

# EVALUATED GUIDELINES ON HARMONIZED WORKFLOWS AND METHODS FOR URBAN AND NON-URBAN AREAS

Deliverable D.T2.3.4 -Annex 1

 **Geologische Bundesanstalt**

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### Annex 1 - Problematic groundwater bodies: Theoretical background, summary of literature studies on the topic

Summary of literature review on risk for open-loop systems related to geochemical properties of groundwater

#### 1.1.1 CHEMICAL PARAMETERS FOR ASSESSMENT OF WATER SUITABILITY FOR USE WITH HEAT PUMPS (VDI 4640 PART 2, 2001a)

For groundwater free of oxygen and with low redox potential, wells can become encrusted if iron or manganese is present. Such groundwater must not come into contact with ambient air. The whole system must therefore be closed and permanently under pressure. To assess the risk of formation of encrustations, an iron and manganese analysis is required and the pH value must be determined. Calcareous precipitations do not play a role for temperature changes of  $\pm 6\text{K}$  ( $^{\circ}\text{C}$ ).

Using these parameters, the investigating laboratory or a specialized institute can assess the suitability of the water for use with heat pumps with respect to the above factors can be assess using following parameters: Temperature, pH value,  $\text{O}_2$  content, conductivity, redox potential, calcium, magnesium, sodium, potassium, iron, manganese, nitrate, phosphate, sulphate, chloride, hydrogen carbonate and ammonium.

To assess impacts of shallow geothermal energy on groundwater quality Bonte (2015) proposed following parameters for monitoring:

- Field parameters (pH, EC, T-downhole, dissolved  $\text{O}_2$ ) - monitor mixing of different water qualities and thermal impacts,
- macro parameters (Cl,  $\text{SO}_4$ , alkalinity,  $\text{NO}_3$ ,  $\text{NH}_4$ , Ca, Mg, Na, K) - monitor quality assurance of analyses (electrical balance, also used for many other aspects),
- redox parameters (Fe,  $\text{SO}_4$ ,  $\text{NO}_3$ ,  $\text{NH}_4$ ,  $\text{CH}_4$ , DOC,  $\text{PO}_4$ ) - monitor changing redox processes,
- carbonate scaling (Ca, Mg, alkalinity, pH, temperature, Fe, DOC),
- iron precipitation (Fe, Mn, pH, T, dissolved  $\text{O}_2$ ,  $\text{NO}_3$ ),
- iron sulphides scaling (Fe,  $\text{SO}_4$ , pH,  $\text{HS}^-$ ),
- corrosion ( $\text{SO}_4$ , Cl).

## 1.1.2 UPDATED WORKFLOWS IDENTIFICATION OF PROBLEMATIC GROUNDWATER BODIES -

### Table 1: Risk scenarios and associated risk

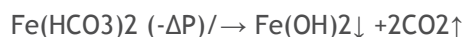
#### 1.1.2.1. Scaling of Iron (Fe) and Manganese (Mn) (Dricoll, 1986)

##### a) Iron (Fe)

Iron is common in many igneous rocks and is found in trace amounts in practically all sediments and sedimentary rocks. Water may dissolve iron upon contact with metal well casings, pump parts and piping. In the presence of air, they ( $\text{Fe}^{2+}$ ) change to ferric ions ( $\text{Fe}^{3+}$ ) and precipitate as ferric oxide or oxyhydroxides. Ferrous ions combine with carbonate ions to form bicarbonate, iron bicarbonates often contribute to the plugging of water well intake screens. Iron oxide scale accumulates on the inner surface of iron pipes when iron put into solution by low pH water combines with dissolved oxygen to form the insoluble oxide. An oxide film then deposits on the corroded surfaces.

Conditions: The more corrosive the water (low pH or high  $\text{O}_2$  content), the more metal it will dissolve. In natural groundwater systems where  $\text{O}_2$  concentrations are low or absent and the pH is 6.5 to 7.5, the iron occurs primarily as dissolved ferrous ions ( $\text{Fe}^{2+}$ ). Ferrous ions concentrations may reach 50 mg/l in water that has a pH of 7 and no oxygen. During pumping velocity-induced pressure changes can disturb the chemical equilibrium of the groundwater and results in the deposition of insoluble iron and manganese hydroxides.

Dissolved iron is affected by *pressure reduction* as indicated:



$\text{Fe}(\text{OH})_2$ - solubility of ferrous hydroxide is less than 20 mg/l.

If oxygen is introduced by aeration during pumping, additional precipitation of ferric hydroxide occurs:



$\text{Fe}(\text{OH})_3$ - solubility of ferric hydroxide is less than 0,01 mg/l.

Further oxidation of the hydroxides of Fe and Mn, or an increase in pH, causes the formation of hydrated oxides containing these ions. Ferrous iron in solution, for example, can react with oxygen to form ferric oxide ( $\text{Fe}_2\text{O}_3$ ):



The ferric oxide is a reddish brown deposit similar to rust, whereas the hydrated ferrous oxide is a black sludge. Iron and manganese deposits are often found associated with calcium- and magnesium-carbonate scale.

Concentrations: In most areas where iron problems exist, the iron concentrations range from 2-10 mg/l. If the iron content of the water exceeds 0.5 mg/l, precipitation of iron is likely, although some precipitation may begin at concentrations as low as 0.25 mg/l.

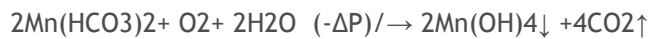


#### b) Manganese (Mn)

It occurs as soluble manganous bicarbonate which changes to insoluble manganese hydroxide when it reacts with atmospheric oxygen. Stains caused by manganese are more objectionable and harder to remove than those from iron.

Conditions: Manganese bicarbonate precipitates out of solution as a black, sooty deposit when CO<sub>2</sub> is liberated from the water near the well. Slime-forming bacteria similar to iron bacteria also may cause oxidation of manganese compounds, forming an insoluble residue. Both iron and manganese can be kept in solution by adding a small amount of sodium hexametaphosphate to the water. The polyphosphate stabilizes the iron and manganese compounds and delays their precipitation; the delay time varies with the amount of polyphosphate added. Stabilizing chemicals must be added before the water is exposed to air.

Soluble manganese becomes insoluble in the same way as iron:



Further oxidation of the hydroxides of Fe and Mn, or an increase in pH, causes the formation of hydrated oxides containing these ions. The insoluble manganese oxide is also black or dark brown. Iron and manganese deposits are often found associated with calcium- and magnesium-carbonate scale.

Concentrations: If the manganese content of the water exceeds 0,2 mg/l and the pH value is high, precipitation of manganese is likely if oxygen is present.

#### c) Iron bacteria

Iron-bearing waters also favor the growth of iron bacteria, such as Crenothrix, Gallionella, and Leptothrix. Iron bacteria can change certain forms of dissolved iron to insoluble ferric iron (Fe<sup>3+</sup>) which is deposited in the sheaths of the organisms and in the voids of sand. In some cases, the bacteria are already in the groundwater before the wells are drilled, and simply multiply as a localized food source is vastly increased through pumping. Alternatively, bacteria may be introduced into wells by drilling operations. For example, abundant iron bacteria are commonly present in some surface waters, especially swamps and marshes. If this water is used to mix drilling fluid without prior chlorination, bacteria will be injected into the ground. Dirty drill rods or bits can also carry bacteria into the well bores. There is also evidence to show that iron bacteria can be carried from well to well on drill rods, bits, pumps, and water tanks. When the iron content of water is naturally high, treatment for removal is the ultimate solution. Iron bacteria produce accumulations of slimy material of gel-like consistency, and oxidize and precipitate dissolved iron and manganese. The combined effect of the growing organisms and the precipitating minerals can plug a well almost completely within a short time. Introduction of a strong solution of chlorine is effective in controlling iron bacteria. Other bacteriocides (oxidants) such as chlorine dioxide also are effective, but may be more expensive to use. Acid is often used following the chlorine treatment to dissolve the precipitated iron and manganese, thus making it possible to remove them from the zone surrounding the well. When iron bacteria are known to exist, a well screen fabricated from a corrosion-resistant material should be selected to withstand the damaging effects of repeated chemical treatments. Correct identification of iron bacteria is best accomplished by scanning electron or transmission electron microscopy and phase contrast techniques.

Conditions: Iron bacteria thrive best in the dark in water containing little or no oxygen but with considerable CO<sub>2</sub> along with dissolved iron. Excessive growth may occur when sufficient iron is

present to support these bacteria. Iron bacteria occur widely in wells open to the atmosphere when sufficient iron and/or manganese are present in the groundwater in conjunction with dissolved organic material, bicarbonate, or carbon dioxide. The principal forms of iron bacteria plug wells by enzymatically catalyzing the oxidation of iron (and manganese), using the energy to promote the growth of threadlike slimes, and accumulating large amounts of ferric hydroxide in the slime. In this process, the bacteria obtain their energy by oxidizing ferrous ions to ferric ions, which are then precipitated as hydrated ferric hydroxide on or in their mucilaginous material that quickly plugs the screen pores of the sediment surrounding the well bore. Many other forms of iron bacteria induce the precipitation of iron through nonenzymatic means. Found almost everywhere in both water and soil, these bacteria promote precipitation of iron by four major mechanisms:

1. Raising the pH value of water by:

- Metabolizing certain protein or protein-derived materials, resulting in the formation of ammonia, which is alkaline,
- consuming the salts of organic acids, which can lead to the synthesis of alkaline hydroxyl groups,
- assimilation of dissolved carbon dioxide in water by cyanobacteria or algae during photosynthesis.

2. Changing the redox potential of the water by algal photosynthesis. In this process, oxygen given off by plants increases the redox potential, thereby causing the precipitation of iron.

3. Liberating chelated iron by inducing a breakdown in the bond between iron and oxalate, citrate, humic acids, or tannins.

Gallionella, a common enzymatic form of iron bacteria, is usually found in water having certain physical and chemical characteristics. Generally the water has: - iron content: of 1 - 25 mg/l and only traces of organic matter, - low in oxygen: 0,1 - 1 mg/l, - usually fresh water, although also been found growing in salt water, - over 20 mg/l CO<sub>2</sub>, redox potential: in the range 200 - 300 mV, pH range: 6 - 7,6, Temperature from 4,4 - 15,6 °C.

d) Sulfate-reducing bacteria

Sulfate-reducing bacteria are found in some groundwater.

Conditions: Conditions favorable for growth include absence of oxygen and fairly high sulfate content. These bacteria gain energy from the oxidation of organic compounds and, in the process, take oxygen from the sulfate ions. Reducing of the sulfate ions (removal of oxygen) produces hydrogen sulfide gas, which can be absorbed easily by the water. In an iron pipe, the water attacks the metal to form iron sulfide, which is deposited as insoluble iron scale in the pipe.

1.1.2.2. Scaling of Iron (Fe) and Manganese (Mn) (VDI 4640 Part 3, 2001b)

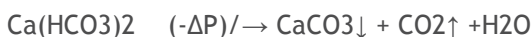
Waters with a low redox potential usually contain high concentrations of iron and manganese ions. If such water comes into contact with atmospheric oxygen, or with water having a higher redox potential, this results in the precipitation of hydrated iron oxide and manganese oxide. These substances can clog up or reduce the permeability of technical installations, especially the injection wells. It is possible to get around these problems in systems with low redox potential by consistently avoiding contact with air; this is done by maintaining pressure and/or using protective gas.

#### 1.1.2.3. Scaling of carbonates (Driscoll, 1986)

Usually results from the precipitation of carbonates, principally calcium, from groundwater in the proximity of the well screen. Calcium carbonate can be carried in solution in proportion to the amount of dissolved CO<sub>2</sub> in the groundwater.

Conditions: If the pH value is above 7.5 the water will tend to be incrusting. A Ryznar Stability Index of less than 7 also indicates incrusting conditions. If the carbonate hardness of the groundwater exceeds 300 mg/l, incrustation of calcium carbonate (lime scale) is likely. The ability of water to hold CO<sub>2</sub> in solution varies with pressure - the higher the pressure, the higher the concentration of CO<sub>2</sub>. Because of the reduction in pressure, some CO<sub>2</sub> is released from the water. When this occurs, the water is often unable to carry its full load of dissolved calcium carbonate and part of this material is then precipitated onto the well screen and in the formation materials adjacent to the well screen. Pumping a well in a confined aquifer produces a similar pressure reduction and resulting precipitation.

Formation of calcium carbonate precipitate from calcium bicarbonate:



$\Delta P$  - change in pressure

$\text{Ca}(\text{HCO}_3)_2$  - solubility of calcium bicarbonate is about 1300 mg/l

$\text{CaCO}_3$  - solubility of calcium carbonate is about 13 mg/l

CO<sub>2</sub> - escapes when the head, or pressure, is reduced

Magnesium bicarbonate changes to magnesium carbonate in the same manner when the CO<sub>2</sub> is released, but magnesium carbonate incrustation occurs only in special instances because it is still soluble at concentrations over 5000 mg/l. Precipitation occurs, therefore, only when the carbonate concentration exceeds this level.

#### 1.1.2.4. Scaling of silica (Driscoll, 1986)

Silica is not readily dissolved by water. As deposited, the scale is commonly calcium or magnesium silicate.

Conditions: The principal dissolved silicon species in groundwater at typical pH values (6 to 9) is Si(OH)<sub>4</sub>. It is important constituent of the incrusting material or scale formed by many groundwaters.

Concentrations: Warm groundwater sometimes contain as much as 100 mg/l silica, and silica concentrations of 20 mg/l are common.

#### 1.1.2.5. Chemical corrosion of casings (Driscoll, 1986)

Acid conditions generally lead to corrosive attack on metallic objects placed in groundwater. The presence of two or more corrosive agents appears to intensify the corrosive attack on metals, compared with the effect caused by individual agents. In corrosive waters, metal screens must be constructed of durable materials. In most cases, type 304 stainless steel will perform satisfactorily for many years.

Conditions: Corrosion becomes a problem when the pH value is below 7, but corrosion rates from steel are minimal at a pH above 11. In time, percolating rainwater enriched in CO<sub>2</sub> reduce the pH value of the groundwater to about 7. Pure water, that is highly demineralized water containing no dissolved gases, is not corrosive to metals. If dissolved oxygen is present, however, a corrosion potential exists. Water with dissolved oxygen corrodes metals more rapidly when the pH is low. However, water with some dissolved oxygen and relatively high electrical conductance (caused by total dissolved solids) will be corrosive even

though the pH may be 8 or more. Susceptible metals include iron, steel, galvanized iron and brass. The rate of corrosion tends to increase directly with temperature, but the amount of oxygen in solution decreases with higher temperatures. Therefore, the corrosion rate may not vary significantly unless the heated water is under pressure. Dissolved oxygen also removes zinc from brass alloys, leaving the metal porous and weakened. Groundwater that contains dissolved hydrogen sulfide gas is easily recognized by its rotten-egg odor. Water with small amounts of hydrogen sulfide forms a weak acid and is usually corrosive. Chemical corrosion occurs when particular constituent is present in water in sufficient concentration to cause rapid removal of material over broad areas, commonly these constituents are CO<sub>2</sub>, O<sub>2</sub>, H<sub>2</sub>S, HCl, Cl and sulfuric acid (H<sub>2</sub>SO<sub>4</sub>).

Potentially corrosive conditions:

- Low pH. If the pH value is less than 7, the water is acidic, and corrosive conditions are indicated. Similarly, a Ryznar Stability Index value greater than 7 indicates corrosive conditions,
- Dissolved oxygen. If dissolved oxygen exceeds 2 mg/l, corrosive water is indicated. Dissolved oxygen may be found in shallow wells in unconfined aquifers,
- Hydrogen sulfide. Hydrogen sulfide in groundwater can be detected readily by its characteristic rotten egg odor. Less than 1 mg/l can cause severe corrosion, and this amount can be detected by odor and taste,
- TDS. If TDS exceed 1000 mg/l, electrical conductivity of the water is great enough to cause serious electrolytic corrosion. To avoid electrolytic corrosion, metal well screens must be made of a single, corrosion-resistant metal,
- CO<sub>2</sub>. If the amount of this gas exceeds 50 mg/l, corrosive water is indicated,
- Chlorides. If the chloride content of the water exceeds 500 mg/l, corrosion can be expected.

#### 1.1.2.6. Electrochemical corrosion (Driscoll, 1986)

Electrochemical corrosion, flow of an electric current facilitates the corrosive attack on a metal.

Conditions: Dissolved oxygen may cause water to attack galvanized iron and some kinds of brass as rapidly as black iron. For electrochemical corrosion, two conditions are necessary: a difference in electrical potential on metal surfaces, and water containing enough dissolved solids to be a conductive fluid (electrolyte). A potential (electrical) difference may develop between two different kinds of metals, or between nearby but separate areas on the surface of the same metal.

Differences in potential on the same metal surface, such as steel pipe, can occur:

- at heat-affected areas around welded joints,
- at heated areas around torch-cut slots,
- -at work-hardened areas around machine-cut slots,
- -at cut surfaces of exposed threads at pipe joints,
- -at breaks in surface coatings such as paint and mill scale.





#### 1.1.2.7. Most prevalent well problems occurring in various types of aquifers (Driscoll, 1986)

- iron precipitation: Alluvial, consolidated sedimentary, semiconsolidated and consolidated sedimentary.
- incrustation of screens: Alluvial, semiconsolidated and consolidated sedimentary.
- biologic fouling: Alluvial, semiconsolidated and consolidated sedimentary.
- fissure plugging: Sandstone, limestone, basaltic lavas (by clay and silt) interbedded sandstone and shale, metamorphic, consolidated sedimentary, semiconsolidated and consolidated sedimentary.
- casing failure: Sandstone, interbedded sandstone and shale.
- corrosion: Sandstone.
- carbonate scale: Limestone.

#### 1.1.2.8. Prevention and Treatment of Iron Bacteria & Chemical Methods to Control Iron Bacteria (Driscoll, 1986)

All drilling fluid mix water should be chlorinated initially to a 50 mg/l free chlorine concentration, even if secured from a chlorinated municipal water supply. If iron bacteria do grow in a well, they can be controlled by chemical treatments and various types of physical methods. In general, chemical treatments are more effective and less expensive than physical methods. But for maximum effectiveness, any chemical treatment must be accompanied by physical agitation of the well. Jetting, air surging, air-lift pumping, and valved surge blocks are the principal methods used to agitate the well. Pasteurization is a physical method that has been developed to control the growth of iron bacteria. At 45 °C the bacterial plugging is dispersed, and at 54 °C the bacteria are killed. Test after pasteurization show a significant drop in the iron bacteria concentration, although bacteria that exist in the formation can quickly reinfest the well.

#### 1.1.2.9. Prevention and Treatment of Incrustation Problems (Driscoll, 1986)

Method designed to reduce the amount of iron incrusting materials reaching the well screen. This method, called Vyredox System, uses a series of injection wells located in a circle around the production well. Oxygenated water is injected into the wells to oxidize iron in solution and promote the growth of iron bacteria so that little iron reaches the production well. In localities where incrustation of wells is prevalent, samples of the incrusting materials and the water should be analyzed. The constituents will normally include calcium carbonate, iron oxide, silica, aluminum silicate, or organic material. The material causing the clogging will usually be a mixture of several things, not a single substance.

##### Acid treatment of wells:

Chemical incrustation can best be removed by treating the well with a strong acid solution that chemically dissolves the incrusting materials so they can be pumped from the well. Their chief value lies in their ability to dissolve mineral scale as well as some of the iron deposits formed by iron bacteria. The acids most commonly used in well rehabilitation are hydrochloric (HCl), sulfamic (H<sub>3</sub>NO<sub>3</sub>S) and hydroxyacetic (C<sub>2</sub>H<sub>4</sub>O<sub>3</sub>). Sulfamic acid is particularly useful in treating calcium and magnesium incrustants, but is less effective when iron or manganese incrustants are present. The addition of rock salt to sulfamic acid, however, will increase the acid ability to dissolve iron deposits. Hydroxyacetic acid is an excellent bactericide and therefore may be effective in treating wells with iron bacteria problems. It kills the bacteria and simultaneously dissolves the bacterial iron depositions as well as other mineral scale.



### 1.1.2.10. Values of chemical parameters of groundwater indicating suitability conditions for the use of open-loop geothermal systems

Characteristics of physical and chemical parameters of groundwater (Kmiciek et al., 2017)

parameter	unit	Chemical composition		Limits for physical and chemical parameters according to								
				Ochsner Wärmeumpen GmbH			Viessmann Ltd.			Dimplex Ltd.		
		min	max	value	copper	stainless steel	value	copper	stainless steel	value	copper	stainless steel
pH	/			<6	0	0	<7,5	0	0	<7,5	0	0
				6-8	+	+	7,5-9	+	+	7,5-9	+	+
				>8	-	0	>9	0	+	>9	0	+
Cl-	mg/l			<100	+	+	<300	+	+	<300	+	+
				100-200	0	+	>300	0	0	>300	0	0
				>200	-	-						
NO3-	mg/l			n.d.	n.d.	n.d.	<100	+	+	<100	+	+
							>100	0	+	>100	0	+
SO42-	mg/l			<50	+	+	<70	+	+	<70	+	+
				50-100	0	+	70-300	0	+	70-300	0	+
				>100	-	0	>300	-	0	>300	-	0
CO2 agg.	mg/l			<5	+	+	<5	+	+	<5	+	+
				5-20	0	+	5-20	0	+	5-20	0	+
				>20	-	0	>20	-	0	>20	-	0
Fe	mg/l			>0,2	-	-	<0,2	+	+	<2	+	+
				(Fe z Mn)			>0,2	0	+	>2	0	+
Mn	mg/l			>0,05	-	-	<0,1	+	+	<0,1	+	+
							>0,1	0	0	>0,1	0	0
O2	mg/l			<1	+	+	<0,2	+	+	<0,2	+	+
				1-8	0	+	>0,2	0	+	>0,2	0	+
				>8	-	+						
EC	uS/cm			>600	-	+	<10	0	0	<10	0	0
							10-500	+	+	10-500	+	+
							>500	-	0	>500	-	0
HCO3-	mg/l			n.d.	n.d.	n.d.	<70	0	+	<70	0	+
							70-300	+	+	70-300	+	+
							>300	0	0	>300	0	0
NH4	mg/l			<2	+	+	<2	+	+	<2	+	+
				2-20	0	+	2-20	0	+	2-20	0	+
				>20	-	+	>20	-	0	>20	-	0
Al	mg/l			n.d.	n.d.	n.d.	<0,2	+	+	<0,2	n.d.	n.d.
							>0,2	0	+	>0,2		
+	the material is usually resistant											
-	use is not recommended											
0	may lead to corrosion where the value of most factors is "0"											
n.d.	not determined											

#### 1.1.2.11. Korrosionsbeständigkeit Kupfer- Nickel- und Edelstahl gelöteter Wärmetauscher

(<http://www.edelstahl-waermetauscher.de/korrosion.htm>)

Wasserinhaltsstoffe:	Kupfer gelötet	Nickel gelötet	Edelstahl gelötet
PH-Wert:	7 - 9	6 - 10	6 - 10
Chloride:	1.4404 (AISI316L) < 1000 mg/kg bei 0°C < 900 mg/kg bei 25°C < 300 mg/kg bei 50°C < 100 mg/kg bei 75°C < 0 mg/kg bei 100°C		
Sulfate:	< 100 mg/kg	< 300 mg/kg	< 400 mg/kg
Nitrate:	< 100 mg/kg	keine Festlegung	
Eisen, gelöst:	< 0,2 mg/kg	keine Festlegung	
Freie Kohlensäure:	< 20 mg/kg	keine Festlegung	
Mangan:	< 0,1 mg/kg	keine Festlegung	
Ammoniak:	< 2 mg/kg	keine Festlegung	
Chlor:	< 0,5 mg/kg	< 0,5 mg/kg	< 0,5 mg/kg
Elektrische Leitfähigkeit:	10 - 500 µS/cm	keine Festlegung	
Sauerstoff:	< 0,02 mg/kg	< 0,02 mg/kg	
Gesamthärte:	6 - 15 °dH	6 - 15 °dH	6 - 15 °dH
Schwefelwasserstoff:	< 0,05 mg/kg	keine Festlegung	
Hydrogencarbonat:	< 300 mg/kg	keine Festlegung	
Sulfid:	<1 mg/kg	<5 mg/kg	<7 mg/kg
Nitrit:	0,1 mg/kg	0,1 mg/kg	keine Festlegung
Partikel:	< 30 mg/kg	< 30 mg/kg	< 30 mg/kg
Kupfer	< 0,05 mg/kg	< 0,05 mg/kg	keine Festlegung

### 1.1.2.12. Vorgaben Plattenwärmetauscher - Grenzwerte Trinkwasserbeschaffenheit

([http://www.kamo.de/pdfs/DWSFWS\\_Vorgaben\\_Plattenwaermetauscher.pdf](http://www.kamo.de/pdfs/DWSFWS_Vorgaben_Plattenwaermetauscher.pdf))

Folgende Werte für Wasserinhaltsstoffe und für Kennwerte sollten eingehalten werden (1.4404 / SA240 316L):				
Wasserinhaltsstoff + Kennwerte	Einheit	Plattenwärmeübertrager kupfergelötet	Plattenwärmeübertrager Vacinox gelötet	Plattenwärmeübertrager Edelstahl geschraubt
pH-Wert		* 7-9 (unter Beachtung SI Index)	6 - 10	6 - 10
Sättigungs-Index SI (delta pH-Wert)		-0,2 < 0 < +0,2	Keine Festlegung	Keine Festlegung
Gesamthärte Total	°dH	6 - 15	6 - 15	6 - 15
Leitfähigkeit	µS/cm	10...500	Keine Festlegung	Keine Festlegung
Abfilterbare Stoffe	mg/l	< 30	< 30	< 30
** Chloride	mg/l	oberhalb 100 °C keine Chloride zulässig		
Freies Chlor	mg/l	< 0,5	< 0,5	< 0,5
Schwefelwasserstoff (H <sub>2</sub> S)	mg/l	< 0,05	Keine Festlegung	Keine Festlegung
Ammoniak (NH <sub>3</sub> /NH <sub>4</sub> <sup>+</sup> )	mg/l	< 2	Keine Festlegung	Keine Festlegung
Sulfat	mg/l	< 100	< 400	Keine Festlegung
Hydrogenkarbonat	mg/l	< 300	Keine Festlegung	Keine Festlegung
Hydrogenkarbonat / Sulfat	mg/l	< 1,0	Keine Festlegung	Keine Festlegung
Sulfid	mg/l	< 1	< 7	Keine Festlegung
Nitrat	mg/l	< 100	Keine Festlegung	Keine Festlegung
Nitrit	mg/l	< 0,1	Keine Festlegung	Keine Festlegung
Eisen, gelöst	mg/l	< 0,2	< 0,2	< 0,2
Mangan	mg/l	< 0,1	Keine Festlegung	Keine Festlegung
Freie aggressive Kohlensäure	mg/l	< 20	Keine Festlegung	Keine Festlegung
<div> <div> ** Bei 20 °C max. 800 mg/l Bei 25 °C max. 600 mg/l Bei 50 °C max. 200 mg/l Bei 100 °C max. 0 mg/l </div> <div> * Der pH-Wert muss größer als 7,4 sein. Liegt der pH-Wert zwischen 7,0 und 7,4, muss der TOC-Wert kleiner 1,5 g/m<sup>3</sup> bzw. kleiner 1,5 mg/l sein. </div> <div> Die genannten Werte sind Richtwerte, die unter bestimmten Betriebsbedingungen abweichen können. Sollten Sie Fragen haben, rufen Sie uns bitte an. </div> </div>				

### 1.1.2.13. Beständigkeitstabelle für Edelstahl-Plattenwärmetauscher für Pink-Frischwassermodule FriWaStar

(<http://www.pink.co.at/inc.download.php?dlf=322>)

## Beständigkeitstabelle für Edelstahl-Plattenwärmetauscher für Pink-Frischwassermodule FriWaStar

#### Einfluss der KW-Beschaffenheit auf die Lotmaterialien Kupfer und Nickel zur Berücksichtigung bei Wasseranalysen.

Die nachstehende Tabelle soll einen Überblick über die Korrosionsbeständigkeit von Edelstählen und Lötwerkstoffen in Leitungswasser bieten. In der Tabelle sind mehrere wichtige chemische Komponenten aufgelistet, die tatsächliche Korrosion ist jedoch ein sehr komplexer Vorgang, der von vielen unterschiedlichen Komponenten in Kombination miteinander beeinflusst wird. Diese Tabelle stellt daher eine beträchtliche Vereinfachung dar und sollte nicht überbewertet werden!

**Erläuterungen:** + unter normalen Bedingungen eine gute Beständigkeit  
0 korrosionsgefährdet, speziell wenn mehrere Punkte mit "0" zutreffen  
- hohe Korrosionsgefahr, nicht geeignet

Wasserinhaltsstoff	Konzentration (mg/l oder ppm)	Zeitgrenzen Untersuchungszeit nach Probeentnahme	KUPFER	EDELSTAHL/NICKEL
Alkalität ( $\text{HCO}_3^-$ )	< 70 70-300 > 300	Innerhalb von 24 Std.	0 + 0/+	+ + +
Sulfat <sup>[1]</sup> ( $\text{SO}_4^{2-}$ )	< 70 70-300 > 300	Keine Grenze	+ 0/- -	+ + +
$\text{HCO}_3^- / \text{SO}_4^{2-}$	> 1,0 < 1,0	Keine Grenze	+ 0/-	+ +
Elektrische Leitfähigkeit	< 10 $\mu\text{S}/\text{cm}$ 10-500 $\mu\text{S}/\text{cm}$ > 500 $\mu\text{S}/\text{cm}$	Keine Grenze	0 + 0	+ + +
pH <sup>[2]</sup>	< 6,0 6,0-7,5 7,5-9,0 > 9,0	Innerhalb von 24 Std.	0 0 + 0	+ + + +
Ammonium ( $\text{NH}_4^+$ )	< 2 2-20 > 20	Innerhalb von 24 Std.	+ 0 -	+ + +
Chloride ( $\text{Cl}^-$ ) <i>Siehe auch nachstehende Tabelle</i>	<100 100-200 200-300 > 300	Keine Grenze	+ + + 0/+	+ + + +
Freies Chlor ( $\text{Cl}_2$ )	< 1 1-5 > 5	Innerhalb von 5 Std.	+ 0 0/-	+ + +
Schwefelwasserstoff ( $\text{H}_2\text{S}$ )	< 0,05 > 0,05	Keine Grenze	+ 0/-	+ +
Frei (aggressiv) Kohlendioxid ( $\text{CO}_2$ )	< 5 5-20 > 20	Keine Grenze	+ 0 -	+ + +
Gesamthärte ("dH)	4,0-8,5	Keine Grenze	+	+
Nitrat <sup>[3]</sup> ( $\text{NO}_3^-$ )	< 100 > 100	Keine Grenze	+ 0	+ +
Eisen <sup>[3]</sup> (Fe)	< 0,2 > 0,2	Keine Grenze	+ 0	+ +
Aluminium (Al)	< 0,2 > 0,2	Keine Grenze	+ 0	+ +
Mangan <sup>[3]</sup> (Mn)	< 0,1 > 0,1	Keine Grenze	+ 0	+ +

[2] Generell erhöht ein niedriger pH-Wert (unter 6) das Korrosionsrisiko und ein hoher pH-Wert (über 7,5) reduziert das Korrosionsrisiko

[3]  $\text{Fe}^{3+}$  und  $\text{Mn}^{4+}$  sind starke Oxidationsmittel und können das Risiko lokaler Korrosion bei Edelstählen erhöhen,  $\text{SiO}_2$  über 150 ppm erhöhen das Verkalkungsrisiko

**Ab einer Gesamthärte von mehr als 13dH<sup>°</sup> empfehlen wir den Einbau einer Wasserenthärtungsanlage.  
Isoliertrennholländer bei allen Anschlüssen einbauen-verhindert elektrische Leitfähigkeit !  
Wasserqualität des Heizungswassers laut Ö-NORM !**

Tab. 4: Beispiel für von einem Wärmepumpenhersteller vorgegebene Grenzwerte für Wärmepumpen mit kupfergelötetem Wärmetauscher und edelstahlgelötetem Wärmetauscher (OCHSNER 2009: 66).

Plattenwärmetauscher	Einheit		kupfergelötet	edelstahlgelötet
Spez. elektr. Leitfähigkeit	µS/cm	>600	--	+
pH-Wert	-	<6	0	0
		6-8	+	+
		>8	--	0
Chlorid	mg/L	<10	+	+
		10-100	+	+
		100-200	0	+
		>200	--	--
Sulfat	mg/L	<50	+	+
		50-100	0	+
		>100	--	0
Kohlensäure	mg/L	<5	+	+
		5-20	0	+
		>20	--	0
Sauerstoff	mg/L	<1	+	+
		1-8	0	+
		>8	--	+
Ammonium	mg/L	<2	+	+
		2-20	0	+
		>20	--	+
Eisen	mg/L	>0,2	-	-
Mangan	mg/L	>0,05	-	-
Sulfid	mg/L	>5	--	+
Chlor	mg/L	>0,5	+	+
+ = Der Stoff ist normalerweise gut beständig - = Von der Verwendung wird abgeraten 0 = Korrosionsprobleme können entstehen, insbesondere, wenn mehrere Faktoren 0 sind				



#### 1.1.2.14. References

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VDI 4640. 2001a: Thermische Nutzung des Untergrundes - Erdgekoppelte Wärmepumpenanlagen (Blatt 2) = Thermal use of the underground - Ground source heat pump systems (Part 2).

VDI 4640. 2001b: Thermische Nutzung des Untergrundes - Unterirdische Thermische Energiespeicher (Blat 3) = Utilization of the subsurface for thermal purposes - Underground thermal energy storage (Part 3).