Water and wastewater treatment – Homework 11 - Solutions

Water resources quality and treatment

The Tables below show the water composition of 5 raw waters used for drinking water production. Assess the water quality in terms of the Swiss drinking water regulations and try to identify the possible water resources. What kind of treatment would you use to produce drinking water from these resources?

Water type 1 (see also homework 1)

Parameter	Measured value
Temperature	7-12°C
pH	6.4-7.1
DOC	1-5 mg/L
UV (254 nm)	1.3-19.5 m^{-1}
Calcium	122 mg/L
Magnesium	3.5 mg/L
Nitrate as $NO3^-$	25 mg/L
Atrazine	150 ng/L
Tetrachlorethylene	20 µg/L
Trichlorethylene	15 µg/L
Bromide	20 µg/L
Turbidity FTU	0.2 - 150

Discussion of water quality for water type 1:

T: varies, however, not dramatically. A temperature of around 10°C is well suited for drinking water purposes. The water has to be from a groundwater or a lake water source (lower levels) and excludes a river water.

pH: It can be low at times. It seems not so well buffered.

DOC: highly variable and very high. DOC concentration should be below 2 mg/L for a good drinking water. This points towards seasonal variations or changes do to extreme events (e.g. heavy rainfalls). This points towards either eutrophic lake water or a karstic water.

UV: Follows same trend as DOC. UV is often used as a proxy for the DOC concentration.

Calcium and Magnesium: The water is quite hard, with a Calcium hardness of about 30 °F : 122 mg/L Ca ≈ 3 mM. 1°F = 0.1mM $CaCO_3$ => 3mM Ca = 30 °F

Nitrate: At the quality goal of drinking water.

Atrazine: Atrazine is above the drinking water standard of 100 ng/L. This is an indicator for agricultural activity. Typically atrazine is much higher in groundwaters than in lake waters.

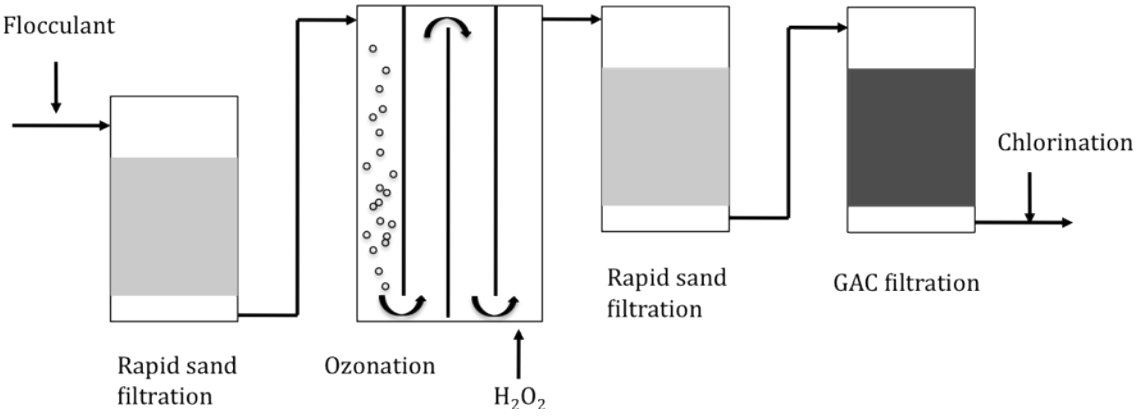
Tetrachloroethylene, trichloroethylene: They are below the drinking water guidelines. They are typical groundwater contaminants.

Bromide: Bromide concentration is low and not regulated.

Turbidity: Turbidity is highly variable and sometimes significantly above the drinking water standard of 1. This points to a source that is closely connected to a surface water.

Overall, the water resource has a character of a groundwater with high hardness but also high variability of DOC and turbidity. This connection points towards a karstic water in a limestone environment. The source water is from the Jura (Porrentruy).

Treatment of water type 1:



Water type 2 (see also homework 1)

Parameter	Measured value
Temperature	11.4°C
pH	7.1
DOC	4 mg/L
Total Hardness °F	39
Calcium Hardness °F	35
Magnesium Hardness °F	3.9
Oxygen	0 mg/L
Nitrate as N	< 0.01 mg/L

Nitrite as N	0.02 mg/L
Ammonium as N	1.2 mg/L
Iron	6.6 mg/L
Manganese	0.22 mg/L

Discussion of water quality for water type 2:

T: Temperature is constant and suitable for drinking water purposes. The water has to be from a groundwater or a lake water source (lower levels) and excludes a river water.

pH: Stable an okay for drinking water purposes.

DOC: Very high. DOC concentration should be below 2 mg/L for a good drinking water. This points towards a eutrophic lake or a groundwater influenced by organic rich soil.

Hardness: The water is hard. This points towards a groundwater.

Oxygen: The oxygen concentration is 0. This points towards a reduced groundwater. This is in agreement with the high DOC concentration.

Nitrogen species: Nitrate concentration is below the detection limit, some nitrite can be found => reduced water resource. Ammonia confirms this finding. It is a result of nitrate reduction.

Iron, manganese: Both metal ions are significantly above the drinking water standard. This confirms that it must be a reduced water resource.

Overall, the water resource has a character of a reduced groundwater with high hardness. Groundwater Alpnach.

Treatment of water type 2:

Removal of ammonia, iron and manganese are the main issues for water treatment. Depending on the size of the community varies options can be envisaged:

In situ treatment:

The yield can be calculated as follows:

In a first approximation only ammonia and iron have to be considered for oxygen consumption.

1 mol of NH_4^+ consumes 2 moles of oxygen (nitrification); $[NH_4^+] = 1.2$ mg/L = 7×10^{-5} M => 1.4×10^{-4} M oxygen.

1 mol of Fe(II) consumes ¼ moles of oxygen; [Fe(II)] = 6.6 mg/L = 1.17×10^{-4} M => 2.9×10^{-5} M oxygen.

In total, 1.69×10^{-4} M oxygen are consumed for the removal of ammonia and iron(II).

The Oxygen concentration of injected water is 8 mg/L = 2.5×10^{-4}M.

Therefore the yield of this system would be about 1.5 (only 1.5 x more water can be extracted than what was injected) which is too small to make the process economically feasible.

If no ammonia would be in the water, the ratio of extracted/injected water would be about 10.

Pump and treat:

Chemical treatment

Iron removal: Aeration – precipitation – sedimentation – filtration. During this process, there will also be partial nitrification and manganese removal.

Ammonia: Break point chlorination or nitrification. Break point chlorination is not favored anymore, because of the high chlorine demand (Breakpoint: Cl_2:NH_4^+ = 1.5, 1.05×10^{-4}M Cl_2 would be required ≈ 7 mg/L!). Nitrification is the preferred process.

Manganese removal: It can be expected that Mn(II) will not be fully removed by oxygenation of the water. Therefore additional treatment with a stronger oxidant is required. Permanganate may be a good choice.

Biological treatment

Treatment scheme according to the exercise notes.

Water type 3

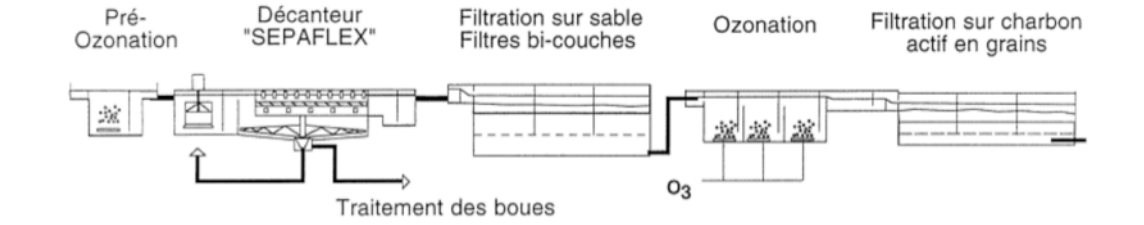
Parameter	Measured value
Temperature	11 - 25 °C
pH	7.5 - 8.4
Turbidity FTU	2.3-60
DOC	7.9 - 20 mg/L
Taste and odor	intense
Total Hardness German °H	15 - 20
Carbonate Hardness German °H	9 - 12
Oxygen	7 - 17 mg/L
Chloride	30 - 160 mg/L
Bromide	0.05 - 0.2 mg/L

Iron	0.05-0.47 mg/L
Manganese	0.06-0.21 mg/L

Discussion of water quality for water type 3:

T: The temperature varies and can reach high levels. This points towards a surface water.
pH: large variation, high pH points towards photosynthesis (surface water).
Turbidity: Large variation, this points to a river water.
DOC: High to very high levels and high variations. These values also point to a surface water.
Taste and odor: The intense taste and odor can be related to algal growth.
Hardness: 1 German °H = 0.178 mmol/L => 2.67-3.56 mmol/L = 26.7 – 35.6 °F, hard!
Oxygen: The water is oversaturated at times which clearly points to photosynthetic activity => surface water.
Chloride: The levels of chloride are elevated (close to sea, anthropogenic activity?).
Bromide: Elevated levels (see chloride). This has to be considered for chemical disinfection processes.
Iron and manganese: Elevated at times, it is unclear whether this is dissolved or particulate.
Overall the water has the character of a surface water. The high fluctuation in turbidity points to a river water. Warnow river Eastern Germany.

Treatment of water type 3:



Pre-ozonation | Sedimentation | Rapid sand Filtration 2-layers | Ozonation | Granular activated carbon filtration

Water type 4

Parameter	Measured value
Temperature	4 - 8 °C
pH	7.8
DOC	1.2 mg/L

Calcium hardness	1.2 mM
Total hardness	1.5 mM
Carbonate hardness French °H	9 - 12
Oxygen saturation	60 - 98 %
Chloride	3 mg/L
EDTA	1 - 3 µg/L

Discussion of water quality for water type 4:

T: Low temperatures throughout the year. 4°C is too low for a groundwater, this points towards a lake water (hypolimnion, water with 4°C has the highest density).

pH: Stable pH points to a stable system (hypolimnion lake or groundwater)

DOC: Low, groundwater or oligotrophic/mesotrophic lake

Calcium hardness: 12°F is a soft water. This points towards a lake water or a groundwater from a crystalline catchment.

Oxygen saturation: some variation, however not critical for water supply. Partial consumption of oxygen points to some seasonal variation => lake water

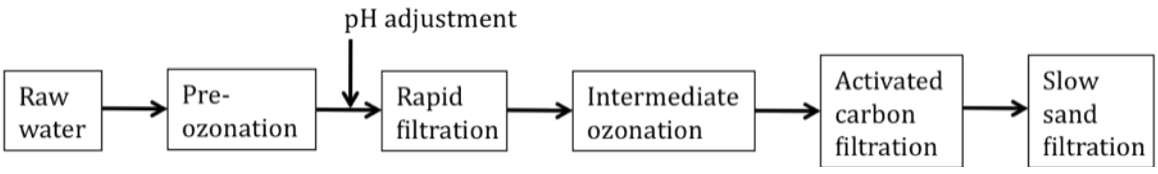
Chloride: Low concentration, only small influence from anthropogenic activity

EDTA: This ligand is present in low concentrations below the tolerance value of 5 µg/L. It is a typical indicator for wastewater influence (surface water).

Overall the water quality data point to a lake water. In this case it is Lake Zürich water.

Treatment of water type 4:

Lake water treatment plant Lengg, Zürich



Water type 5

Parameter	Measured value
Chloride mg/L	6.30
Enterococci /100 mL	25-300
Escherichia coli /100mL	42-200

Fluoride mg/L	0.05
Taste and odor	-
Total Hardness °F	28.40
Nitrate mg/L	20.90
pH	7.14
Oxygen mg/L	9.35
Oxygen saturation %	87.20
Turbidity FTU	0.2-10
Temperature ^{o}C	10-15

Discussion of water quality for water type 5:

Chloride: This concentration is typical for Swiss waters

Enterococci: This value is above the tolerance value (non-detect in 100 mL)

Escherichia coli: This value is above the tolerance value (non-detect in 100 mL)

Fluoride: Natural element, the concentration is significantly below the tolerance value of 1.5 mg/L.

Total hardness: This water is quite hard. This points towards a groundwater.

Nitrate: Even though the nitrate is below the tolerance value (40 mg/L) and even below the quality goal (25 mg/L), this elevated value points towards agricultural activity.

pH: Value within the range of typical drinking waters

Oxygen: Concentration close to saturation

Turbidity: Variable, points to a karstic water

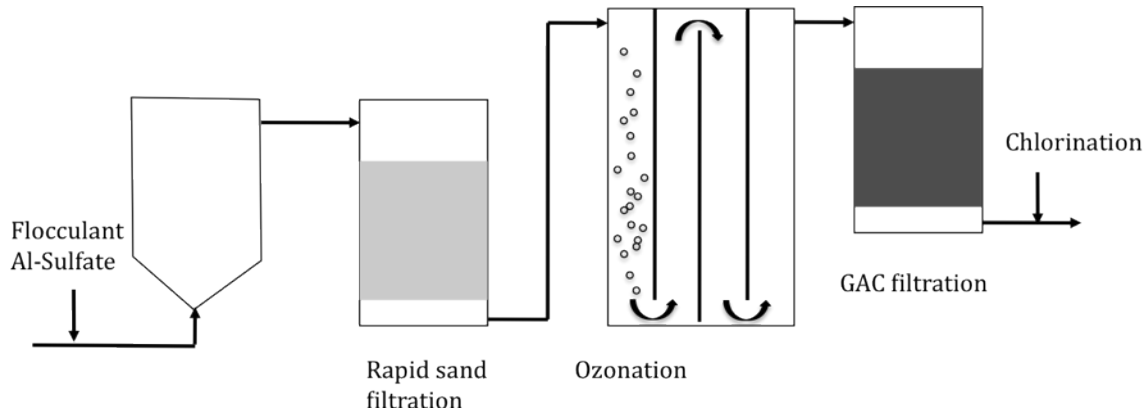
Temperature: Some variability, points to surface influence => karstic water.

Overall, this is a karstic water (Jura, Canton Baselland) with bacteriological problems, probably from agriculture.

Treatment of water type 5:

The main objective is the hygienic quality of the water which can be achieved by disinfection or membrane filtration. To achieve a good disinfection, particles have to be removed first. The following treatment systems were implemented for such waters:

1. Flocculation with Al-sulfate – Sedimentation – Rapid sand filtration – Ozonation – Activated carbon filtration (biological) – Final disinfection with chlorine



2. Flocculation with Al-sulfate – Sedimentation – Membrane filtration – Ozonation – Activated carbon filtration (biological) – UV disinfection