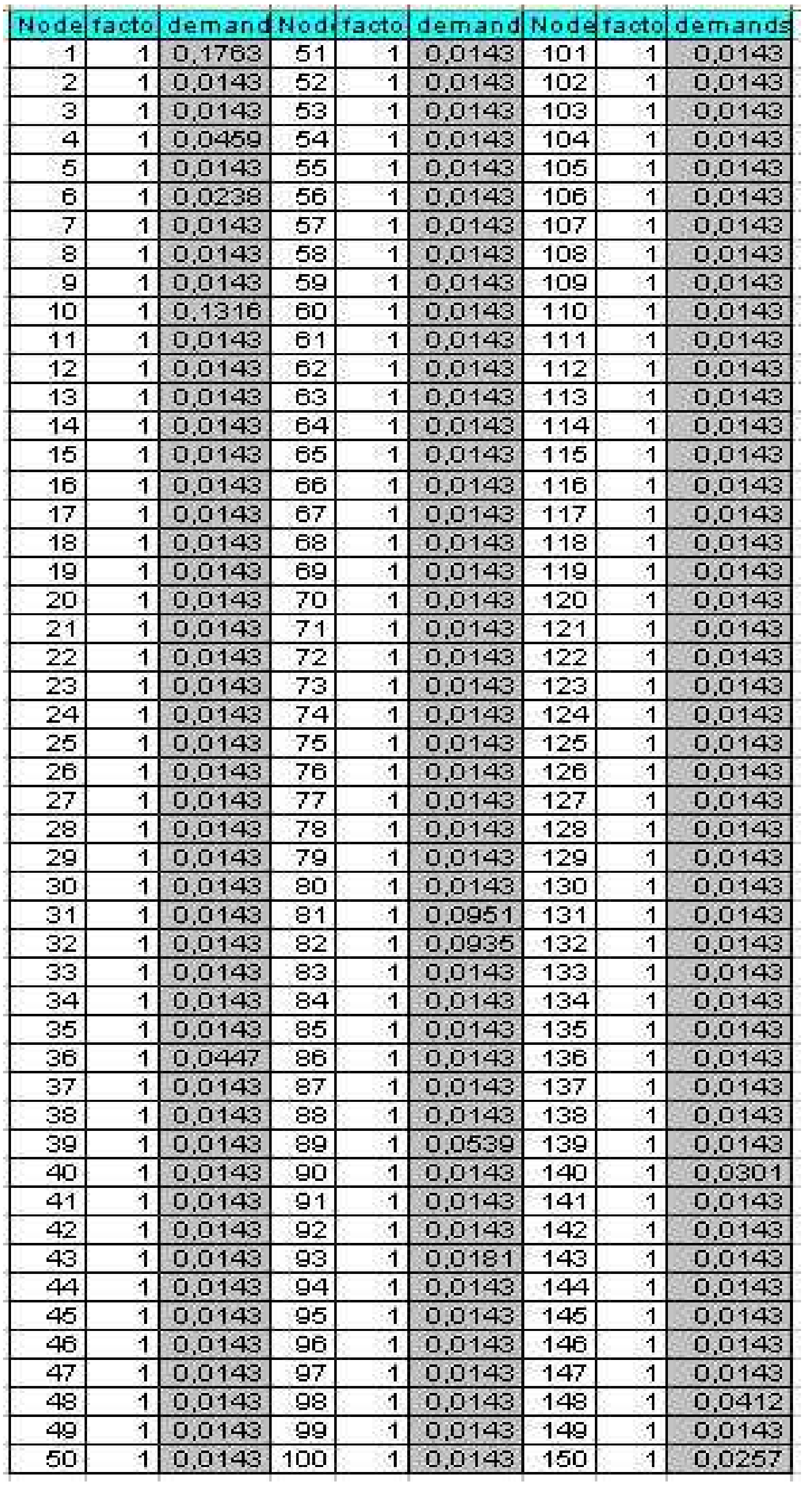
Figure: Valve

Network calculations:



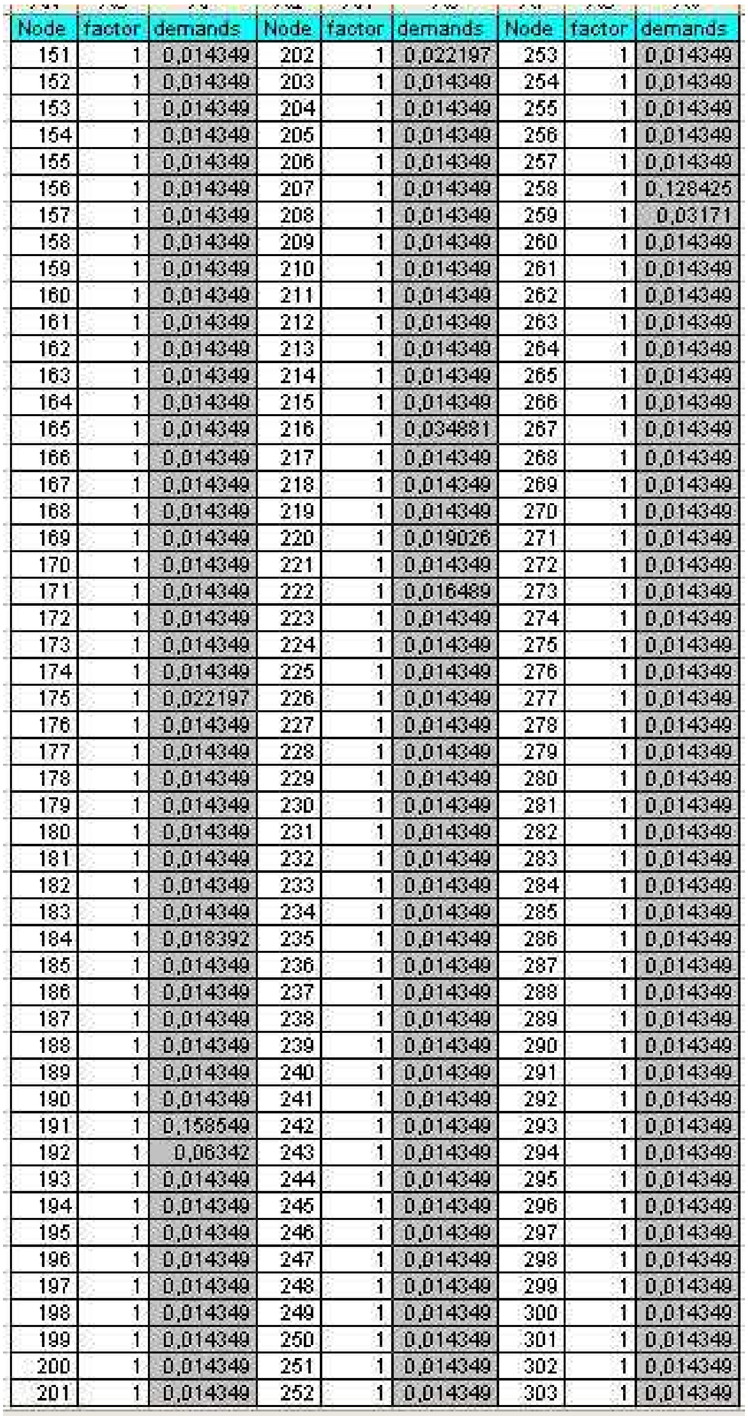
water demand for ronde			
	m3/year	l/s	
Q=	168000	5,327245053	5,327245
Qbignodes=		1,295249873	
Qsmallnodes=		4,03199518	
number of small nodels=	281		
average demand for each small node=		0,014348737	

Figure 1.1 shows calculation of water demand for Rønde



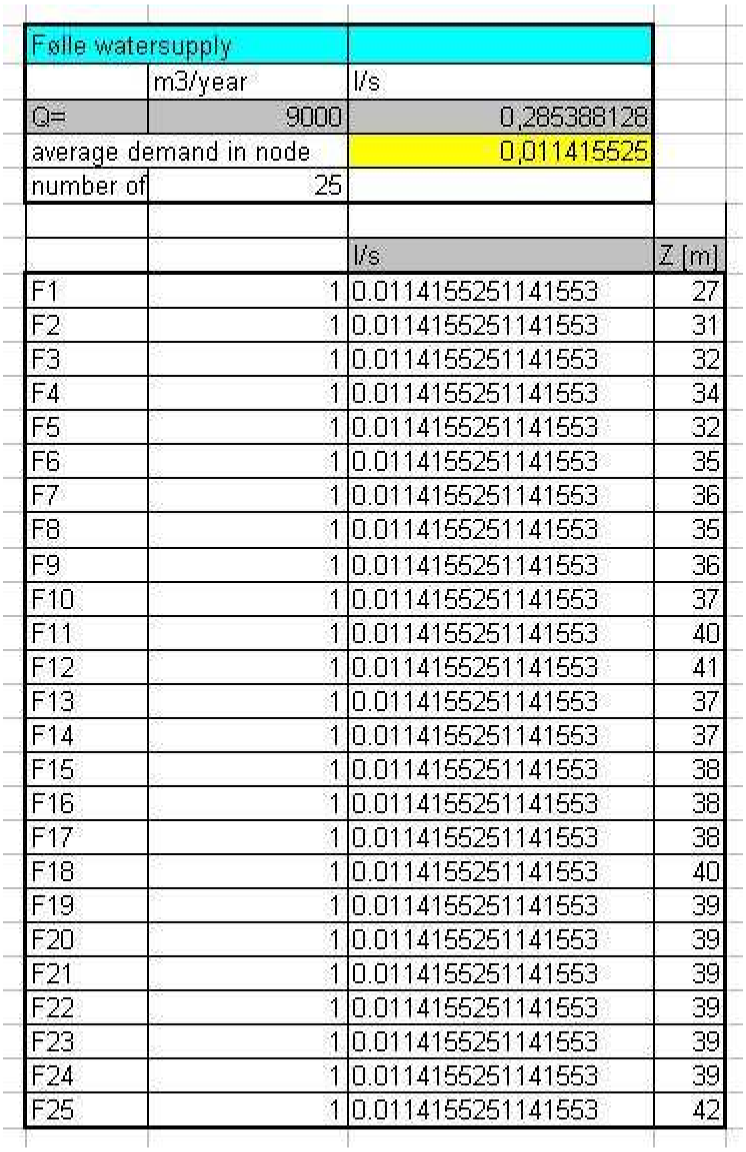
Node	facto	demand	Nod	facto	demand	Node	facto	demands
1	1	0,1763	51	1	0,0143	101	1	0,0143
2	1	0,0143	52	1	0,0143	102	1	0,0143
3	1	0,0143	53	1	0,0143	103	1	0,0143
4	1	0,0459	54	1	0,0143	104	1	0,0143
5	1	0,0143	55	1	0,0143	105	1	0,0143
6	1	0,0238	56	1	0,0143	106	1	0,0143
7	1	0,0143	57	1	0,0143	107	1	0,0143
8	1	0,0143	58	1	0,0143	108	1	0,0143
9	1	0,0143	59	1	0,0143	109	1	0,0143
10	1	0,1316	60	1	0,0143	110	1	0,0143
11	1	0,0143	61	1	0,0143	111	1	0,0143
12	1	0,0143	62	1	0,0143	112	1	0,0143
13	1	0,0143	63	1	0,0143	113	1	0,0143
14	1	0,0143	64	1	0,0143	114	1	0,0143
15	1	0,0143	65	1	0,0143	115	1	0,0143
16	1	0,0143	66	1	0,0143	116	1	0,0143
17	1	0,0143	67	1	0,0143	117	1	0,0143
18	1	0,0143	68	1	0,0143	118	1	0,0143
19	1	0,0143	69	1	0,0143	119	1	0,0143
20	1	0,0143	70	1	0,0143	120	1	0,0143
21	1	0,0143	71	1	0,0143	121	1	0,0143
22	1	0,0143	72	1	0,0143	122	1	0,0143
23	1	0,0143	73	1	0,0143	123	1	0,0143
24	1	0,0143	74	1	0,0143	124	1	0,0143
25	1	0,0143	75	1	0,0143	125	1	0,0143
26	1	0,0143	76	1	0,0143	126	1	0,0143
27	1	0,0143	77	1	0,0143	127	1	0,0143
28	1	0,0143	78	1	0,0143	128	1	0,0143
29	1	0,0143	79	1	0,0143	129	1	0,0143
30	1	0,0143	80	1	0,0143	130	1	0,0143
31	1	0,0143	81	1	0,0951	131	1	0,0143
32	1	0,0143	82	1	0,0935	132	1	0,0143
33	1	0,0143	83	1	0,0143	133	1	0,0143
34	1	0,0143	84	1	0,0143	134	1	0,0143
35	1	0,0143	85	1	0,0143	135	1	0,0143
36	1	0,0447	86	1	0,0143	136	1	0,0143
37	1	0,0143	87	1	0,0143	137	1	0,0143
38	1	0,0143	88	1	0,0143	138	1	0,0143
39	1	0,0143	89	1	0,0539	139	1	0,0143
40	1	0,0143	90	1	0,0143	140	1	0,0301
41	1	0,0143	91	1	0,0143	141	1	0,0143
42	1	0,0143	92	1	0,0143	142	1	0,0143
43	1	0,0143	93	1	0,0181	143	1	0,0143
44	1	0,0143	94	1	0,0143	144	1	0,0143
45	1	0,0143	95	1	0,0143	145	1	0,0143
46	1	0,0143	96	1	0,0143	146	1	0,0143
47	1	0,0143	97	1	0,0143	147	1	0,0143
48	1	0,0143	98	1	0,0143	148	1	0,0412
49	1	0,0143	99	1	0,0143	149	1	0,0143
50	1	0,0143	100	1	0,0143	150	1	0,0257

Figure 1.2 shows calculation of water demand for each node.



Node	factor	demands	Node	factor	demands	Node	factor	demands
151	1	0,014349	202	1	0,022197	253	1	0,014349
152	1	0,014349	203	1	0,014349	254	1	0,014349
153	1	0,014349	204	1	0,014349	255	1	0,014349
154	1	0,014349	205	1	0,014349	256	1	0,014349
155	1	0,014349	206	1	0,014349	257	1	0,014349
156	1	0,014349	207	1	0,014349	258	1	0,128425
157	1	0,014349	208	1	0,014349	259	1	0,03171
158	1	0,014349	209	1	0,014349	260	1	0,014349
159	1	0,014349	210	1	0,014349	261	1	0,014349
160	1	0,014349	211	1	0,014349	262	1	0,014349
161	1	0,014349	212	1	0,014349	263	1	0,014349
162	1	0,014349	213	1	0,014349	264	1	0,014349
163	1	0,014349	214	1	0,014349	265	1	0,014349
164	1	0,014349	215	1	0,014349	266	1	0,014349
165	1	0,014349	216	1	0,034881	267	1	0,014349
166	1	0,014349	217	1	0,014349	268	1	0,014349
167	1	0,014349	218	1	0,014349	269	1	0,014349
168	1	0,014349	219	1	0,014349	270	1	0,014349
169	1	0,014349	220	1	0,019026	271	1	0,014349
170	1	0,014349	221	1	0,014349	272	1	0,014349
171	1	0,014349	222	1	0,016489	273	1	0,014349
172	1	0,014349	223	1	0,014349	274	1	0,014349
173	1	0,014349	224	1	0,014349	275	1	0,014349
174	1	0,014349	225	1	0,014349	276	1	0,014349
175	1	0,022197	226	1	0,014349	277	1	0,014349
176	1	0,014349	227	1	0,014349	278	1	0,014349
177	1	0,014349	228	1	0,014349	279	1	0,014349
178	1	0,014349	229	1	0,014349	280	1	0,014349
179	1	0,014349	230	1	0,014349	281	1	0,014349
180	1	0,014349	231	1	0,014349	282	1	0,014349
181	1	0,014349	232	1	0,014349	283	1	0,014349
182	1	0,014349	233	1	0,014349	284	1	0,014349
183	1	0,014349	234	1	0,014349	285	1	0,014349
184	1	0,018392	235	1	0,014349	286	1	0,014349
185	1	0,014349	236	1	0,014349	287	1	0,014349
186	1	0,014349	237	1	0,014349	288	1	0,014349
187	1	0,014349	238	1	0,014349	289	1	0,014349
188	1	0,014349	239	1	0,014349	290	1	0,014349
189	1	0,014349	240	1	0,014349	291	1	0,014349
190	1	0,014349	241	1	0,014349	292	1	0,014349
191	1	0,158549	242	1	0,014349	293	1	0,014349
192	1	0,06342	243	1	0,014349	294	1	0,014349
193	1	0,014349	244	1	0,014349	295	1	0,014349
194	1	0,014349	245	1	0,014349	296	1	0,014349
195	1	0,014349	246	1	0,014349	297	1	0,014349
196	1	0,014349	247	1	0,014349	298	1	0,014349
197	1	0,014349	248	1	0,014349	299	1	0,014349
198	1	0,014349	249	1	0,014349	300	1	0,014349
199	1	0,014349	250	1	0,014349	301	1	0,014349
200	1	0,014349	251	1	0,014349	302	1	0,014349
201	1	0,014349	252	1	0,014349	303	1	0,014349

Figure 1.3 shows calculation of water demand for each node.



Følle watersupply			
	m3/year	l/s	
Q=	9000	0,285388128	
average demand in node		0,011415525	
number of	25		
		l/s	Z [m]
F1	1	0.0114155251141553	27
F2	1	0.0114155251141553	31
F3	1	0.0114155251141553	32
F4	1	0.0114155251141553	34
F5	1	0.0114155251141553	32
F6	1	0.0114155251141553	35
F7	1	0.0114155251141553	36
F8	1	0.0114155251141553	35
F9	1	0.0114155251141553	36
F10	1	0.0114155251141553	37
F11	1	0.0114155251141553	40
F12	1	0.0114155251141553	41
F13	1	0.0114155251141553	37
F14	1	0.0114155251141553	37
F15	1	0.0114155251141553	38
F16	1	0.0114155251141553	38
F17	1	0.0114155251141553	38
F18	1	0.0114155251141553	40
F19	1	0.0114155251141553	39
F20	1	0.0114155251141553	39
F21	1	0.0114155251141553	39
F22	1	0.0114155251141553	39
F23	1	0.0114155251141553	39
F24	1	0.0114155251141553	39
F25	1	0.0114155251141553	42

Figure 1.4 shows calculation of water demand for each node in Følle.

RISK ASSESSMENT OF NETWORK

Many conditions exist that may result in degradation of water quality in the distribution system. It is possible to have problems like cross-connections, corrosion, biological growth, bursting pumps, closed valves, pumping failures etc.

Using a model, operator can simulate what is occurring at any location in the distribution system under the full range of possible conditions. There are some programmes, which are monitoring programmes for following of distribution. Also, maps are helping for identifying problem and location. But, it is not available for each point. In this case, it is needed to make local measurements.

First of all, measures should be taken to protect equipment.

Figure: Maintenance

Source of Contamination:

Physical	Chemical	Biological
Shavings Plastics Dust Radioactive fallout	Pesticides Natural substances Solvents	Coliform Animals/insects Pollen Pathogenic bacteria

Figure: Sources

Some points to consider

There is possible some critical problems and need to control:

- ✓ Leakage in distribution system
- ✓ Power failure

- ✓ Contamination of supply facilities
- ✓ Threats of sabotage
- ✓ Fire and explosion

Figure: Pipe burst

Technical problems

It is possible to have some kind of technical problems in network. These problems can be occurred in a wide variety of network elements like; reservoir, tank, pipe, pump, valve, intersections etc.

Reservoir

- ✓ Generally, reservoir can be built strong against risk of earthquake and vibration of some reasons (exactly, very low probability of earthquake in Denmark)
- ✓ The need to secure against the risk of sabotage
- ✓ For preventing of problems, need covering and protecting reservoirs. For example reservoir's inlet and outlet using for sampling so that we have to protect these points.
- ✓ We have to check; access hatch, ventilation, filters and concrete.
- ✓ Cleaning sludge in sedimentation basin

Figure: Reservoir in Rønde

Pipe

Pipes are like vessels in distribution system. It needs to be clean, steady and safe. Sometimes, it canbe damaged due to leaks, water quality, microorganisms, sabotage, earthquake etc. For example, ''red water '' problem is due to iron which should be checked for preventing corrosion.

Location of leaks

Rarely, forces water to surface so that it is sometimes hard to find location. A leak gives a hissing sound therefore sometimes it is possible to hear its voice. Generally, the leakage water of region should be closed for repairing pipes and night hours must be chosen. Also, a special material can be chosen for leakage location. Firstly, trouble place can be cut and this material will be used for that point.

Repairing of pipes

Firstly, turn the water off as soon as you release there is a problem. Valve is possible to use for turning water off.

Figure: Pump in Rønde Reservoir

Pump

Check:

- ✓ Controlling yield (Q), pressure and power consumption
- ✓ Protection against outside influences
- ✓ Flow-meters
- ✓ Valves
- ✓ Pressure transmitter
- ✓ Pressure switch

Valve

It is necessary to control valve is opened or closed. Otherwise, some problems may occur;

- ✓ It has to be closed while flushing pipe
- ✓ Also, while pump is running, the necessary valve must be open

Low pressures

It is very significant and widespread problem in distribution systems. Because, low pressure can be occurred because of the some reasons. In general, poor pressures tend to be caused by inadequate capacity in a pipe or pump, high elevations, or some combination of the two. To be followed such a problem:

- ✓ Making operational changes such as opening valves
- ✓ Changing pump settings
- ✓ Locating and repairing any leaks
- ✓ Cleaning pipes
- ✓ İnstalling new tank

WaterWorks

Theoretical oxygen demand

	(mg O2/mg)	Concentration	mg O2/l		mg O2/l		mg O2/l		mg O2/l
Well		217		272		321		352	
Iron	0,14	2	0,28	1,7	0,238	2,1	0,294	1,1	0,154
Mn	0,29	0,12	0,0348	0,1	0,029	0,11	0,0319	0,061	0,01769
NH4+	3,6	0,68	2,448	0,73	2,628	0,78	2,808	0,64	2,304
H2S	0,51								
CH4	4								
TOD			**2,7628**		**2,895**		**3,1339**		**2,47569**

	mg O2/l
Maximum Oxygen demand:	3,1368
Minimum Oxygen Demand:	2,47569
Average Oxygen Demand:	2,79079667

Volume of oxygen needed:

$$TOD \cdot Q = Mass\ Flow\ oxygen = 6440\ mg/h$$

Mass flow of air: $\frac{6440}{0,21} 30666,7\ mg\ Air\ /h$

Reactions in filters

In the filters, some chemical reactions take place:

$Fe^{2+} + 0_2 + H_2O \rightarrow Fe(OH)_3 + ½\ H^+$

$2\ Mn^{2+} + O_2 + 2\ H_2O \rightarrow 2MnO_2 + 4\ H^+$

$NH_4^+ + 2\ O_2 \rightarrow NO_3^- + H_2O + 2\ H^+$

Hydraulic in filters

There are the formulas used to calculate the different parameters:

$$FR = \frac{Q}{A} \qquad Vreal = \frac{FR}{n} \qquad EBCT = \frac{A \cdot D}{Q} \quad Tres = EBCT \cdot n$$

Where:

Q= Flow

A= Area

n = Porosity = 0,4

D= Depth

Backwash period

Concentration of Iron in raw water c Fe [mg/l] was taken from Jupiter database.
Surface area of sand filter Area [m2] was calculated.
Flow of raw water Flow [m3] was taken from Appendix 1

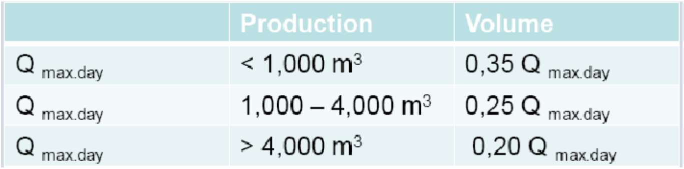
	CFe	TotalArea	Flow	Fe Load	Run lenght	Period	Period
Units	mg/l	m2	m3/h	kg Fe/m^2/h	kg Fe/m^2	d	m^3
Average	1,73	14,58	32,9	$3.9 \cdot 10^{-3}$	0,5	5,3	4213,62

$$FeLoad = \frac{Fe_{demant} * Q}{A} \qquad Period = \frac{RunLength}{LoadFe} \qquad Period, m^3 = \frac{RunLength}{cFe/1000} * Area$$

Water needed for backwash: 40 m/h · 4,86 m^2 · 5min · 1/60 = 16,2 m^3

Storage Tank Dimension

To calculate the Volume for the consumers:



	Production	Volume
$Q_{max.day}$	< 1,000 m^3	0,35 $Q_{max.day}$
$Q_{max.day}$	1,000 – 4,000 m^3	0,25 $Q_{max.day}$
$Q_{max.day}$	> 4,000 m^3	0,20 $Q_{max.day}$

$Q_{max,day}$= 805 m3/day → V_{com} = 0,35 · 805 = 281,75 m^3

To calculate the volume of water needed for backwash please go to enclosure .

The water for case of fire is set up as $150m^3$. The Authorities should say if it is enough.

	m3	m3
Vcom	281,75	285
fire	150	150
BW	16,2	20
Tot	447,95	455

Optional Part: Experiment I

Screen test

Three different kinds of screens were provided to the group. To know which one was the best, a recreation of the sampling situation in the waterworks was done.

To do this, 2 m of tube with a diameter equal to the tube which would be used in the waterworks was used. In one of its extremes the screens were plugged and in the other the syringe to extract the water. The side of the tube with the filters was introduced in a test tube half-full of sand and water.

The first conclusion obtained was the difficulty of introducing the tube in the tube and with only 7 cl of water above it. The sand got very compact really fast and it made impossible to put the tube inside of it.

The first screen tested was the one with the biggest separation between cuts:

- It wasn't difficult to extract water
- It didn't clog fast

The second screen was the other cut tube:

- It wasn't difficult to extract water at the beginning, 2 syringes later it became more and more difficult
- When the tube was taken out of the test tube, the screen was with lot of particles, it was almost clogged.

The pierced tube:

- It wasn't difficult to extract water, and actually, it was easier than with the first one.
- It didn't clog and when it was taken out, it was completely clean.

The tube chosen was the pierced one.

It was checked that there wasn't any problem of extracting water with the syringe having a headloss of 2 m.

A problem was found during the test, a piece of soft plastic used to avoid the inlet of air while flushing the syringe failed when it was used 4 or 5 times. Bridles should be used to avoid this problem.

Virkon S

Key Information

Virkon® S, the premier broad spectrum virucidal veterinary disinfectant, is recognised by industry and governments worldwide as a disinfectant of choice for livestock disease prevention and control.

Virkon® S has a unique formulation; no other disinfectant has the same powerful composition. In terms of efficacy Virkon® S has been proven highly effective against 65 strains of virus in over 19 viral families, 400 strains of bacteria and over 100 strains of fungi. This list of proven efficacy includes the major OIE List A diseases of concern; Avian Influenza (H5N1), Newcastle Disease, Classical Swine Fever (Hog Cholera) and Foot and Mouth Disease.

Virkon® S' versatility provides the flexible solution for; surface, water and aerial disinfection, in hard water, on porous surfaces, at low temperatures and in the presence of organic challenge.

UK DEFRA Approved - Foot and Mouth Disease, Swine Vesicular Disease, Diseases of Poultry and General Orders

Powerful - independently proven effective against viral, bacterial and fungal disease causing organisms including the lethal H5N1 Avian Influenza Virus.

Fast-acting - a one percent solution of Virkon® S is independently proven to kill bacteria with contact times as low as five minutes and the tough to kill parvovirus in ten minutes or less.

Versatile - surface, equipment, vehicle, footdip, water delivery system and aerial disinfection.

Independently proven effective on porous surfaces, in hard water, at low temperatures and in the presence of organic challenge.

Readily soluble in tap water , Virkon® S dissolves into a pink solution.

An environmentally acceptable product with an exceptional safety profile towards man and animals when used and disposed of as instructed on the label.

Transport and storage - being a powdered disinfectant formulation Virkon® S can be swiftly transported by air and can be stored for long periods making it the ideal choice for stockpiling in bulk.

Mode of Action

DuPont™ Virkon® S does not elicit a specific toxicological effect on the target organism, instead it achieves deactivation and/or destruction of the target organism through general oxidative disruption of key structures and compounds vital to normal activity (e.g. proteins and lipids).

There is no evidence to suggest that bacterial disease causing organisms develop resistance towards Virkon® S as opposed to other disinfectant types.

Composition

Virkon® S is meticulously controlled during the manufacture process to be a balanced, stabilized blend of peroxygen compounds, surfactant, organic acids and an inorganic buffer system.

Disposal

Do not allow Virkon® S disinfectant solutions to enter watercourses.

Dispose of Virkon® S, disinfectant solutions directly to foul sewer.

Independent studies have shown that diluted Virkon® S should not, when used as directed, pose any threat to sewage treatment facilities.

Kit HACH LCK 304

Determination of Nitrogen:

5 ml of water are needed. It is added into a cuvette with the two others reactive agents. It needs to be shaking for 15 min to complete the chemical reaction, and then the absorbance of the remaining substance is measured.

Principle:

Ammonium ions react at pH=12,6 with hypoclorite ions and salycilate ions in the presence of sodium nitroprusside as a catalyst to form idophenol blue

It should work in a pH 4-9 and in a 20ºC temperature.

Determination of Iron:

2 ml of water are needed. It is added into a cuvete with the other reactive agent. It needs to be shaking for 15 min to complete the chemical reaction, and then the absorbance of the remaining substance is measured.

Principle:

Iron(II) ions form an orange-red complex with 1.10-phenanthroline. Any Iron(III) present in the water sample are reduced to iron(II) by Ascorbic acid before the complex is formed.

It should work in a 3-10 pH range and in a 15-25ºC range of temperature

Experimental Hydraulics in the filter

$FR = \frac{Q}{A}$ $\quad Vreal = \frac{FR}{n}$ $\quad EBCT = \frac{A \cdot D}{Q}$ $\quad Tres = EBCT \cdot n$

Where:

Q= Flow

A= Area

n = Porosity = 0,4

D= Depth

Data from the analysis

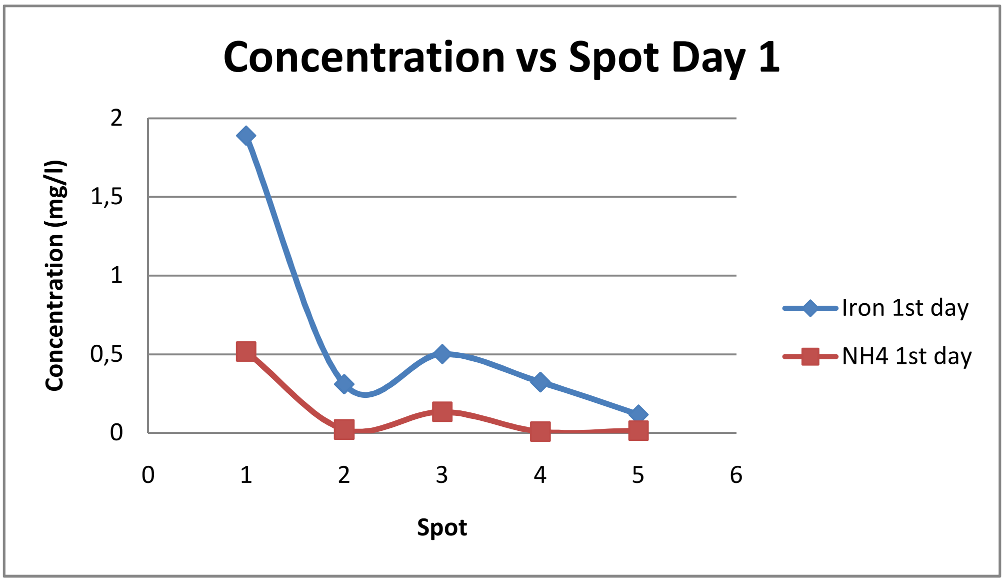
- First day:

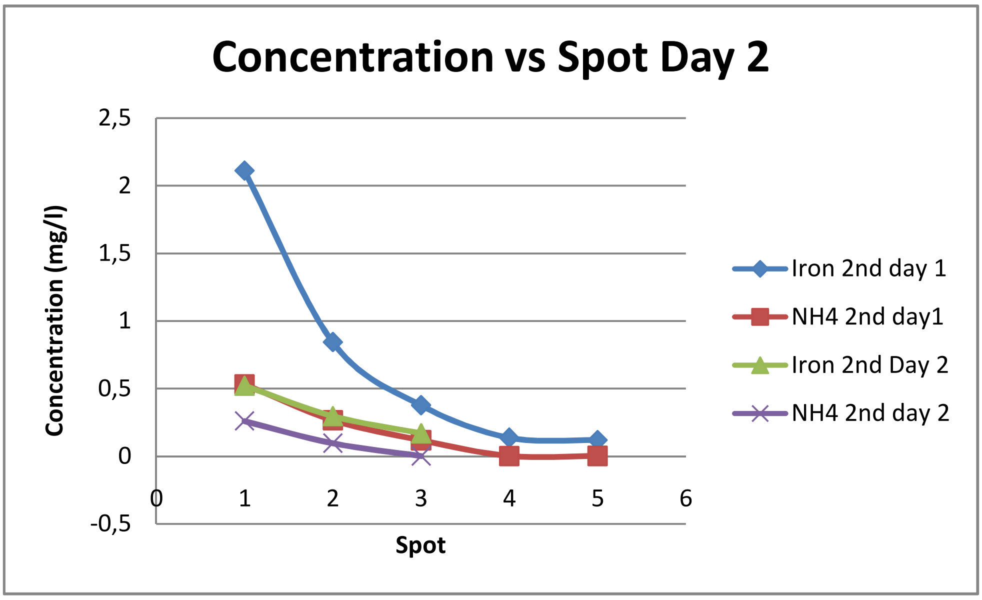
Spot	Fe	NH_4^+	Fe	NH_4^+
Raw	1,89	0,518		
3	0,311	0,022		
2	0,502	0,135	0,417	0,119
1	0,324	0,009		
Outlet	0,118	0,015		

In this first day, only measurement during the second round was done, in the level II. With this the error made in the extraction will be calculated later.

- Second Day:

Spot	Fe (mg/l)	NH_4^+ (mg/l)	Fe (mg/l)	NH_4^+ (mg/l)
Raw	2,11	0,53		
3	0,843	0,266	0,522	0,26
2	0,376	0,118	0,297	0,096
1	0,136	0,001	0,17	0,001
Outlet	0,119	0,002		





Relative Error

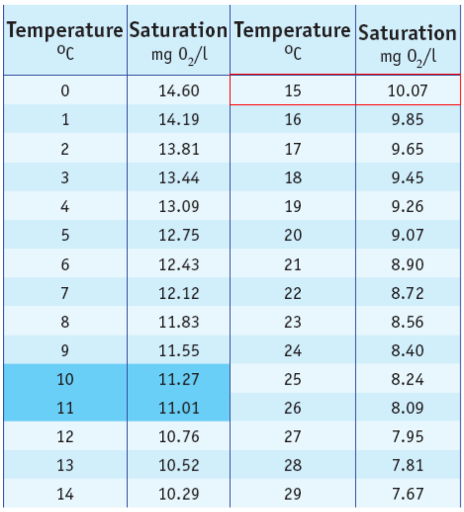
Day 1			Day 2	
Rel Error Fe	Rel Error NH4		Rel Error Fe	Rel error NH4
			0,38078292	0,02255639
0,16932271	0,11851852		0,21010638	0,18644068
			-0,25	0

Error = $\frac{\Sigma \mathrm{error}}{8}$ =0,10471595 · 100 = 10,47 %

Optional Part: Experiment II

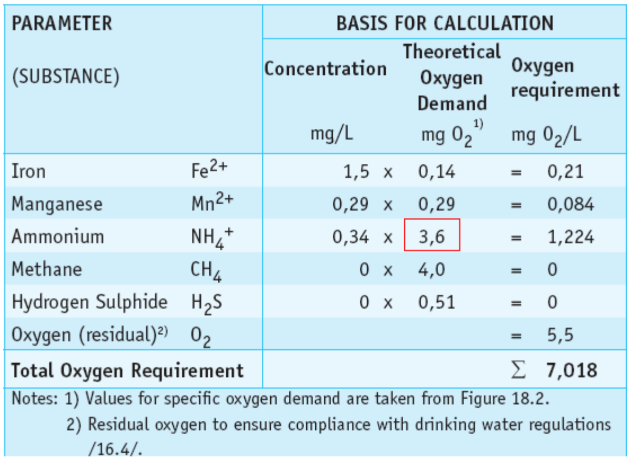
Concentration of the Ammonium dissolution

By looking at the table below, an oxygen concentration in water of 10 mg O_2/L was assumed.



Temperature °C	Saturation mg O_2/l	Temperature °C	Saturation mg O_2/l
0	14.60	15	10.07
1	14.19	16	9.85
2	13.81	17	9.65
3	13.44	18	9.45
4	13.09	19	9.26
5	12.75	20	9.07
6	12.43	21	8.90
7	12.12	22	8.72
8	11.83	23	8.56
9	11.55	24	8.40
10	11.27	25	8.24
11	11.01	26	8.09
12	10.76	27	7.95
13	10.52	28	7.81
14	10.29	29	7.67

Then, knowing the amount of oxygen available in the water, the quantity of nitrogen that can be oxidized is calculated using the next table:



PARAMETER (SUBSTANCE)		BASIS FOR CALCULATION Concentration mg/L		Theoretical Oxygen Demand mg O_2 1)		Oxygen requirement mg O_2/L
Iron	Fe^{2+}	1,5	x	0,14	=	0,21
Manganese	Mn^{2+}	0,29	x	0,29	=	0,084
Ammonium	NH_4^+	0,34	x	3,6	=	1,224
Methane	CH_4	0	x	4,0	=	0
Hydrogen Sulphide	H_2S	0	x	0,51	=	0
Oxygen (residual)2)	O_2				=	5,5
Total Oxygen Requirement					Σ	**7,018**

Notes: 1) Values for specific oxygen demand are taken from Figure 18.2.
2) Residual oxygen to ensure compliance with drinking water regulations /16.4/.

If it's known that the Theoretical Oxygen Demand for the Ammonium is 3,6 mg O2 and it is also known the level of oxygen in water, the concentration of the dissolution is to be calculated:

$$Cammonium = \frac{Co2}{TOD} = \frac{10\ mg/l}{3,6\ mg\ O2} = 2,78\ mg/l\ NH_4^+$$

We need, therefore, a 2,78 mg/l NH_4^+ dissolution.

In order to do it:

Ammonium molecular weight: 18 g/mol

Units are changed, from weight to mols: $\frac{2{,}78\frac{mg}{l}}{1800\ mg/mol} = 1{,}54 \cdot 10^{-4}\ mol/l$

The ammonium will be got from the dissolution of $(NH_4)_2SO_4$, which can be found as a solid pure reactive agent.

Sulphate ammonium molecular weight: 132,1 g/mol.

There are twice more mols of ammonium in $(NH_4)_2SO_4$ than in the normal molecule of NH_4^+.

Then, to know how much of this reactive agent is to be added in 1 liter of demineralized water:

$\frac{1{,}54 \cdot 10^{-4}\ mol/l}{2} \cdot 132{,}1\frac{g}{mol} = 0{,}0102\ g/l$ $(NH_4)_2SO_4$

It must be added 10,2 mg $(NH_4)_2SO_4$ and add water till reaching 1 L of volume.

Waiting time between samples calculation

As it is explained in the report, 0,2 l of sand are introduced into a glass and then, another 0,2 l of a ammonium dissolution will be added to the same glass.

Then, if measurements of the nitrification process in the sand are to be carried out, it is necessary to know how many samples are to be taken and how big the waiting time between them should be.

To know this time, an assumption is to be made, the concentration of ammonium in the dissolution in contact with the sand will be decreased a 50 % in 5 min.

Then, if we add 0,2 l of a dissolution 2,76 mg N/l, the mass of nitrogen added:

$M_{N,total} = Concentration \cdot Volume = \frac{2{,}76mgN}{l} \cdot 0{,}2l = 0{,}552$ mg N

Some of this water will go through the sand, thanks to its porosity. Therefore, to know the mass of nitrogen in the water which is in the sand:

$M_{N,sand} = V \cdot n \cdot C = 0{,}2 \cdot 0{,}4 \cdot 2{,}76 = 0{,}2208\ mg\ N$

Where:

V=Volume Sand

n= porosity

C= Concentration

Making a mass balance, it is easy to calculate the mass of nitrogen in the water which is not in contact with the sand:

$M_{N,water}$= $M_{N,total}$ - $M_{N,sand}$ = 0,3312 mg N

Then after 5 min, $[NH_4^+]$ should be reduced to 50% in the filters:

Time = 0 min → 0,2208 mg N

Time = 5 min →0,1104 mg N → New mass of nitrogen in water inside sand.

If the glass is mixed, the water in the sand plus the water without any contact is mixed, and the new mass of nitrogen will be the sum of them:

$M_{T,N,t=5}$ = 0,1104 mg N + 0,3312 mg N = 0,4416 mg N

The new concentration of nitrogen in the water will be:

C_N= $\frac{Mass\ Nitrogen}{Volume} = \frac{0,4412}{0,2} = 2,21\ mg\ N/l$

Knowing this new concentration, the new mass of nitrogen in the sand and in water is to be calculated:

$M_{N,sand}$= $V \cdot n \cdot C = 0,2 \cdot 0,4 \cdot 2,21 = 0,177\ mg\ N$

$M_{T,N}$ = 0,4416 mg N

$M_{N,W}$=0,265 mg N

Then after 5 min, $[NH_4^+]$ should be reduced to 50% in the sand:

t=5 min →0,177 mg N

t= 10 min → 0,086 mg N → New mass of nitrogen in water inside sand.

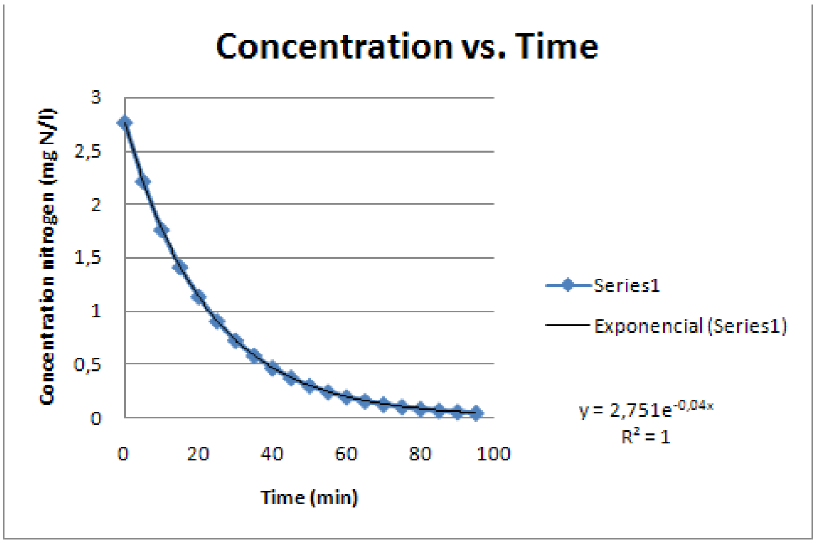
$M_{T,N,t=10}$ = 0,086 + 0,265 = 0,351 mg N

The new concentration of nitrogen in water will be:

C_N= $\frac{Mass\ Nitrogen}{Volume} = \frac{0,351}{0,2} = 1,755\ mg\ N/l$

This process was done from 0 min to 100 min, in the table below the results can be viewed, and next to it, the corresponding graph to those data:

t (min)	C (mg N/l)
0	2,76
5	2,21
10	1,755
15	1,406
20	1,13
25	0,9
30	0,72
35	0,576
40	0,4608
45	0,36864
50	0,2949
55	0,236
60	0,1888
65	0,15104
70	0,121
75	0,0968
80	0,07744
85	0,0619
90	0,04952
95	0,039616
100	0,0317
105	0,0253



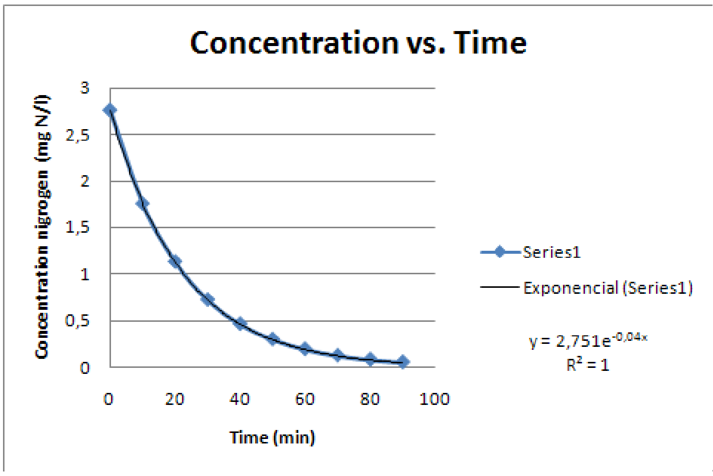
As it can be seen in the graph, it is the typical picture of a 1st order kinetic reaction whose ecuation should be:

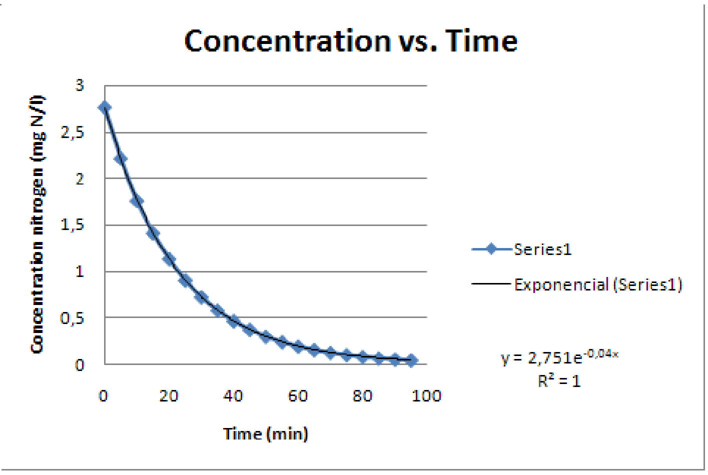
$$C = Co \cdot e^{-K \cdot t}$$

Effectively, the equation presented in the graph matches with a 1st order reaction.

The time between samples was decided creating a new graph taking the data every 15 and 10 min.

When 15 min were taken, the graph was slightly different. However taking 10 min, the equation of the graph was exactly the same. Then it was decided that the waiting time between samples should be inside of the 10-15 min range.





Furthemore, as only 10 kit were available to take samples, it fits perfectly to take a sample every 10 min.

Water in sand calculation.

Some sand is taken from the recipient where it was kept. It's weight is measured in an accurate scale. (Remember to tare first the recipient where the sand is going to be hold)

After 4 days it's weight is measured again. All the water is supposed to have evaporated.

This sample of sand can also be put into a oven, to ensure that all the water is gone, but one have to be careful because more elements in the sand, such as organic matter, can burn too and then it will be a mistake to think that all the difference in the weight is because of water.

$W_o - W_{4d} = W_{water}$ $\frac{Wo-W4d}{Wo} \cdot 100 =$ % weight of water in the sand.

Where:

W_o= Sands weight at the beginning $\frac{60,7-52,3}{W60,7o} \cdot 100 = 24,92\%$

W_{4d}=Sands weight after drying the sample

W_{water} =Weight of water.

Calibration of the results

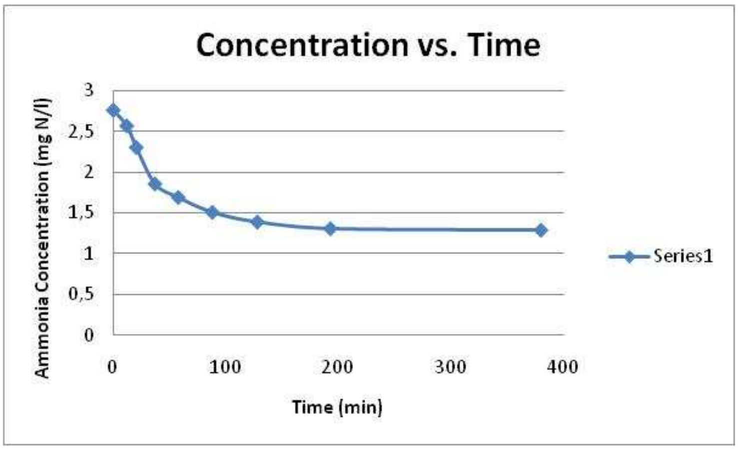
To try to avoid the problem of the turbidity, the results were calculated in base of the raw water analysis.

The operation made:

$$Ccalibr. = \frac{2{,}76\ mg/l \cdot Creal}{12{,}08\ mg/l}$$

t(min)	C(mg/l)	Creal (mg/l)	Ccalibr. (mg/l)
0	3,02	12,08	2,76
12	2,81	11,24	2,56807947
20,5	2,52	10,08	2,30304636
37	2,03	8,12	1,85523179
57,7	1,85	7,4	1,69072848
88	1,65	6,6	1,50794702
128	1,52	6,08	1,38913907
193	1,43	5,72	1,30688742
380	1,41	5,64	1,28860927

The graph Ccalibr. Vs. Time was plotted:



However, all this wasn’t used for further calculations.

Nessler method to measure Ammonium in water

The Nessler reactive agent (potasium iodium mercuriate) in presence of ammonium ions gets discomposed, and it forms di-mercury ammonium iodine, what allows a colorimetric determination of ammonium ions.

Reactive Agents:

- Extra demineralised water, without any ammonium ions.
- Nessler Reactive agent: Weigh the following quantities for 100 ml:
    - Mercury II red iodine(HgI_2)→ 10 g
    - Potassium iodine (KI)→ 7,5 g
    - Sodium hydroxide (Na(OH))→ 20 g

The KI should be added over the HgI_2 and the 100ml water. Once it is dissolved, the NaOH is to be added. All this mixing should be done under an extractor fan due to the mercury; it is really toxic and easy to inhale.

- 1 g/l nitrogen Standard solution: Weigh 3,82 ammonium chlorine and reach 1000 ml with demineralised water.
- 0,01 g/l nitrogen Standard solution: Take 10 ml from the previous standard solution and reach 1000 ml with demineralised water.

Calibration Curve:

Take six 50ml volumetric flasks:

Flasks	1	2	3	4	5	6
Std 2 (ml)	0.5	1.0	2.0	3.0	4.0	5.0
Deminer. Water (ml)	49.5	49	48	47	46	45
mg N/l	0.1	0.2	0.4	0.6	0.8	1
Nessler (ml)	2	2	2	2	2	2

Let all the dissolution to rest 10 min. Make all readings in a spectrophotometer in a 425 nm wavelength. There should be also a white sample, what is the same as before but instead of adding some nitrogen standard solution only 50 ml demineralised water.

After all the measurements are done, a calibration curve is to be done, always including all the results in base the white sample.

This curve will give the concentration of nitrogen expressed in mg/l. To get the results in mg NH4+/l, they should be multiplied by 1,29.

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