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Drinking water treatment at the Austrian- Czech border

Waldviertel The drinking water problem zone in Austria

by

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Abstract

The functioning of the drinking water treatment plant of the Austrian City of Schrems was analysed during the four weeks of project work.

This included:

- The functioning of the treatment plant and the well and source water was monitored during extreme weather conditions, in this case snow melt and resulting flooding
 - UV permeability falls drastically
 - pH value, Total Hardness and Carbonate Hardness are relatively stable
 - Conductivity decreases because of increasing surface water
 - Manganese and Iron have similar behaviour; increase during snow melt
- The crucial UV permeability for UV disinfection of min. 20% has been guaranteed by analysis of the effect of Ozone on the UV permeability
- Iron removal has been optimised
 - The effect of Ozone on Humic Substances has been analysed
 - The amount of Iron complexed with Humic Acids that cannot be removed has been decreased
 - Iron removal in the filters works best at a pH of 6.9 – 7.2, which was accomplished by addition of Sodium Hydroxide
 - Iron removal can be improved by optimising the washing cycles of the filters
- A comparison between KMnO_4 value and TOC value has been accomplished

1. Introduction

1.1. General Situation in Austria

In principle 5 types of drinking water exist in Austria:

- The normal groundwater in Austria flows in so-called Aquifers. These Aquifers are natural water transport systems. Most of the groundwater flows towards rivers. Aquifers are sealed up at the bottom by clay. Wells are built on Aquifer underground lakes, which make the uses of pumps inevitable. Surface sources are aquifers, which hit the surface at a certain point. Usually sources are located on top of an underground stream to guarantee a continuous flow without the use of pumps.

There are 3 technical utilised levels of groundwater in Austria:

1st level: The groundwater is in connection with the surface. Generally speaking the water is about 50 days old before use and is located in 8-10 metres depth. This water makes up the bulk of the water used by private persons (8-10 meters).

2nd level: The 2nd level groundwater is also called deepwater. There is little nitrate and oxygen in the water. This waters shows reducing conditions. The nitrogen will be present as ammonium and the sulphate will be partly present as sulphide (smell of rotten eggs). This water is about 50 years old and in a depth of 10-20 metres.

3rd level: In this water there is no sulphate, no oxygen, no nitrates and no iron (III). Traces of heavy metals can be found in these waters, which are strongly reducing (sulphide, ammonium). This water is in a depth of 20-250 meters.
[6]

- Karst sources in the Limestone Alps are not as stable as groundwater to weather situations. The Limestone Alps are built up of cliffs and ravines through which surface water (rain, snow, glacier run-off) can flow. There is very little filtering effect, and therefore the water might be microbiologically questionable during extreme weather conditions. In regions where karst sources are used for human drinking water supply, strict controls are put in place to prevent any contamination. The water has a slightly increased total hardness as the water flows through the CaCO₃ formations.

The sources originate directly out of the mountain and the water is approximately 3-6 days old. Vienna, the Austrian capital, is supplied by karst sources.

[12]

- Dolomite sources originating in the Dolomite Alps produce the best drinking water in Austria. The water is fine-filtered by flowing through the dolomite stone MgCa(CO₃)₂. The water sinks slowly through the dolomite. The sources are however not as productive as karst sources.

[12]

- Vienna has an emergency drinking water supply, which is made up of wells next to the Danube. This bank-filtrate is river water filtered through the sandbank. This alternative drinking water supply was introduced after the disaster of Chernobyl. If the Viennese karst sources become polluted, the inhabitants would be affected within 10 days. This is why the riverbank-wells, which are more stable to sudden changes, were built, but are not in use under normal circumstances.
[12]
- In Austria there is no real surface water. The drinking water is never taken from rivers, reservoirs, lakes or any other water features.

1.2. Economic Situation

Water in Austria is not free. The prices vary from 50 cent – 5€ per cubic metre, but an average of 1.50€/m³. In recent years a slight cost increase was seen.

If the communal water suppliers (mostly cities and towns) build a drinking water supply, residents in that area have to get connected, or prove that their private well has perfect drinking water quality. However the water suppliers can still enforce a connection to their central water supply.

There are very few private suppliers of drinking water and the ones existing are usually part owned by the government.
[13]

1.3. Situation Waldviertel

The region in the northeast of Lower Austria is called Waldviertel. It is a region that ranges from the river Danube to the Austrian-Czech border.

The water quality in Waldviertel is comparable with Scandinavia, Czech Republic, Scotland, Russia, and all moor regions. [15]

The water in Waldviertel is a first and second level groundwater. Depending on the region some towns have a deep well supply and therefore a drinking water classified as 2nd level Aquifer water.

In general the water quality in Waldviertel is the worst in whole Austria. The water has a very low pH value of about 4.5, which leads to problems at the drinking water treatment, but also in wastewater treatment. The microbiology in wastewater treatment plants is negatively affected by this low pH value. The pH value is due to the high amount of CO₂. The CO₂ is produced by decomposition of humus and the absorption from air. There is also a very large amount of humic substances in the water, which are big organic molecules, which can shield microorganisms during UV disinfection. Therefore Humic Acids are classified as a secondary contamination hazard. [7]

The untreated groundwater has normally a very low total hardness, therefore the water is very unstable and unbuffered. [11]

1.4. Situation City of Schrems

Schrems has one of the better drinking water qualities in Waldviertel. Its 3 wells and 2 sources are first level groundwater.

Normal Situation at Schrems:

- low pH value
- low conductivity
- high Iron and Manganese concentrations
- low water hardness
- Iron complexed with Humic Substances
- high contents of oxidisable substances
- UV Permeability of about 40-50%

[13]

Situation during snowmelt and/or string rain, i.e. extreme weather situations

- Iron and Manganese concentrations increase
- Conductivity decreases
- UV permeability falls below the required 20%

1.5. Questions of Interest:

Lower Austrian government:

- What is the correlation between TOC value and KMnO_4 value?
- How can iron removal be optimised in the filters?
- How can the Iron complexed with humic substances be removed?
- How can the drinking water treatment plant function be optimised during extreme weather conditions to ensure an UV permeability of >20%?

[11]

City of Schrems:

- How do the values of each parameter compare to each other – multivariate analysis of certain parameters?
- What is the trend of each parameter vs. time?
- How is the functionality of every treatment step affected by varying raw water conditions?

[12,13]

The following parameters were monitored daily for 4 weeks and under extreme weather conditions:

- UV Permeability
- SAK 254
- SAK 436
- Iron
- Manganese
- Total Hardness
- Carbonate Hardness
- pH value
- Conductivity
- KMnO_4 value

- TOC value
- Ozone

The parameters were measured for every well and source and after every treatment step → sampling points:

- Well Langeegg
- Well Kollersdorf
- Forest Well
- Source Langeegg
- Source Kottlinghörmanns
- Before Aeration
- Before Ozonation
- After Ozonation
- After filter 1
- After filter 2
- After filter 3
- After filter 4
- Before deacidification and remineralisation filter
- After deacidification and remineralisation filter
- After activated carbon filter
- Distributed drinking water of the city of Schrems

Samples were taken at 8 o'clock in the morning and at 4 o'clock in the evening.

1.6. Aims of this Project

The water supply in Austria is very traditional and old-fashioned. Only in recent years a strict drinking water control system was introduced. As a result of this it was seen in detailed analysis, that the sources have a very varying behaviour depending on the weather situation. The City of Schrems was interested in the change of their sources during snowmelt.

It is important for the Waldviertel region that the influences of snow melt and flooding are monitored to know the effect on the drinking water treatment plants.

It is necessary for the responsible people to know how a drinking water treatment plant can be optimised to increase the drinking water quality.

A correlation between a KMnO_4 value and a TOC value is required by the Lower Austrian government, because both tests are seldom available at the same time in every laboratory. It is also important to know the precision of each method in respect to the other.

The drinking water treatment plant of the City of Schrems under all circumstances shall attain the following parameters.

Austrian drinking water bylaw (BGBl 304/2001): indicating parameters

- SAK 436: 0.5 m^{-1}
- Manganese: 0.05 mg/l
- KMnO_4 : 5.0 mg/l O_2
- TOC: values without abnormal variation
- Total Iron: 0.2 mg/l
- Conductivity: 2500 mS/cm
- pH value: 6.5-9.5

Codex Alimentarii Austriaci: guidelines

- Total Hardness: $8.4 \text{ }^\circ\text{dH}$
- Carbonate Hardness: for informational purposes only
- SAK 254: 2.0 m^{-1}
- UV Permeability: 2.0 m^{-1}

UV Permeability and SAK 254 should be the same;
EU regulation exactly same as the bylaw parameters

2. Materials and Methods

2.1. Description of the Drinking Water Treatment Plant of the City of Schrems

The drinking water treatment plant of the City of Schrems is designed to supply 10000 people. The plant is relatively new, the oldest parts being the aeration tower and the ozonation plant (13 years old).

The 2 sources are collective sources of many different sourcing points. The sources are collected together, as they show similar behaviour.

Of the three wells, the Langeegg well is the one that is used most. It produces the most water and is the most stable of all three wells. The Well Kottinhörmanns is only switched on when the Well Langeegg and the sources together cannot deliver enough water. The forest well, having the worst water quality of all the wells is only an “emergency well” and very rarely connected to the treatment plant.

[13]

Piping Scheme, City of Schrems, 7.11.2005

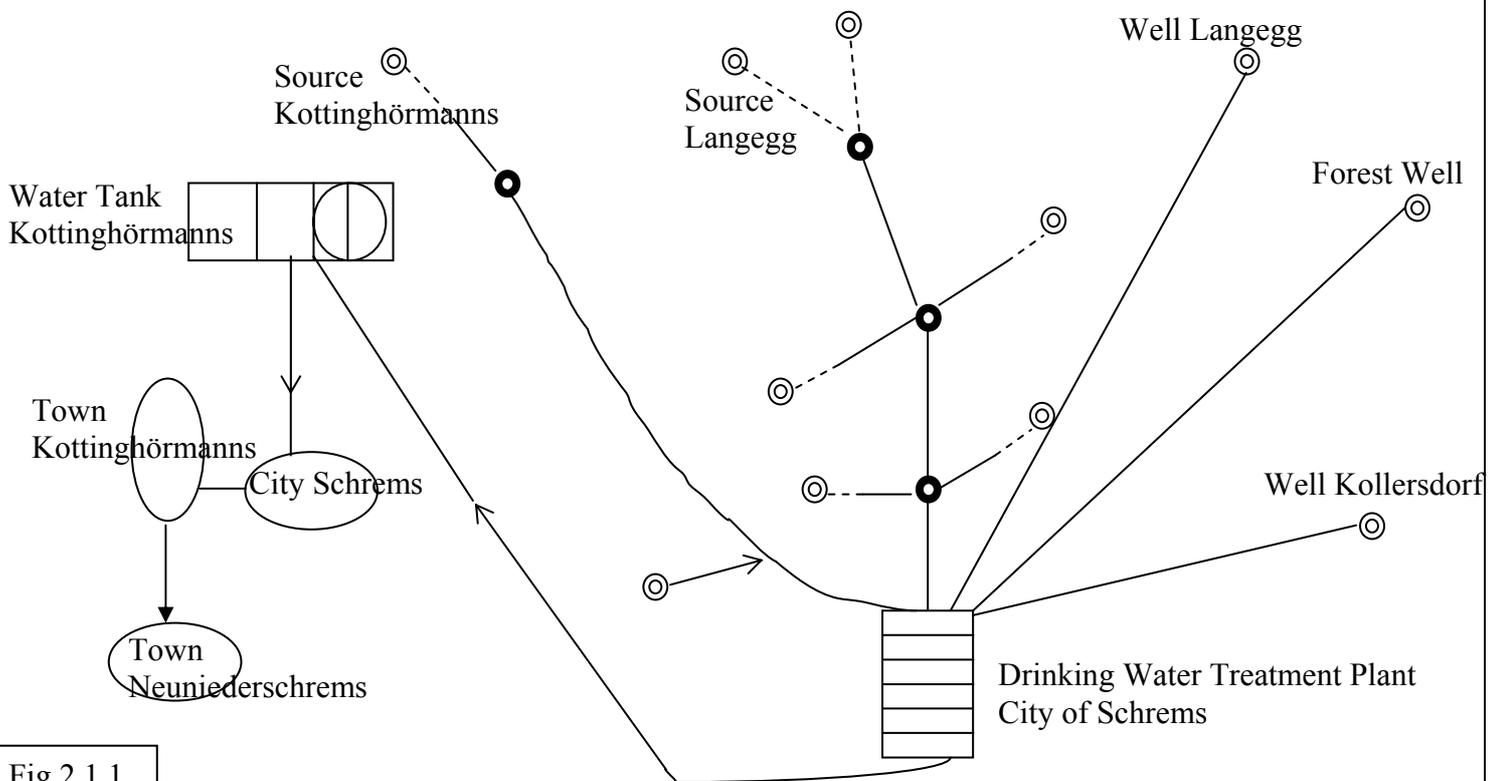


Fig 2.1.1.

[12]

Drinking Water Treatment Plant Eugenia, City of Schrems [9]

Aeration-Plant

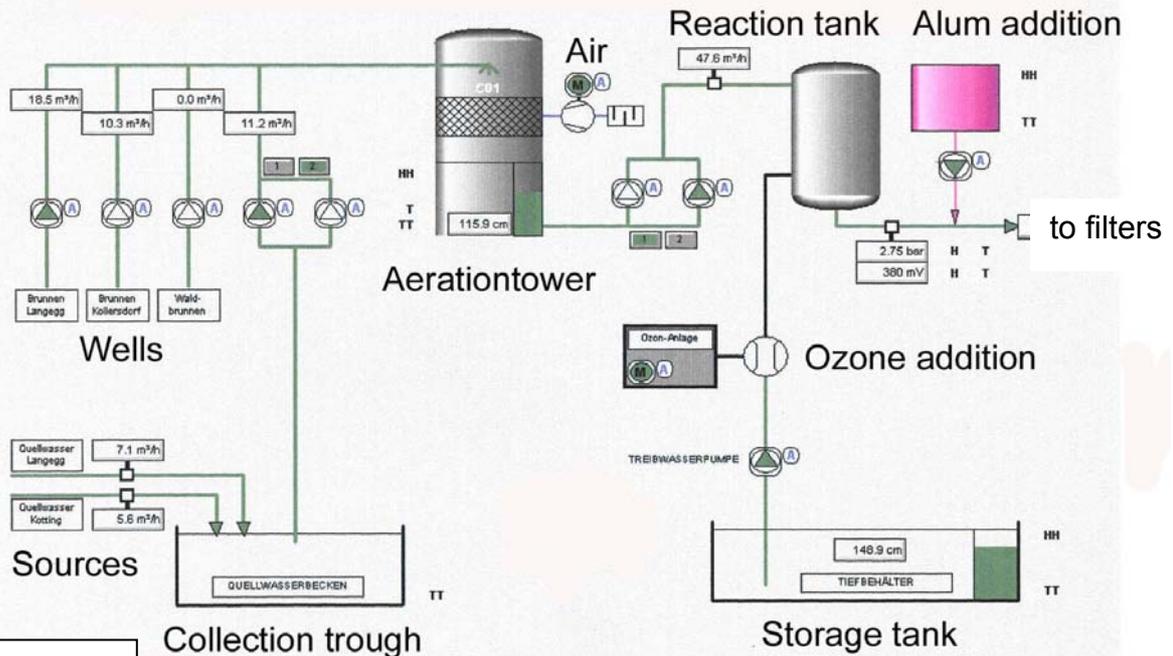


Fig. 2.1.2

Filtration Plant (4 Tanks)

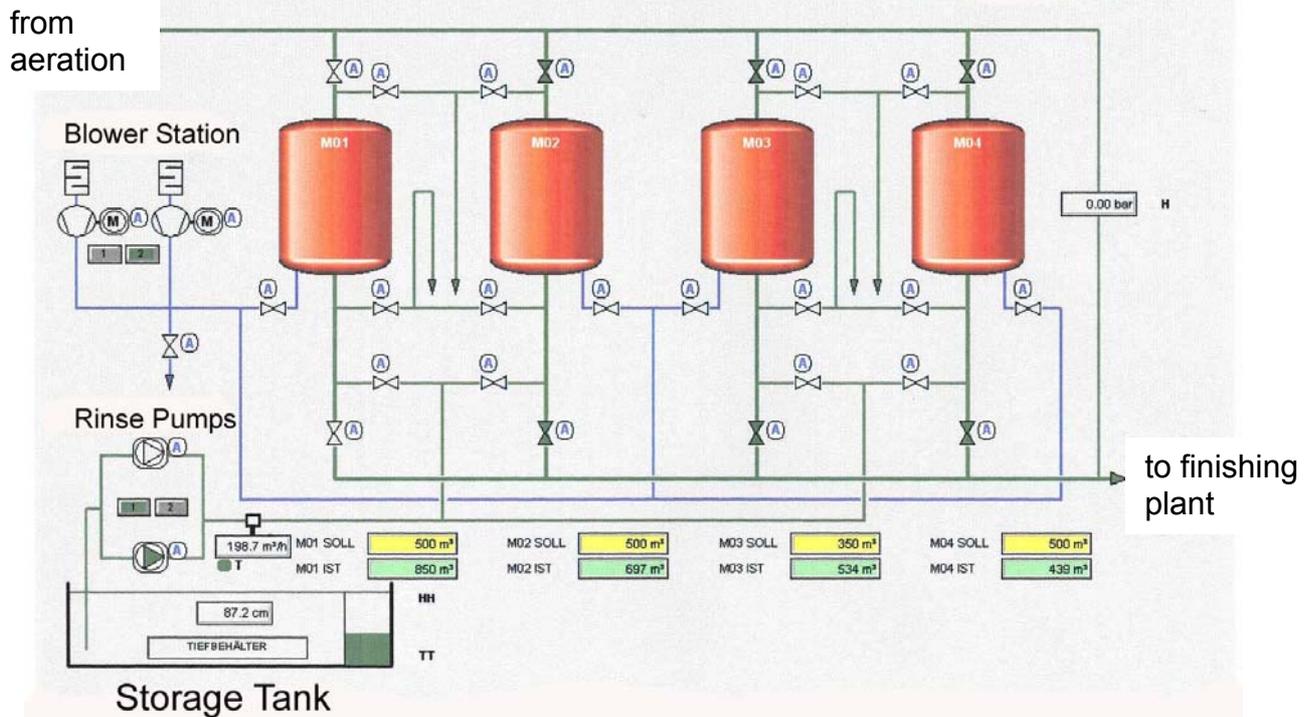


Fig. 2.1.3

Finishing Plant

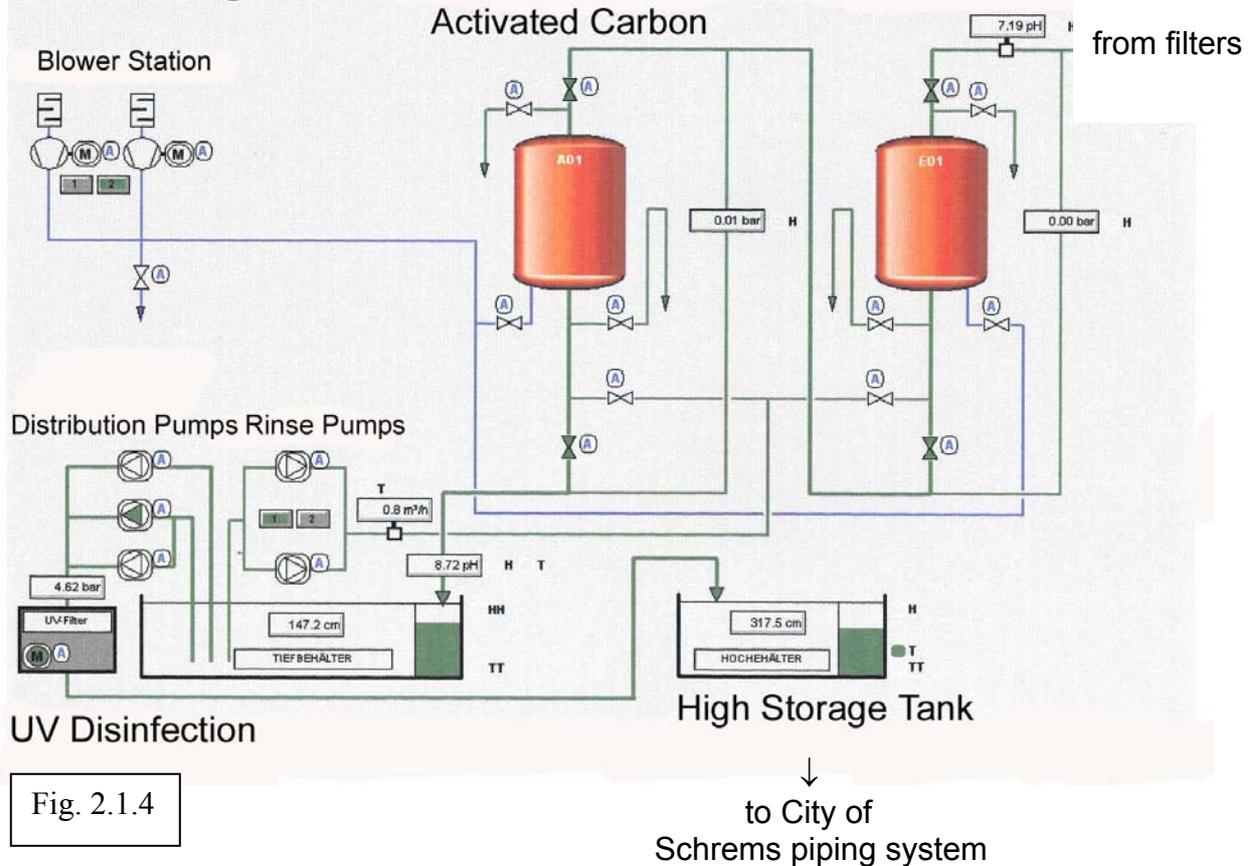


Fig. 2.1.4

- Aeration plant:

The Aeration plant is at the beginning of the drinking water treatment. The water from the sources is collected together in one trough. This is done to equilibrate extreme peaks in the water and to have always a little more water than actually needed for emergency scenarios. The City of Schrems would be allowed to use the water from the sources as drinking water without treatment. [12]

The three wells can be separately switched on/off via valves. The water from the sources and from each well can be used for drinking water treatment but do not have to. [13]

Usually the water from the sources, the Well Langegg and the Well Kottinghörmanns are used for drinking water treatment and mixed together before the Aeration tower. [13]

In the Aeration tower CO₂ in the water is expelled by air to increase the pH value.

As an unwanted further effect some of the Iron (II) gets oxidised by O₂ and transformed into Iron (III) which falls out (Iron starts to flocculate at a pH value of 2.5). [4]

The ozonation has two main functions. It is used to oxidise Manganese and cracks the organic humic substances, which decrease the UV permeability. These are oxidised to CO_2 and H_2O .

Ozone, as seen during this project work also functions to crack the iron complexed with humic substances. The Iron can then be removed better in the multilayer filters. . [12]

Aluminium sulphate addition: This is the only treatment step that was intended for Iron removal. The Iron removal should work with Aluminium Hydroxide flocculation. Aluminium hydroxide binds strongly (adsorption) to Iron as well as Humic Acids. The gel like iron aluminium hydroxide compound can be easily removed in the filters. . [13]

- Filtration units

There are four multilayer filters, as the filtering cycle is the most time consuming part in the drinking water treatment. One of the four filters is always on standby or executing the washing procedure. The washing cycle was also optimised during this project, as the filter washing times are really important for a good filtering effect. The washing times have been analysed at 850, 500 and 400m³ flow rate.

The topmost layer of the multilayer filters is made up of Hydroanthrazite. This layer attracts Manganese Dioxide. As soon as some Manganese Dioxide is present more Manganese Dioxide can be formed (product catalysis). After a certain amount of Manganese dioxide has been build up on the Hydroanthrazite layer no more ozone is necessary to oxidise Manganese. This can be achieved by O_2 only.

In the filters the aluminium and Iron “flocs” should be removed. . [14]

- Finishing plant

The remineralisation/deacidification filter is filled with “Aktolit”, a mixture of partly calcinated CaCO_3 and a little MgCO_3 . The purpose of the remineralisation is to increase the total hardness. The optimal value for total hardness would be 10 °dH (= 2mmol/l). The minimum recommended value of 8.4 °dH (= 1.5mmol/l) however is never reached, because the water is so soft in Waldviertel. The deacidification of the water brings the pH value from approximately 6.8 to 8.2. . [12]

The activated carbon filter is the filter with the biggest surface. Due to this Ozone and Humic Acids are removed. If there is any Iron complexed into the humic substances, this Iron is clogging the filter pores, thus reducing the surface. One of the aims of this project was to remove all iron complexed with humic substances in the multilayer filters to increase the lifetime of the activated carbon filtration unit. . [14]

UV disinfection: The UV disinfection works only at a minimum of 20% UV permeability. Below this value the drinking water treatment plant shuts down, because the removal of all microorganisms cannot be guaranteed under such circumstances.

The UV disinfection works at 254 nm where a certain part of a bacteria's DNA gets denatured, thus killing the microorganism. . [12]

In the High Storage Tank the water is stored for at least two days. The freshly treated water is mixed with large amounts of older water to equilibrate the water quality.

Some Iron and Manganese falls out in the High Storage Tank, which has to be cleaned therefore regularly. The removal of all the Iron and Manganese during the treatment is first priority at the drinking water treatment plant in Schrems. . [13]

2.2. Materials/Equipment and Methods. [8, 10, 16]

The detailed working procedures of the "Hach-Lange" photometric methods, German procedures of all other methods and a description of the "Xion 500 Hach-Lange" spectrometer and the "PM-02 Dr. Gröbel" photometer can be found in the appendix.

Water sampling:

„Schott“ 500ml glassbottles are most suitable for taking drinking water samples, which do not have to be sterile. The bottle should be washed with deionised water and three times with the sample water. The tap from which the water sample is taken should be left running for some time, to ensure no old water from the piping system is sampled. For metal analysis an extra water sample should be taken. This water sample should be preserved by 1-2% conc HNO₃ and is taken in a LDPE plastic bottle.

SAK 436:

“Xion 500 Hach-Lange” Spectrometer

The water sample is filtered with a membrane filter (0,45µm) to remove particles. The sample is then measured using a quartz cuvette (10cm) in the photometer at 436nm

UV Permeability:

“UVC-Photometer PM-02 Dr.Groebel”

The absorption of the water sample is measured at 254 nm (vs. 18.2 MΩ H₂O)

SAK 254: . [2]

“UVC-Photometer PM-02 Dr.Gröbel”

After filtration of the water sample using a membrane filter (0,45µm) the absorption is measured at 254 nm (vs 18.2 MΩ H₂O)

$$SAK_{436}, SAK_{254} \text{ or UV} = E/D \quad [m^{-1}]$$

SAK₄₃₆, SAK₂₅₄, UV spectral absorption coefficient (SAK) [m⁻¹]
E extinction (absorption)
D length [m]

Manganese:

conc HNO₃

“Hach-Lange” photometric method LCW 032

All manganese ions are reduced to manganese (II) ions with ascorbic acid. In weakly alkaline solutions these react with 1-(2-pyridylazo)-2-naphthol (PAN) to form a red complex, which is measured photometrically

Iron:

conc HNO₃

“Hach-Lange” sample preparation LCW 902

“Hach Lange” photometric method LCW 021

The water sampled is heated with Sulphuric Acid and Ammoniumperoxidisulphate to crack the Iron complexed with humic substances.

By reduction with ascorbic acid all iron ions are transformed into iron (II) ions in a buffered medium, these react with 2,2-bipyridine to form a red complex, which can be measured photometrically.

TOC (Total Organic Carbon):

“Hach-Lange” photometric method LCK 380

By digestion with sulphuric acid and Peroxidisulphate, Carbon containing compounds are transformed into Carbon dioxide. This reacts with an indicator solution. Inorganic bound Carbon is expelled in gaseous form beforehand by acidification.

Ozone:

“Hach-Lange” photometric method LCK 310

In weakly acidic solution Ozone reacts with Dipropyl-para-phenylenediamine (DPD) to form a red/violet dye, which can be measured photometrically

pH:

Microprocessor pH-Meter, WTW pH 95, pH/Cond 340i
pH-electrode, WTW SenTix 41, WTW SenTix 21
certified buffersolutions Merck pH 7.00 & 10.00 / WTW 4.01 & 7.00
KCl (3M) (electrode conservation solution)

The pH electrode has to be cleaned using distilled water before each use. The electrode is immersed in the fresh water sample and moved until there is a stable reading. The electrode has to be calibrated frequently. After use the electrode has to be stored in KCl solution.

Conductivity:

WTW LF 330 with stand. conductivity measuring cell, TetraCon® 325
KCl solution CertiPUR Merck 1.01203 (1,41 mS/cm at 25°C)

The conductivity electrode has to be cleaned using distilled water before each use. The electrode is immersed in the fresh water sample and moved until there is a stable reading. The electrode has to be calibrated frequently.

Total Hardness:

Titriplex-Solution III 0,1mol/l, Merck No. 1.09992
Ammonia solution, conc. (25%), Merck No. 1.05432
Indicator Buffertablets, Merck Nr. 1.08430
Calcium-Standardsolution CertiPUR Merck 1.19778
Magnesium-Standardsolution Fluka Chemika 63041
Control sample (Ca+Mg salt solution) 1 mL in 100 mL H₂O

The total hardness is determined by volumetric titration of Ca and Mg with EDTA against "Murexin". The colour change is from red to green.

When using 100ml water sample 1ml 0,1M Titriplex-Lösung III equals 1mmol/l (Ca+Mg)

1mmol/l (Ca+Mg) equals 5.6°dH

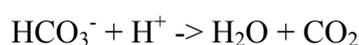
Carbonate Hardness:

Sulphuric Acid 0,05 mol/l
Sodium Carbonate p.a. Merck 1.06392
Control Sample (Sodium carbonate) solution with 1 mL in 100 mL

Carbonate hardness is determined by the volumetric titration of Hydrogen carbonate with Sulphuric Acid against Methyl Orange. Colour change from yellow to pink.

When using 100ml water sample 1ml 0,05M H₂SO₄ equals 1mmol/l

1mmol/l equals 2.8°dH



KMnO₄ value:

Sulphuric Acid conc. 95-97%, 18 mol/l, Merck No. 1.00731

Sulphuric Acid 2 mol/l

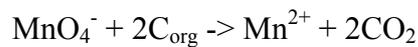
di-sodium oxalate, Merck No. 1.06557

Potassiumpermanganate Titrisole 0,02 mol/l, Merck No. 1.09935

Potassiumpermanganate solution 0,002 mol/l

Control sample (Resorcine-solution)

The water sample is heated with Sulphuric Acid and Potassium Permanganate. Oxidisable substances in the sample reduce some of the permanganate. The reduced amount of permanganate is then measured by titration with Potassium Permanganate after adding excess of Sodium Oxalate solution.



$$\frac{V_1 - V_0}{V_2} * f = I_{Mn} = \text{mg/l O}_2 \quad f = 16$$

V₀ zero value (distilled water)

V₁ sample value

V₂ standardisation of Potassium permanganate with 5 ml of equimolar Sodium Oxalate solution

3. Test Arrangement and Procedure

3.1. Test Arrangement

Three types of samples had to be taken from each tap:

- “preserved” water sample for iron and manganese analysis
- “carefully” taken sample, to ensure no air is left in the sample bottle, which has to be analysed straight away for ozone
- “normal” water sample for every other analysis

After measuring Ozone, pH and conductivity were measured.

UV permeability, SAK 254 and SAK 436 were measured afterwards, when the water had reached a certain temperature (8°C) to prevent a hazing up of the quartz cuvette in the UV-Vis spectrometer.

The water samples were then used for the KMnO_4 and Hardness analyses.

Finally the metal analyses were carried out, because the water samples did not change because they are preserved by acid. [12]

3.2. Experimental Procedure

The filters in the drinking water treatment plant should remove Iron with the help of a substance with the trade name “Alifat” (Aluminium sulphate). “Alifat” is a substance that works best at a pH range of 6.9-7.2. The raw water after ozonation has a pH value of max 6.8, but normally well below that. With the help of Sodium Hydroxide the pH was brought to a value of 7.1. It was seen that the iron removal in the filters did increase slightly. More importantly, after the increase in pH it was seen, that no more iron was removed in the remineralisation and activated carbon filters, which was decreasing the filter effect vastly. [14]

4. Discussion and Results

4.1. Results

8.00 PN	Parameter Einheit	Durchfluss m³/d	pH	LF µS/cm	KH °dH	GH °dH	Fe filtriert mg/l	Fe mg/l	Mn mg/l	UV Durchl. 254nm %	SAK254 %	SAK436 1/m	KMnO4 mg/l	Ozon mg/l	TOC
1	Brunnen	236	6.25	327	2.1	4.48		0.588		8	11	0.018	2.1		
2	Kollersdorfer	132	5.75	168	2.1	4.2		0.244		7	7	0.019	2.4		
3	Waldbrunnen	85	6.69	215	4.2	2.62		1.304		0	1	0.054	5.9		
4	Quellwasser		5.64	116	0.84	3.08		0.11		26	27	0.001	0.9		
5	Quellwasser	201	5.01	259	0.7	3.92		0.071		26	26	0.002	0.6		
6	vor Riesler		6.15	225	1.96	5.32		0.56		5	8	0.014	2.1		
7	nach Riesler	654	6.67	229	2.1	4.76	0.33	0.536		6	7	0.016	2.4		
8	nach Ozon		6.81	243			0.241	0.427		7	8	0.019		0.026	
9	nach Filter 1	0								23					
10	nach Filter 2	218	6.69	243	1.96	4.48		0.112		23	35	0	1.3		
11	nach Filter 3	217	6.69	242	2.1	4.2		0.1		24	34	0	0.8		
12	nach Filter 4	218	6.7	243	1.96	4.48		0.113		27	35	0	0.5		
13	vor Entsauerung		6.71	245	2.1	4.76		0.101		28	36	0	1.3		
14	nach		8.36	290	3.5	6.16		0.055		31	31	0	1.1		
15	nach Aktivkohle		8.33	291	3.64	6.16		0.049		33	34	0	1.0	0.018	
16	nach		8.23	309	3.5	6.44	0.069	0.054		44	44	0	1.1		

16.00 PN	Parameter Einheit	Durchfluss m³/h	pH	LF µS/cm	KH °dH	GH °dH	Fe filtriert mg/l	Fe mg/l	Mn mg/l	UV Durchl. 254nm %	SAK254 %	SAK436 1/m	KMnO4 mg/l	Ozon mg/l	Ozon mg/l
21	Langegger														
22	Kollersdorfer														
23	Waldbrunnen														
24	Quellwasser														
25	Quellwasser														
26	nach														

Parameter Einheit	KH ml	GH ml	Fe filtriert mg/l	Fe mg/l	KMnO4 ml
1	0.75	0.8		0.637	1.24
2	0.75	0.75		0.293	1.34
3	1.5	0.45		1.353	2.5
4	0.3	0.55		0.159	0.86
5	0.25	0.7		0.12	0.76
6	0.7	0.95		0.609	1.24
7	0.75	0.85	0.379	0.585	1.34
8			0.29	0.476	
9					
10	0.7	0.8		0.161	0.98
11	0.75	0.75		0.149	0.82
12	0.7	0.8		0.162	0.74
13	0.75	0.85		0.15	0.98
14	1.25	1.1		0.104	0.92
15	1.3	1.1		0.098	0.9
16	1.25	1.15	0.118	0.103	0.92

26.3.2006: Beginning of flooding, all set target analyses were reached

8.00 PN	Parameter Einheit	Durchfluss m³/d	pH	LF µS/cm	KH °dH	GH °dH	Fe filtriert mg/l	Fe aufgeschl. mg/l	Mn mg/l	UV Durchl. 254nm %	SAK254 %	SAK436 1/m	KMnO4 mg/l	Ozon mg/l	TOC mg/l
1	Brunnen	326	6.4	310	1.96	4.48		0.201	3	5	0.02	3.5		9.58	
2	Kollersdorfer	102	6.06	198	2.24	5.6		0.176	1	2	0.03	4.5		10.9	
3	Waldbrunnen	2	6.58	205	3.78	5.6		0.401	0	0	0.063	7.0		12.2	
4	Quellwasser		5.98	106	0.7	2.52		0.113	1	2	0.026	3.6		7.04	
5	Quellwasser	314	5.07	225	0.42	3.36		0.129	2	2	0.019	4.6		7.24	
6	vor Riesler		5.96	212	1.12	4.48		0.159	2	3	0.02	3.9		8.01	
7	nach Riesler	744	6.34	211	1.54	3.36		0.159	2	4	0.018	3.8		7.41	
8	nach Ozon		6.58	217				0.136	3	5	0.015		0.089		
9	nach Filter 1	85	6.45	221	1.12	3.92		0.092	15	25	0	1.6		7.69	
10	nach Filter 2	247	6.47	220	1.26	3.92		0.07	23	22	0.003	1.7		6.77	
11	nach Filter 3	161													
12	nach Filter 4	247	6.44	222	1.26	4.2		0.089	16	24	0	1.8		6.57	
13	vor Entsauerung		6.46	222	1.26	3.64		0.079	19	25	0	1.4		5.91	
14	nach		7.97	261	2.66	5.04		0.038	17	21	0.001	2.3		6.04	
15	nach Aktivkohle		8.07	265	2.94	5.32		0.024	19	22	0	1.7	0.007	5.89	
16	nach		8.05	283	3.08	5.6		0.018	27	27	0	0.9		5.51	

16.00 PN	Parameter Einheit	Durchfluss m³/h	pH	LF µS/cm	KH °dH	GH °dH	Fe filtriert mg/l	Fe aufgeschl. mg/l	Mn mg/l	UV Durchl. 254nm %	SAK254 %	SAK436 1/m	KMnO4 mg/l	Ozon mg/l	Ozon mg/l
21	Langegger		6.43	290						0					
22	Kollersdorfer		6.1	195						1					
23	Waldbrunnen		6.56	205						0					
24	Quellwasser		5.83	105						2					
25	Quellwasser		5.08	221						2					
26	nach		8	283						28					

Parameter Einheit	KH ml	GH ml	Fe filtriert mg/l	Fe aufgeschl. mg/l	KMnO4 ml
1	0.7	0.8			1.78
2	0.8	1			2.08
3	1.35	1			2.88
4	0.25	0.45			1.82
5	0.15	0.6			2.12
6	0.4	0.8			1.9
7	0.55	0.6			1.86
8					
9	0.4	0.7			1.18
10	0.45	0.7			1.2
11					
12	0.45	0.75			1.24
13	0.45	0.65			1.12
14	0.95	0.9			1.4
15	1.05	0.95			1.2
16	1.1	1			0.96

30.3.2006: Results from TOC analysis obtained, comparison TOC – KMnO₄ values, peak of flooding

8.00 PN	Parameter Einheit	Durchfluss m ³ /d	pH	LF	KH %dH	GH %dH	Fe filtriert mg/l	Fe aufgeschl mg/l	Mn mg/l	UV Durchl. 254nm %	SAK254 %	SAK436 1/m	KMnO4 mg/l	Ozon mg/l	TOC
1	Brunnen	452	6.38	261	1.68	3.36		0.307		2	2	0.035	6.2		
2	Kollersdorfer	145	5.85	161	1.4	3.92		0.287		1	1	0.043	7.4		
3	Waldbrunnen	17	6.52	187	3.36	5.6		1.173		0	1	0.055	8.3		
4	Quellwasser		5.91	123	0.7	3.08		0.107		4	5	0.023	5.4		
5	Quellwasser	209	4.95	244	0.7	3.92		0.102		2	2	0.026	7.5		
6	vor Riesler		6.19	212	1.68	3.36		0.434		1	2	0.035	6.9		
7	nach Riesler	823	6.58	216	1.68	3.36	0.2	0.395		1	2	0.037	7.8		
8	nach Ozon		6.77	226			0.173	0.34		2	2	0.033			
9	nach Filter 1	273	6.73	233	1.54	3.92		0.154		7	14	0.009	5.2		
10	nach Filter 2	103													
11	nach Filter 3	171	6.7	235	1.82	3.92		0.105		10	14	0.009	4.5		
12	nach Filter 4	274	6.75	234	1.82	3.92		0.141		8	15	0.011	5.4		
13	vor Entsauerung		6.73	235	1.82	3.92		0.142		8	14	0.013	4.6		
14	nach		8.19	274	3.36	6.72		0.053		13	13	0.01	4.3		
15	nach Aktivkohle		8.31	275	3.36	5.88		0.057		15	15	0.009	4.1		
16	nach		8.22	283	3.22	6.16	0.098	0.045		18	18	0.009	3.9		
16.00 PN	Parameter Einheit	Durchfluss m ³ /h	pH	LF µS/cm	KH %dH	GH %dH	Fe mg/l	Fe aufgeschl mg/l	Mn mg/l	UV Durchl. 254nm %	SAK254 %	SAK436 1/m	KMnO4 mg/l	Ozon mg/l	Ozon mg/l
21	Langegger		6.2	248						2					
22	Kollersdorfer		5.91	161						1					
23	Waldbrunnen		6.43	187						0					
24	Quellwasser		5.71	122						4					
25	Quellwasser		5.07	245						3					
26	nach		8.11	366						20					
Parameter Einheit					KH ml	GH ml	Fe filtriert	Fe aufgeschl					KMnO4 ml		
1	Brunnen				0.6	0.6		0.356					1.94		
2	Kollersdorfer				0.5	0.7		0.336					2.32		
3	Waldbrunnen				1.2	1		1.222					2.6		
4	Quellwasser				0.25	0.55		0.156					1.68		
5	Quellwasser				0.25	0.7		0.151					2.34		
6	vor Riesler				0.6	0.6		0.483					2.16		
7	nach Riesler				0.6	0.6	0.249	0.444					2.42		
8	nach Ozon						0.222	0.389							
9	nach Filter 1				0.55	0.7		0.203					1.62		
10	nach Filter 2														
11	nach Filter 3				0.65	0.7		0.154					1.4		
12	nach Filter 4				0.65	0.7		0.19					1.7		
13	vor Entsauerung				0.65	0.7		0.191					1.44		
14	nach				1.2	1.2		0.102					1.34		
15	nach Aktivkohle				1.2	1.05		0.106					1.28		
16	nach				1.15	1.1	0.147	0.094					1.22		

7.4.2006: Ozonation was cleaned and repaired, to study the effect of Ozone on UV Permeability, Iron complexed with humic substances, and the water quality in general

8.00 PN	Parameter Einheit	Durchfluss m ³ /d	pH	LF	KH %dH	GH %dH	Fe filtriert mg/l	Fe aufgeschl mg/l	Mn mg/l	UV Durchl. 254nm %	SAK254 %	SAK436 1/m	KMnO4 mg/l	Ozon mg/l	TOC
1	Brunnen	214	6.37	260	1.4	4.2		0.391		2	3	0.031	4.2		
2	Kollersdorfer	1	5.85	165	1.4	4.2		0.269		1	1	0.042	4.8		
3	Waldbrunnen	1	6.49	188	3.36	5.6		1.075		0	1	0.053	5.2		
4	Quellwasser		5.74	122	0.7	3.08		0.083		5	5	0.026	2.4		
5	Quellwasser	275	4.82	251	0.56	3.92		0.108		2	3	0.026	3.9		
6	vor Riesler		6.22	206	1.4	3.36		0.397		1	2	0.033	3.8		
7	nach Riesler	491	6.66	209	0.98	3.36	0.124	0.31		2	3	0.034	3.7		
8	nach Ozon		6.71	223			0.13	0.249		15	6	0.02		1.06	
9	nach Filter 1	68	6.59	227	1.12	5.04		0.075		35	43	0.008	1.4		
10	nach Filter 2	162	6.57	226	0.98	4.2		0.072		39	26	0.006	1.2		
11	nach Filter 3	146	6.61	227	0.98	4.2		0.072		46	47	0.003	0.3		
12	nach Filter 4	110													
13	vor Entsauerung		6.59	228	0.98	4.2		0.054		41	46	0.003	0.8		
14	nach		8.16	267	2.38	5.6		0.053		36	38	0.006	1.0		
15	nach Aktivkohle		8.29	266	2.66	5.6		0.045		35	34	0.007	1.3	0.033	
16	nach		8.07	277	2.8	5.6	0.061	0.055		24	25	0.009	2.4		
16.00 PN	Parameter Einheit	Durchfluss m ³ /h	pH	LF µS/cm	KH %dH	GH %dH	Fe mg/l	Fe aufgeschl mg/l	Mn mg/l	UV Durchl. 254nm %	SAK254 %	SAK436 1/m	KMnO4 mg/l	Ozon mg/l	Ozon mg/l
21	Langegger														
22	Kollersdorfer														
23	Waldbrunnen														
24	Quellwasser														
25	Quellwasser														
26	nach														
Parameter Einheit					KH ml	GH ml	Fe filtriert	Fe aufgeschl					KMnO4 ml		
1	Brunnen				0.5	0.75		0.44					2.04		
2	Kollersdorfer				0.5	0.75		0.318					2.24		
3	Waldbrunnen				1.2	1		1.124					2.36		
4	Quellwasser				0.25	0.55		0.132					1.46		
5	Quellwasser				0.2	0.7		0.157					1.94		
6	vor Riesler				0.5	0.6		0.446					1.92		
7	nach Riesler				0.35	0.6	0.173	0.359					1.88		
8	nach Ozon						0.179	0.298							
9	nach Filter 1				0.4	0.9		0.124					1.16		
10	nach Filter 2				0.35	0.75		0.121					1.08		
11	nach Filter 3				0.35	0.75		0.121					0.8		
12	nach Filter 4														
13	vor Entsauerung				0.35	0.75		0.103					0.94		
14	nach				0.85	1		0.102					1.02		
15	nach Aktivkohle				0.95	1		0.094					1.1		
16	nach				1	1	0.11	0.104					1.48		

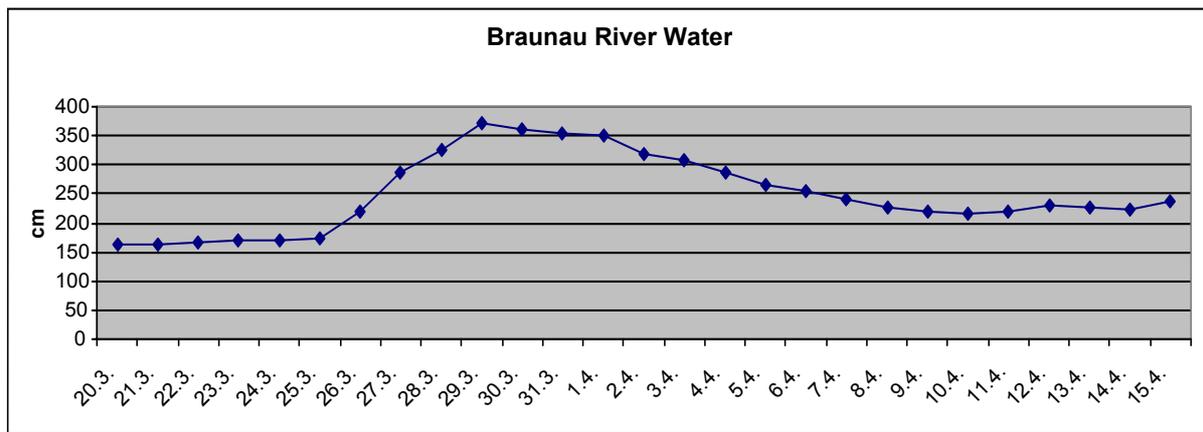
8.4.2006: Repaired ozonation works without fault, big impact on UV Permeability can be seen

4.2. Discussion of Methods [12, 16]

- *pH value, conductivity:*
The electrodes had to be calibrated frequently to give the right reading. This was done with certified buffer solutions. Additionally a control sample was run every day
- *UV permeability, SAK 254, SAK 436:*
The spectrometers are calibrated each year
- *Manganese, Ozone:*
Following the correct procedure the photometric determination of these parameters yielded sensible results
- *Carbonate Hardness:*
The samples were used undiluted because there was little carbonate hardness in the water samples
- *Total Hardness:*
High iron contents (forest well) influence the correct titration for the total hardness value. Thus it was necessary to dilute the water samples at different ratios, depending on the iron content and the expected total hardness value.
- *TOC:*
The TOC value is not a very precise value. As with the KMnO_4 value the TOC test only shows a trend in oxidisable substance. The test yields results, but they are no absolute values.
- *KMnO_4 value:*
The Potassium permanganate value for oxidisable substances is very relative. For the test there is an acceptance limit of $\pm 25\%$ in the EU. The values are not absolute values and can at best only show a trend in oxidisable substances. The results obtained do not correlate very well to each other, making this test the hardest to interpret.
- *Iron:*
It was crucial to crack the samples before analysing for iron, as a lot of iron is complexed with humic substances. The samples had to be diluted down by 50% because of the very high iron contents. In comparison with Atomic Absorption Spectroscopy the results obtained are only relative. However as the results do not vary vastly from one day to another a trend can be seen, although the values should not be accepted as absolute values. The photometric method is much cheaper and faster and was therefore used.

4.3. Discussion of Results

The results obtained for each parameter were graphically presented. [3] The parameters were interpreted vs. each sampling point and vs. time. Some important parameters were looked at using multivariate analysis, overlaying the curves to show the behaviour of the parameters relative to each other. [1] All diagrams can be found in the appendix.



[12]

Fig. 4.3.1

The water level of the Braunau River shows the time of the snowmelt and the amount of total water. From this diagram it can be seen when the worst results for the drinking water quality were most likely to occur. The Braunau river water level is connected to rainfall and the average daily temperature.

Sampling points with assigned numbers as used in graphs

1	Langegg Well	17	Langegg Well
2	Kollersdorf Well	18	Kollersdorf Well
3	Waldbrunnen (Forest Well)	19	Waldbrunnen (Forest Well)
4	Langegg Source	20	Langegg Source
5	Kottinghörmanns Source	21	Kottinghörmanns Source
6	before aeration		
7	after aeration		
8	after ozonation		
9	after Filter 1		
10	after Filter 2		
11	after Filter 3		
12	after Filter 4		
13	before deacidification		
14	after deacidification		
15	after activated carbon		
16	after high storage tank	22	after high storage tank

Fig. 4.3.2

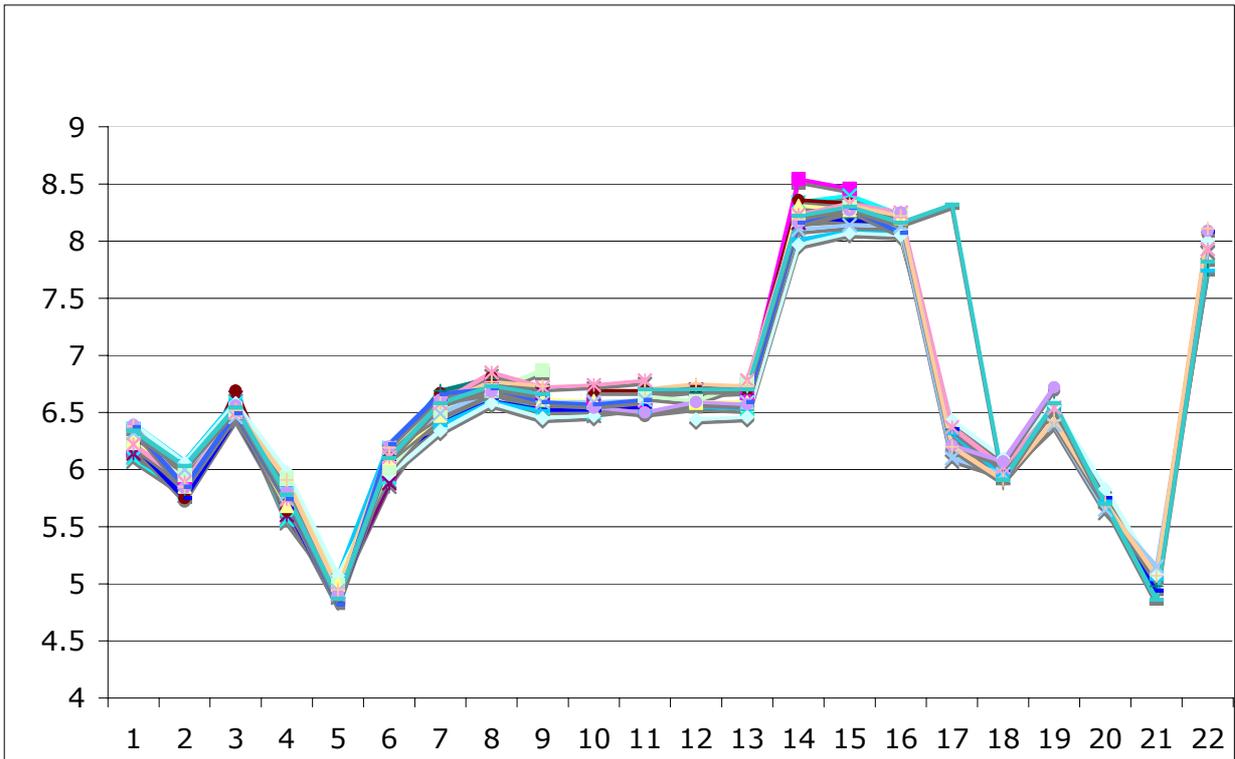


Fig. 4.3.3.

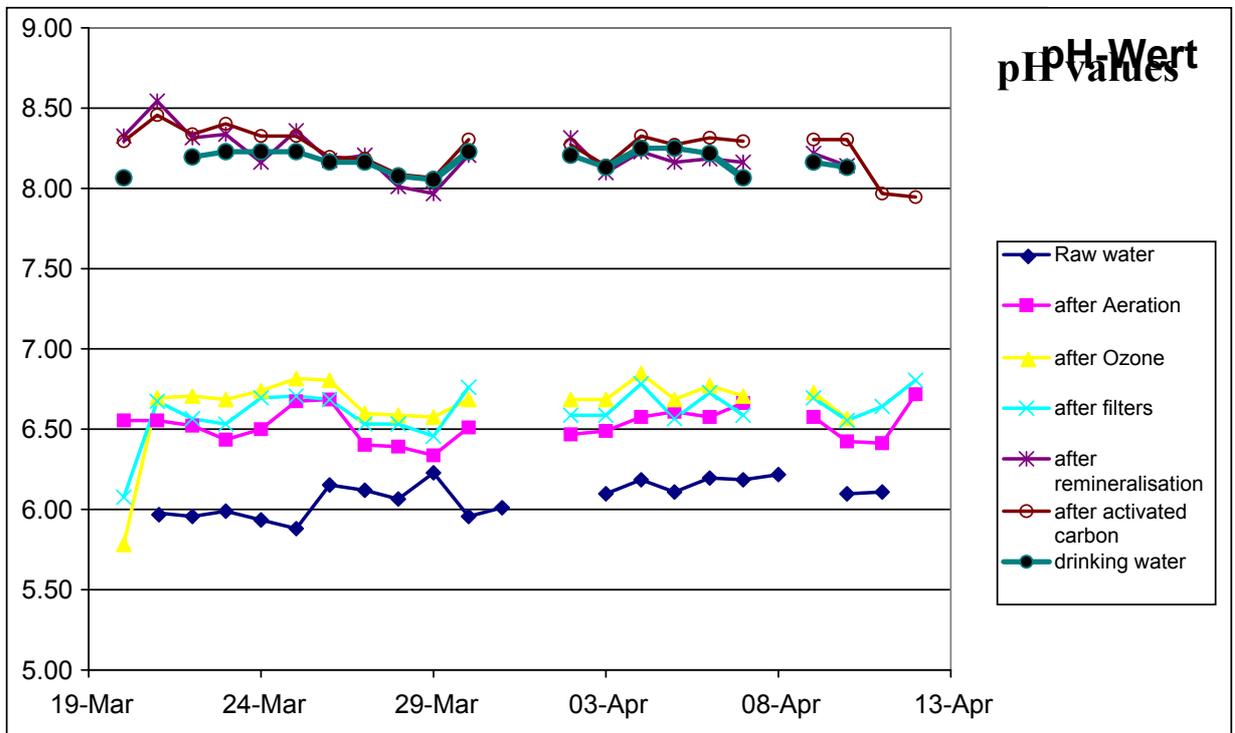


Fig. 4.3.4.

pH values: The pH of the raw water is very low with the sources having a lower pH than the wells. The pH value is not at the optimal value of 7.0 for iron removal in the filters. After deacidification the pH value is increased to about 8.3
 The pH value is a stable parameter during snow melts.

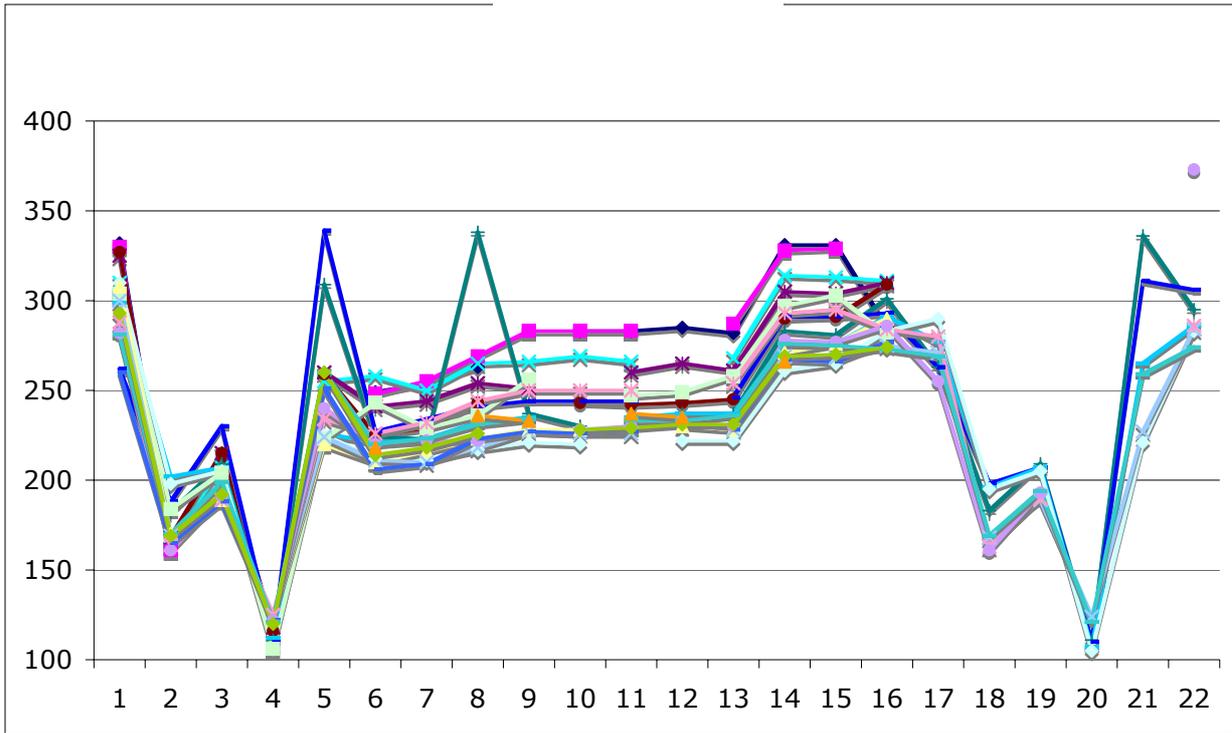


Fig.4.3.5.

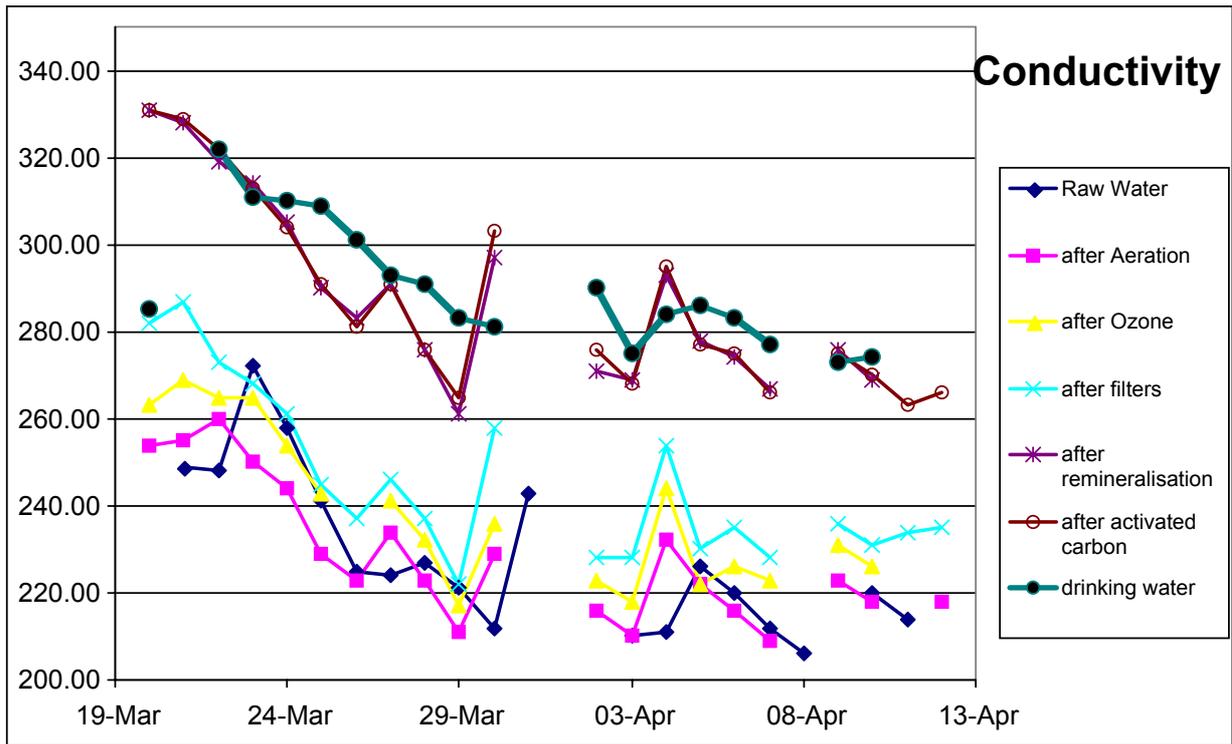


Fig. 4.3.6.

Conductivity: Conductivity in general is very low and measured in mS. Conductivity decreases during snow melt, as more surface water with very low conductivity gets into the groundwater. [6] After remineralisation the conductivity is slightly increased.

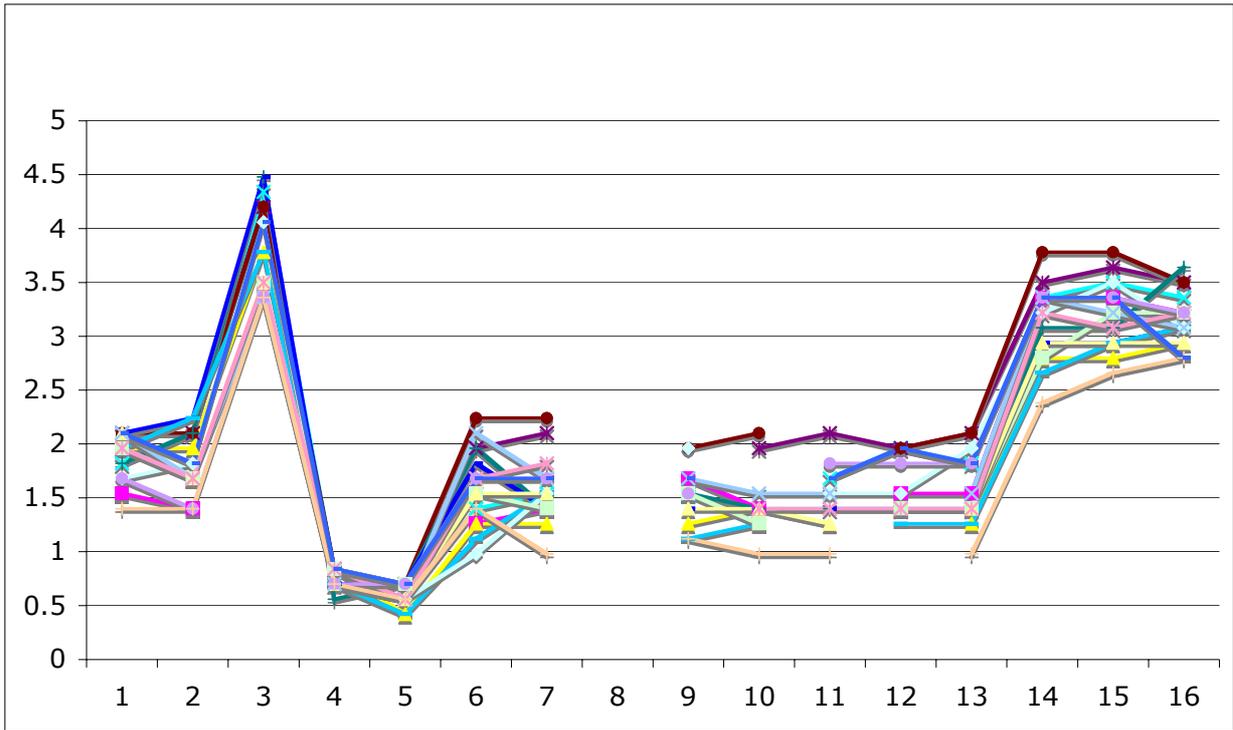


Fig. 4.3.7.

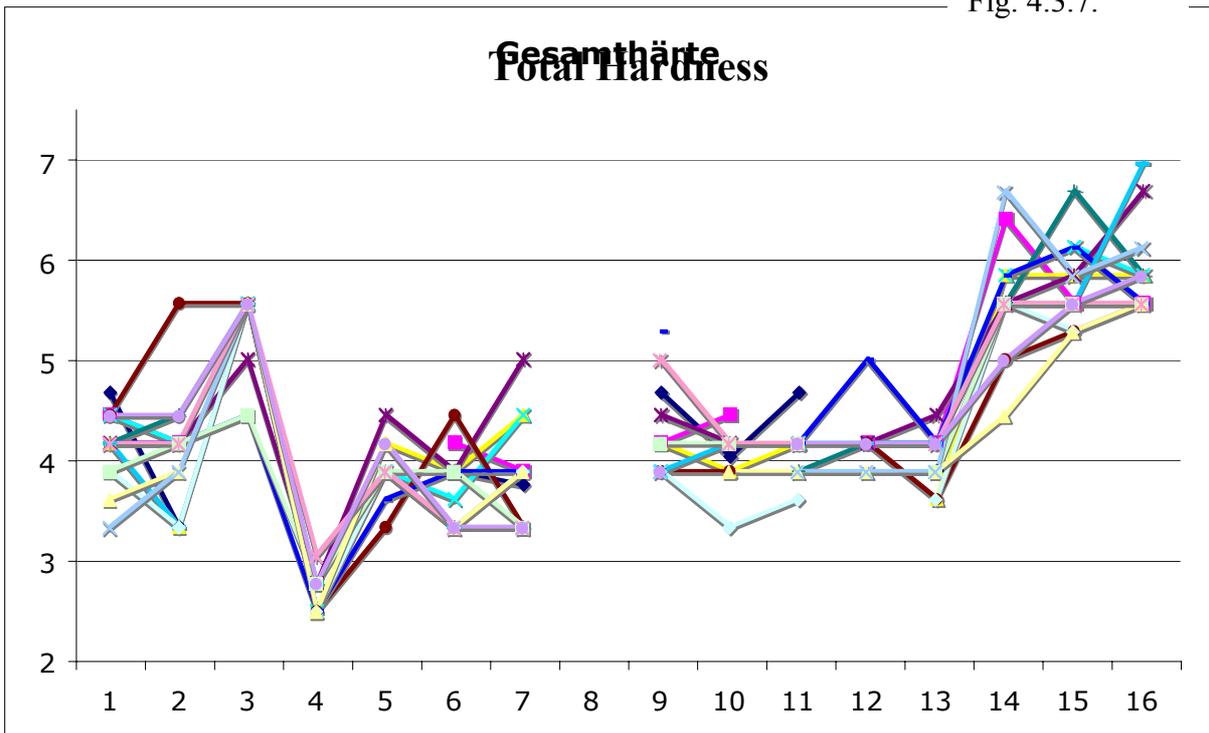


Fig. 4.3.8.

Carbonate Hardness and Total Hardness: The hardnesses are very low. They are increasing after remineralisation. Although the total hardness 8.4 °dH, which is the recommended value cannot be reached. The softness of the water may lead to health problems (coronary diseases). The hardnesses are relatively stable during snowmelt, as the lines overlap mostly.

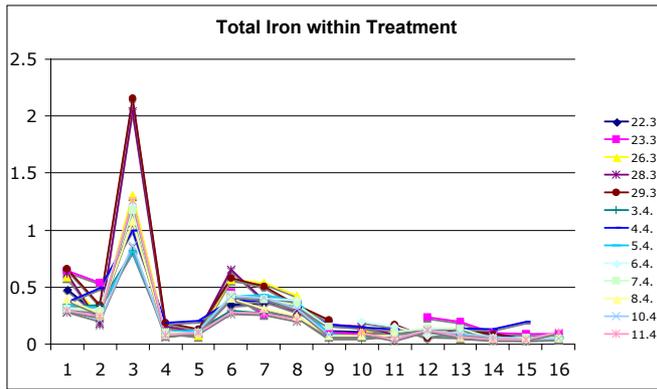


Fig 4.3.9

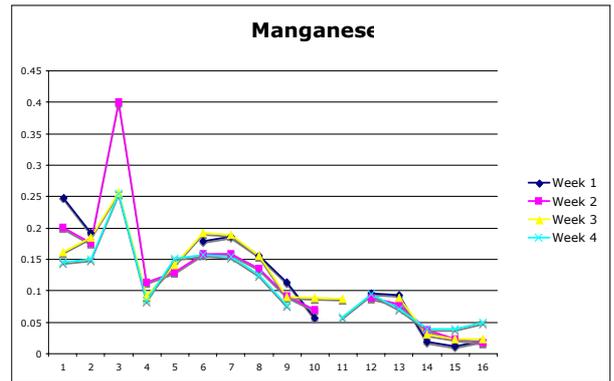


Fig 4.3.10

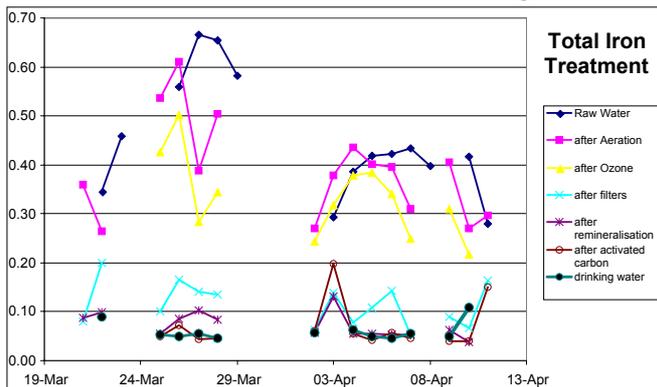


Fig 4.3.11

Iron & Manganese: Iron and Manganese show similar behaviour during snowmelt. When the iron increases the Manganese increases and vice versa. When there is more iron in the water the drinking water treatment plant is optimised to remove most of the iron. Therefore the Manganese will not be removed as effectively as normally, thus leading to very high Manganese concentrations in the drinking water.

Most of the iron and manganese is removed in the multilayer filters, for which they are designed. However some of the iron (Fig. 4.3.11.) is removed by the remineralisation and activated carbon filter. The gel like iron will clog these filters and the filtering effect will be reduced. One of the most important aims of this experiment was, to optimise the iron removal in the multilayer filters, so that no iron at all is removed in the remineralisation and activated carbon filter. [7, 4]

Iron and Manganese are measured in mg/l

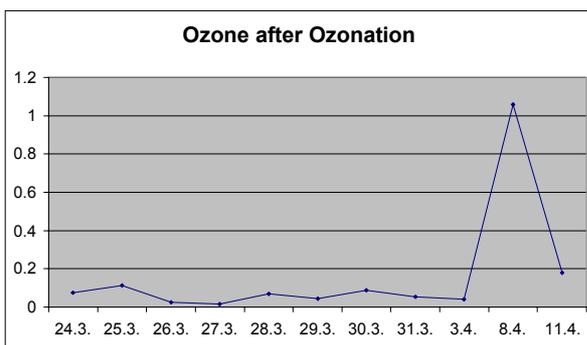


Fig 4.3.12

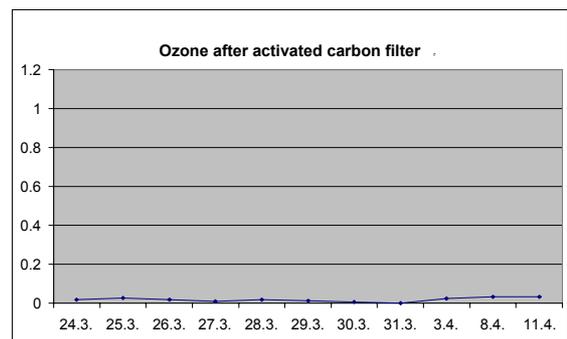


Fig 4.3.13

Ozone: The amount of Ozone is crucial for the UV permeability and measured in mg/l. The Ozone cracks the Iron complexed with humic substances and oxidises manganese. On the 8th of April the ozonation unit was cleaned and repaired and showed that a higher amount of Ozone has a significant effect on the drinking water quality. The activated carbon filter is designed to remove all the Ozone from the water. [5]

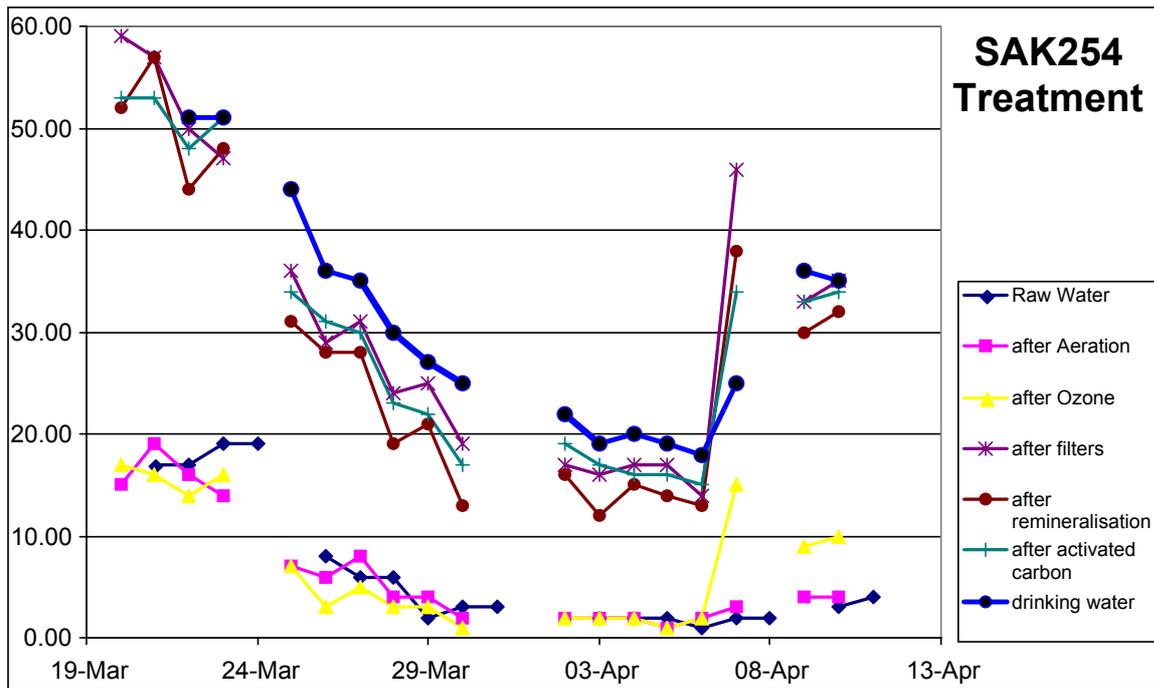


Fig 4.3.14

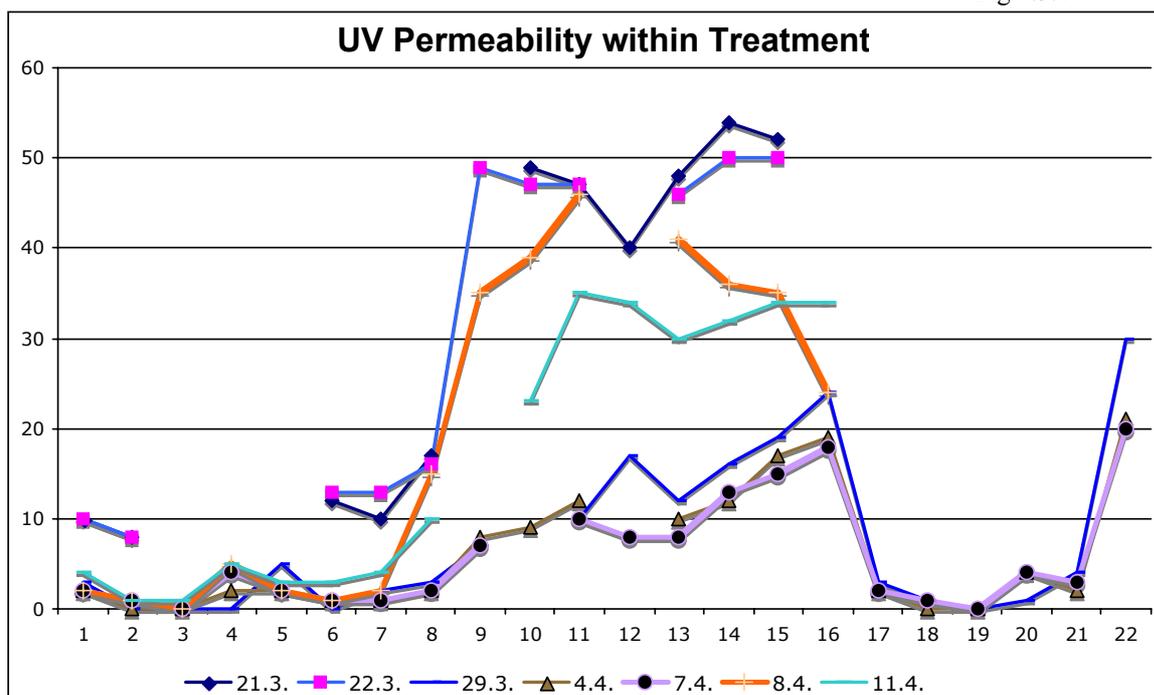


Fig 4.3.15

SAK 436, SAK 254 and UV Permeability show the same trend. The UV Permeability is one of the most important parameters for the drinking water treatment in Schrems. If the UV permeability falls below 20% the plant shuts down. The 20% is required for UV disinfection and below that value the microbiological safety of the water cannot be guaranteed. The UV permeability falls rapidly during extreme weather conditions and falls even below the 20% mark (5th, 6th of April). Ozone has a drastic effect on the UV permeability and a working Ozonation unit can bring the UV permeability well above the required 20%. The UV permeability is strongly affected by Manganese concentrations and concentrations of Humic Substances.

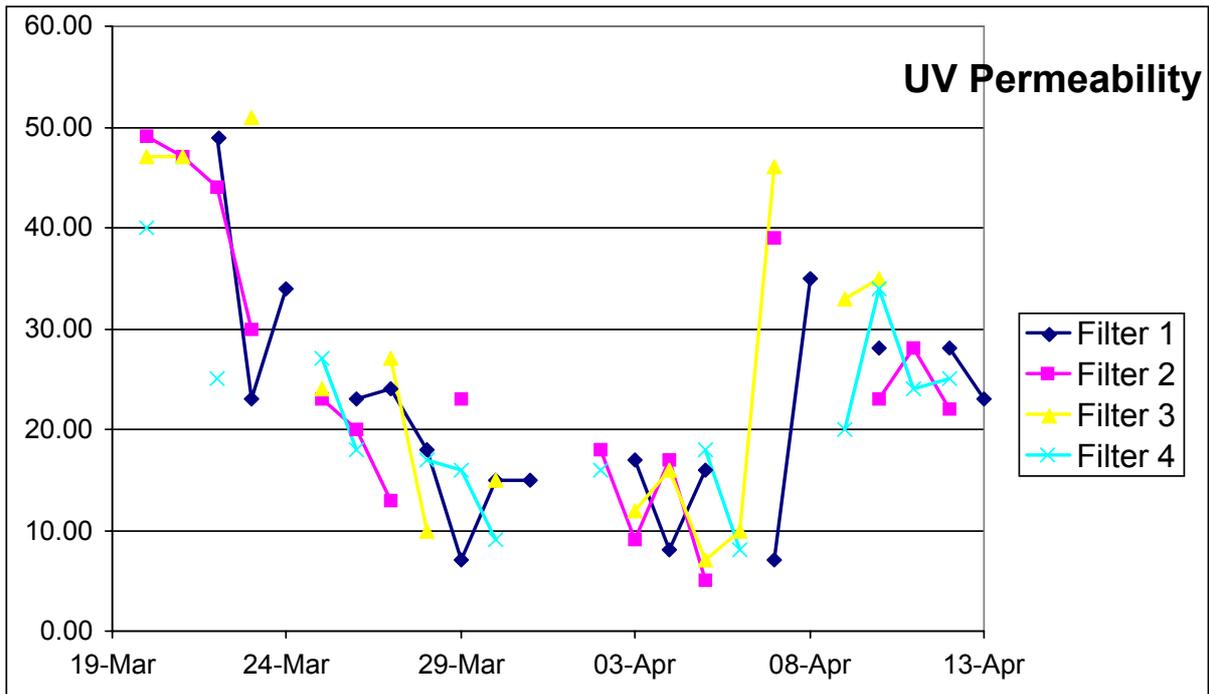


Fig 4.3.16

The washing cycle of the filters can also be used to increase the UV permeability. Of all four filters, filter 3 was set at a lower flow rate, thus washing more often. The UV permeability was always one of the highest for filter 3, suggesting that a shorter “working time” between washing/cleaning improves the filtering effect. [13]

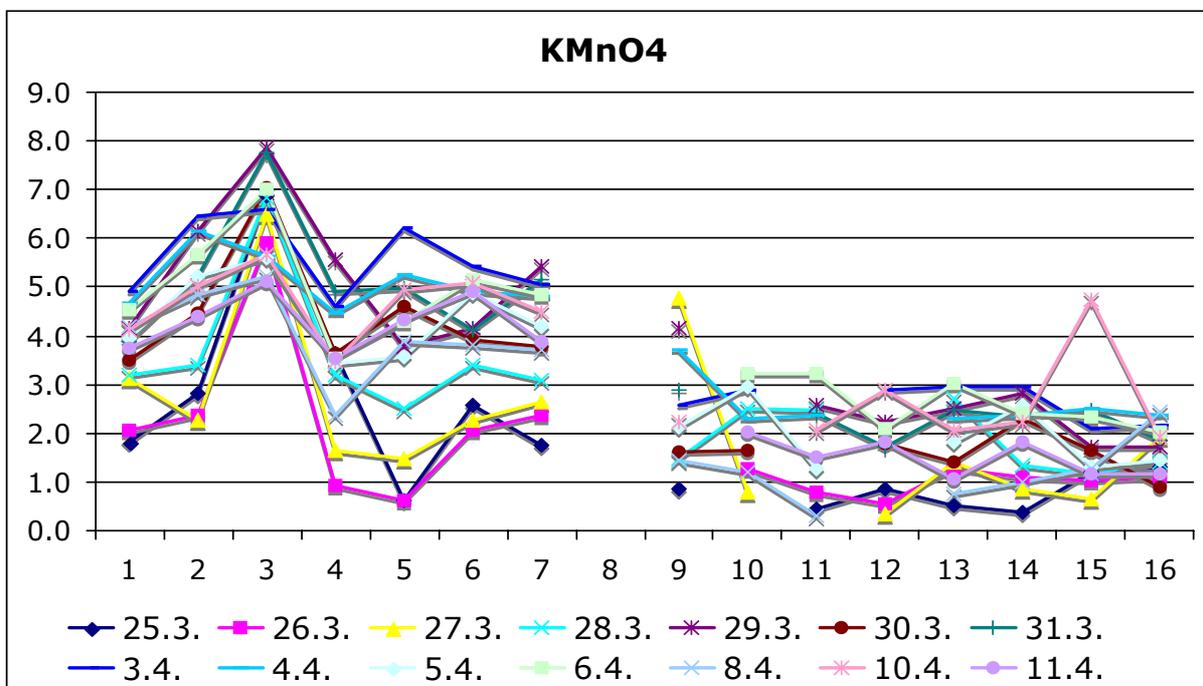
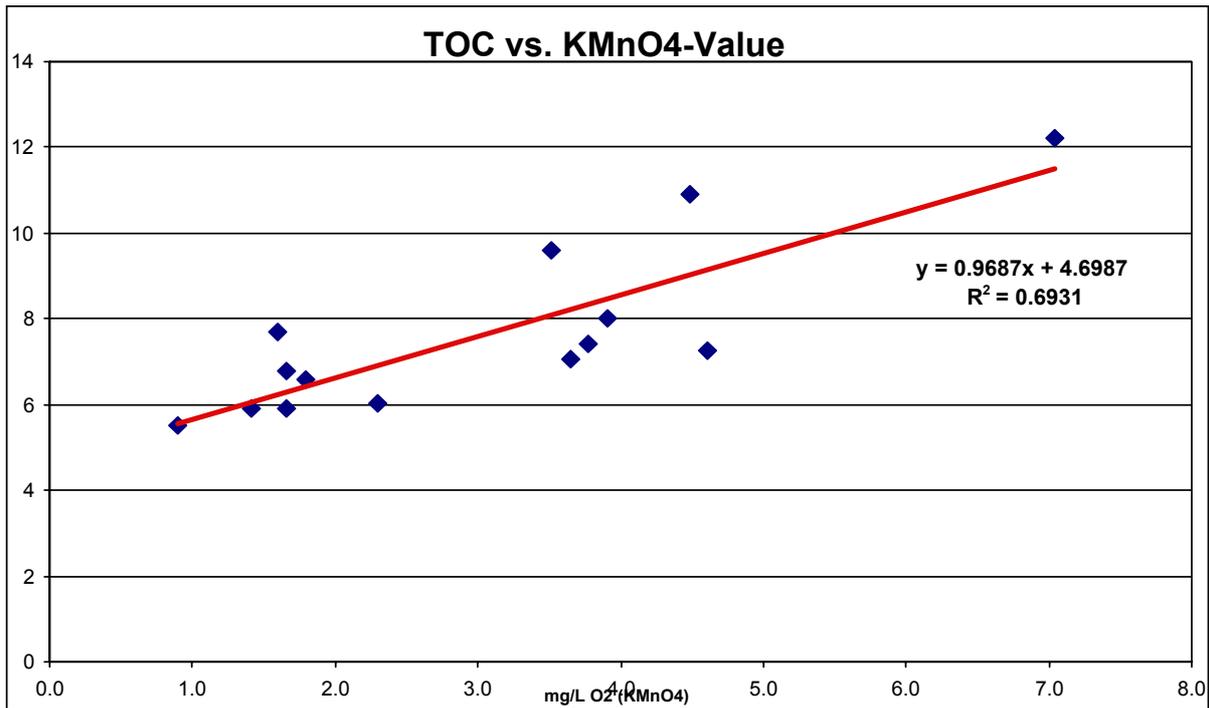


Fig 4.3.17

KMnO₄ value: The KMnO₄ value shows, that there are a lot of oxidisable substances in the water samples. Most of these substances are removed in the multilayer filters. A KMnO₄ value after the Ozonation (no.8) did not work out, as the value was not measurable.



[3]

Fig 4.3.18

A correlation between TOC and KMnO₄ was found and is now used as a guideline for the Lower Austrian government. This is important because very rarely both tests are available at the same time. The correlation curve does not pass through zero, because in the TOC the Carbon is measured and with the KMnO₄ the amount of Oxygen is measured. [1]

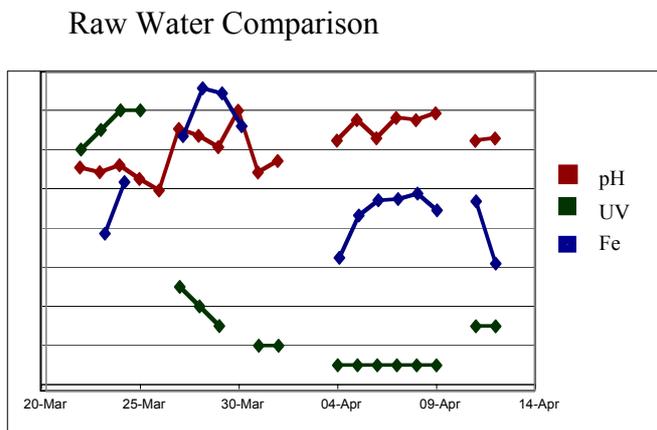


Fig 4.3.19

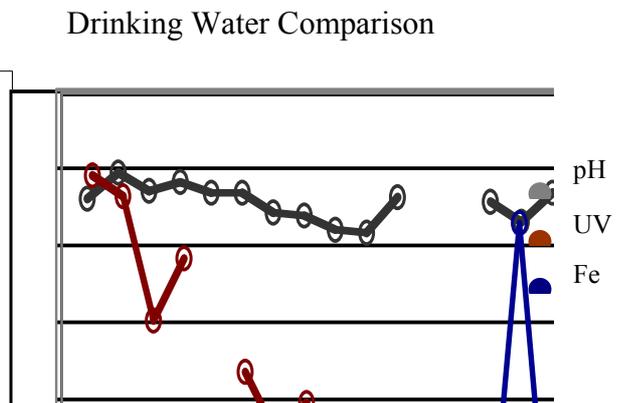


Fig 4.3.20

When comparing the pH value, the UV permeability and the “free” Iron it is seen, that these parameters are not affecting each other. Even when having an extreme Iron peak, the UV permeability does not change significantly. The pH value is relatively stable and is not affected by changing UV Permeability or Iron contents in the water.

The iron value in these graphs does not include the iron complexed with humic substances. It can be seen from the previous graphs, that the total Iron has an effect on the UV Permeability; therefore the complexed iron is responsible for a decrease in the UV permeability.

4.4. Aims reached?

- The water supply in Austria is very traditional and old-fashioned. Only in recent years a strict drinking water control system was introduced. As a result of this it was seen in detailed analysis, that the sources have a very varying behaviour depending on the weather situation. The City of Schrems was interested in the change of their sources during snowmelt.

The sources vary most during extreme weather conditions. They are highly affected by an increase in surface water, such as rain or snowmelt. Due to the flooding of whole forests the sources had a drastic change in UV permeability. However after the snowmelt, the sources were fast recovering the standard water quality, which is drinking water quality even without treatment.

- It is important for the Waldviertel region that the influences of snow melt and flooding are monitored to know the effect on the drinking water treatment plants.

During extreme weather situations the drinking water has a decrease in quality. The UV permeability falls, iron and manganese concentrations increase, conductivity decreases and the amount of oxidisable substances multiplies.

- It is necessary for the responsible people to know how a drinking water treatment plant can be optimised to increase the drinking water quality.

Ozonation is very important for the UV Permeability, which is so crucial for UV disinfection.

A more effective washing cycle for the multilayer filters can increase the filtering effect.

A higher pH in the raw water will improve the filtering effect on iron complexed humic substances. As a result the activated carbon filter and the remineralisation/deacidification filter will not become clogged by iron. The Aeration Tower alone cannot reach this higher pH.

- A correlation between a KMnO_4 value and a TOC value is required by the Lower Austrian government, because both tests are seldom available at the same time in every laboratory. It is also important to know the precision of each method in respect to the other.

The correlation gives a value, although both tests are not very precise. The Lower Austrian government now uses this value as a guideline.

4.5. Future Prospects

The work done for the City of Schrems is applicable in the whole of Waldviertel. The results obtained can be partly accepted by other drinking water treatment plants in this region as a guideline.

[12] As a prospective project the Iron removal in the filters can be further optimised. Using Sodium Hydroxide to increase the pH value of the raw water is very dangerous. NaOH is difficult to handle, the pH value can easily be brought to a value that is well above the required max 7.2 [14]

Sodium Hydroxide is also quite expensive in the amounts needed. The pH value may be increased by the addition of CaCO_3 and MgCO_3 to the untreated water. This is done now after the multilayer filtration units in the remineralisation filter.

Another advantage of this technique would be that the hardness is twice increased, maybe reaching the suggested value of 8.4 °dH [2]

However the whole water treatment plant has to be redesigned to test a radical change like this. A small-scale laboratory based experiment if the desired effect could be reached would be necessary beforehand. [5]

Presently the responsible officials of the Lower Austrian government are funding a new project to investigate the above concept.

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