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**TYPES OF WATER USED IN  
ICELANDIC "HITAVEITAS"**

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Orkustofnun, Geothermal Division

OS-91033/JHD-18 B

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## ABSTRACT

The Icelandic space heating systems "Hitaveitas" are based on the use of geothermal power, generally through direct use of geothermal water. The hitaveitas are generally open systems where the water is not recirculated, but disposed of into the sewage after use. In a few cases fresh water is heated by geothermal power in heat exchangers and then circulated and treated in a similar way as in the case of direct use of low-temperature geothermal water. Most of the geothermal water has low mineral concentrations and fulfills the main requirements for drinking water, but some of the waters are unsuitable for both consumption and direct use for heating. The water used in Icelandic hitaveitas has been classified into eight main groups, seven of which are low-temperature geothermal water, on basis of the chemical properties most important for utilization: salinity, concentration of hydrogen sulfide and oxygen. The eighth group is fresh water heated by geothermal power.

Traditionally, Icelandic hitaveitas have almost exclusively used water in group 1, which is fresh, oxygen free and with concentration of hydrogen sulfide exceeding 0,1 mg/kg. However, with the great expansion in geothermal heating during the last fifteen years the use of less suitable types of water has become common, i.e. groups 2-7.

## INTRODUCTION

In Iceland about 85% of all houses are now heated by geothermal power. In 1970 a similar number was 50%. At present there are some 40 official space heating systems or hitaveitas in Iceland (fig.1).

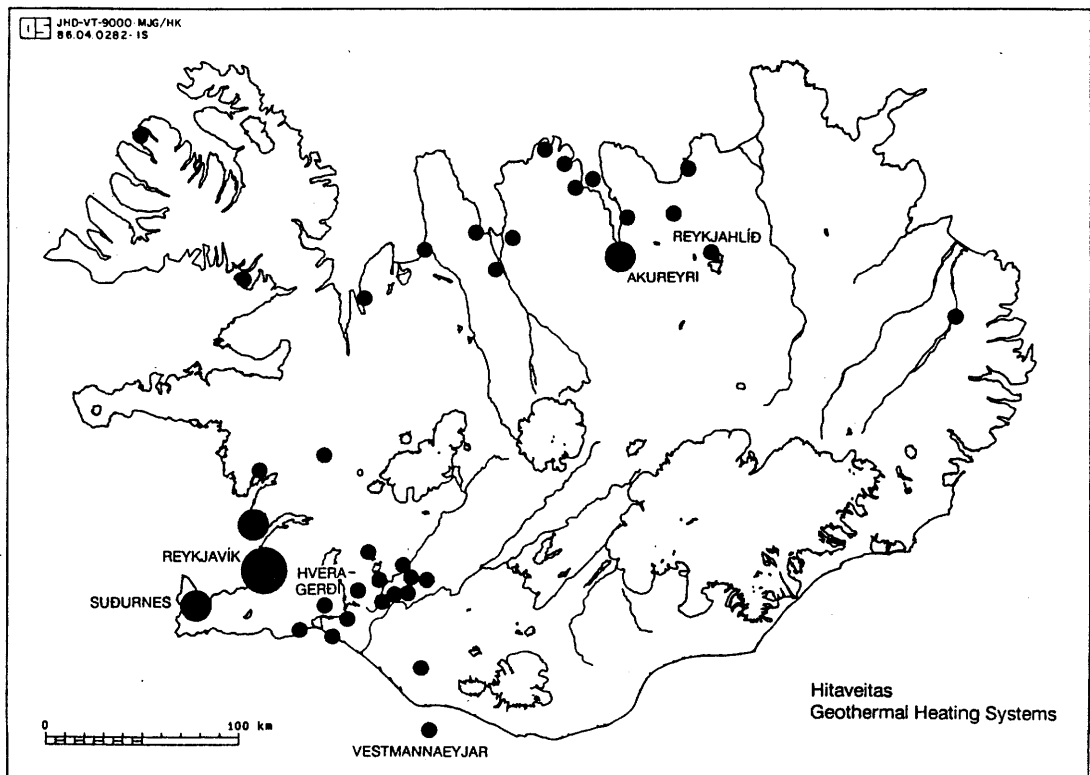


Figure 1. Hitaveitas (district heating systems) in Iceland.

Most of the hitaveitas use geothermal water from one of the low-temperature geothermal fields in Iceland, which are defined as having water temperatures lower than 150°C at 1 km underground depth (Kristmannsdóttir, 1990). In these systems the geothermal water is used directly for heating and as tap water, and then disposed of into the sewage system. In a few cases high-temperature geothermal water is used in hitaveitas. High-temperature geothermal fields are defined as having water temperature exceeding 200°C at 1 km underground depth. Such water is highly mineralised (table 1) and unfit for direct use due to high risk of scaling and corrosion of pipelines (Kristmannsdóttir, 1989).

*Table 1. Chemical composition of selected high-temperature geothermal waters. Concentration in mg/l.*

Geothermal area	Date	Enthalpy H <sub>o</sub> KJ/kg	SiO <sub>2</sub>	Na	K	Ca	Mg	SO <sub>4</sub>	Cl	F	Al	Fe	Total diss. solids	CO <sub>2</sub>	H <sub>2</sub> S	H <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub>	Coll. press. P <sub>e</sub> bars
Námafjall a	830525	2248	162	35	5.0	0.1	0.0	1.7	9	0.19	0.4	<0.025	229	815	975	62	1.38	12.3	19.2
BJ-12 b			619	135	19.0	0.4	0.01	6.5	34	0.73	1.47	<0.025	862	22.2	108	0.02	0.0	0.0	
Krafla a	771029	1973	313	83	14.2	1.4	0.05	55.5	38	0.31	0.5	0.01	489	48597	478	40	42	0.0	12.4
KJ-7 b			787	209	35.8	3.5	0.13	139	95	0.78	1.23	0.02	1229	255	9.4	0.01	0.01	0.0	
Svartsengi a	810220	1029	437	6478	935	938	0.57	28.1	13925	0.19	0.50	0.13	21404	662	6.2	0.0	0.09	2.8	14
SG-6 b			504	7468	1078	1082	0.66	32.4	16052	0.22	0.62	0.15	24675	16.5	0.3	0.0	0.0	0.01	
Reykjanes a	831024	1317	587	9079	1388	1526	0.93	16.2	17749	0.15	0.80	0.7	30927	1523	48	0.10	0.05	3.9	43
Rn-9 b			812	12564	1920	2112	1.28	22.4	24558	0.21	1.2	0.9	42797	14.2	1.0				
Hveragerði a	820618	850	242	149	11.4	1.7	0.0	39.4	126	1.62	0.50	<0.025	701	448	46	0.3	0.33	11.5	7.1
NLF-2 b			254	156	11.9	1.8	0.003	41.2	132	1.69	0.51	<0.025	734	71	20	0.0	0.0	0.02	

a: total flow

b: water boiled at 180°C

In systems based on high-temperature water cold groundwater is heated in heat-exchange plants and distributed in the same way as in the hitaveitas using low-temperature geothermal water. Two Icelandic hitaveitas use a closed circulation system as is most common in the Nordic countries, and one of these two does not even use geothermal power. In the first hitaveitas there were not so many problems connected with the use of geothermal water for direct heating as those systems were built in areas with easy access to plentiful water with chemical properties well suited for this purpose. Later on, during and after the oil-crisis when new hitaveitas were built all over the country, they had to make use of much less suitable fluids and accordingly had to deal with new technical problems. As hitaveitas had been operated for decades without any major problems no consideration was in many cases paid to the chemical properties of the water during design and building of the district heating systems. Consequently, when operation started major problems were encountered and installations were damaged.

In no cases have any major environmental problems occurred as a result of the disposal of hot water.

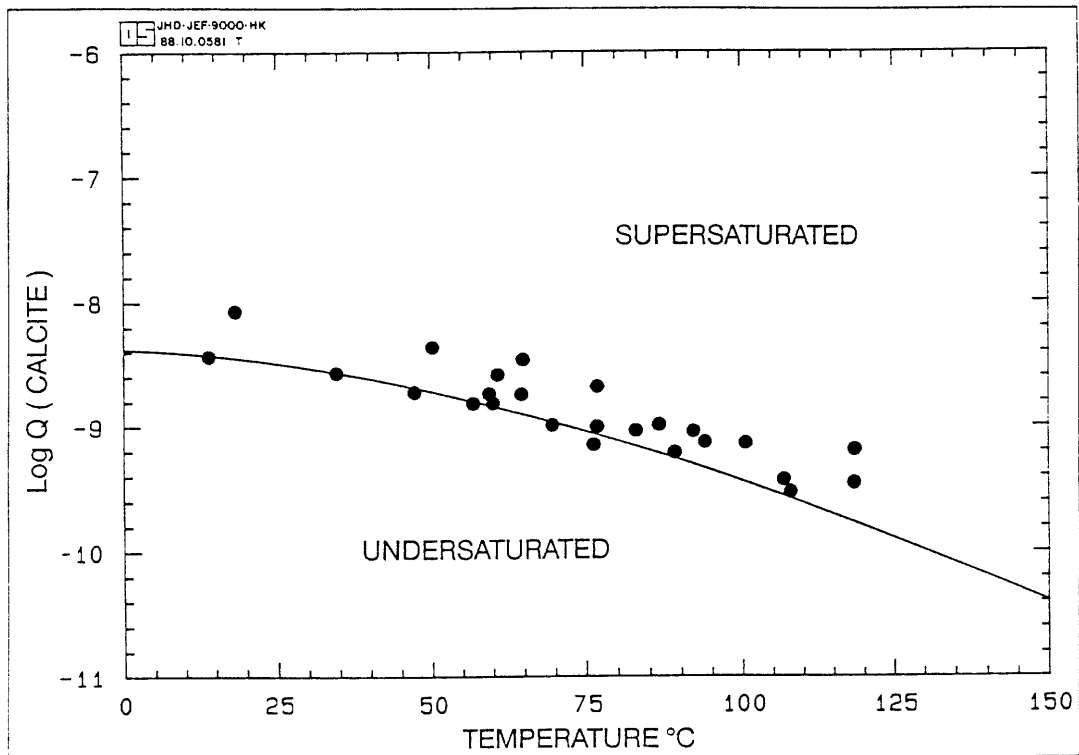


Figure 2. The state of calcite saturation in low-temperature geothermal water in Iceland.

### CHEMISTRY OF WATER IN HITAVEITAS IN ICELAND

Most geothermal water in Iceland is of meteoric origin and only in a few places is the water contaminated with sea-water. The low-temperature water has in most cases low concentrations of dissolved solids, but the mineralisation increases by increased reservoir temperature of the geothermal fields. The reservoir rocks are dominantly basalts as Iceland is principally built up of basaltic volcanics. The fluids evolved by reaction with these rocks at elevated temperatures have a high pH value, and are in equilibrium with the silica mineral chalcedony (Arnórsson et al., 1983) as well as several aluminium-, alkali-, iron- and magnesiumsilicates and calcium carbonate. Typical composition of Icelandic low-temperature geothermal waters is shown in table 2, and figure 2 shows an example of mineral equilibrium in the fluids by temperature.

The numbers in table 2 refer to the classification introduced in the next section. As shown in the table the concentration of dissolved solids is typically about 200-400 mg/kg in the waters, but may reach up to 4000 mg/kg in waters infiltrated by sea-water. In one case a low-temperature geothermal brine of the same salinity as seawater has been exploited for aquacultural purposes, but nowhere for a hitaveita. The salinity has in some cases increased by infiltration of sea-water during production (Kristmannsdóttir, 1986) and thereby the production properties of the water have changed with time.

As shown in table 2 the waters commonly contain some hydrogen sulfide but only in rare cases any dissolved oxygen. Oxygen uptake may occur in storage tanks and through the walls of plastic pipes (Ólafsson, 1988) which are increasingly being used for distribution of hot water.

Carbonate low-temperature geothermal waters occur in a few places, but have nowhere been used for hitaveitas. Carbonate water has been used for heating in a few cases, but only in small district heating systems using heat exchangers.

The heated fresh waters used in hitaveitas have still lower concentrations of dissolved solids than the low-temperature geothermal waters. Yet the equilibrium concentration of a few components such as calcium, magnesium and carbonate is higher in the cold fresh water than in geothermal water and so is dissolved oxygen. Most of the oxygen is disposed of by the heating and deaerating the water and the rest is eliminated by addition of geothermal steam. The addition of steam also serves to lower the pH of the water and thereby the supersaturation with respect to magnesium silicates (see fig. 3), which have very low solubilities at elevated temperatures.

Table 2. Chemical composition of water used in Icelandic Hitaveitas.

Group	Fresh water			Slightly saline geothermal water			Saline geothermal water	Heated water	Carbonate water
	1	2	3	4	5	6	7	8	
Temp.°C	130	66.5	60.3	117	79	75	71	96	73
pH/°C	9.3/23	9.9/22	10.1/20	8.4/22	9.6/22	9.7/21	7.3/22	8.8/18	7.02/20
Tot.carb. (CO <sub>2</sub> ) (mg/l)	19.6	14.8	13.4	9.8	6.0	6.4	40.3	44.8	446
Hydrogen sulfide (H <sub>2</sub> S)	"	0.22	0	0.02	0.10	0	0	1.0	0.06
Silica (SiO <sub>2</sub> )	"	146.2	70.8	71.7	122.9	69.2	69.0	25.9	167
Tot.diss.solids (TDS)	"	331	239	183	3484	804	1113	86	904
Oxygen (O <sub>2</sub> )	"	0	<0.005	0.200	0	0.005	0.020	-	-
Sodium (Na)	"	62.2	54.8	35.1	597	224	344	11041	255
Potassium (K)	"	2.9	0.8	0.5	14.0	4.4	4.7	399	9.2
Magnesium (Mg)	"	0.007	0.012	0.007	0.380	0	0.001	109.2	3.0
Calcium (Ca)	"	3.1	2.3	2.4	522.9	56.9	35.6	1915	27
Fluoride (F)	"	1.13	1.52	0.150	0.667	0.279	1.29	0.039	1.5
Chloride (Cl)	"	46.3	24.9	7.9	1616.8	388.8	501.4	19950	99
Sulfate (SO <sub>4</sub> )	"	28.6	39.4	5.4	304.4	47.8	117.5	1534	65
Iron (Fe)	"	0	-	-	0.025	0	0	1.1	0.6

## SCALING AND CORROSION

In general only a few serious problems have to be dealt with in connection with the direct use of Icelandic geothermal waters in hitaveitas.

The geothermal water commonly contains hydrogen sulfide which is corrosive for steel pipes, but a coating of iron sulfide is normally formed within the pipe, preventing further corrosion.

Copper pipes will be quickly corroded and copper sulfide in turn precipitated from the water, but it does not form any protective film on the pipe wall and a fresh surface is continually exposed to the corrosive fluid.

The geothermal water is normally free of oxygen when it emerges from the wells, even though it does not contain hydrogen sulfide. Quite commonly it will take up some oxygen in storage and levelling tanks and plastic pipes, and if there is no hydrogen sulfide in the water to react with it there is a danger of corrosion in pipes and radiators. The salinity of the waters is of utmost importance in this respect as increased salinity catalyses the corrosion, even at low to moderate concentration levels. In waters with chloride concentration even as low as 50 mg/kg the concentration of 10 ppb of dissolved oxygen may cause considerable corrosion of steel radiators. In fresh water, with chloride concentration of 10-20 mg/kg, the rate of corrosion will be much slower and a concentration of 10 ppb of dissolved oxygen is considered more or less harmless.

In rare cases water originated at shallow depths and/or below 70°C is used in hitaveitas. In such waters some dissolved oxygen may be encountered. In hitaveitas sodium sulfite is commonly added to water of this type for amendment.

Zink in brass and galvanized pipes is easily dissolved in geothermal water and duly precipitated as zink sulfide or as zink silicate (Kristmannsdóttir, 1989).

The cement matrix in eternitt pipelines commonly used in distribution nets in Icelandic hitaveitas dissolves in the geothermal water greatly increasing the pH and Ca concentration of the water whereby the scaling potential of the water is enhanced. The dissolution of the matrix gradually breaks up the structure of the pipes and turns loose asbestous threads from the walls.

Scaling by calcium carbonate is the most troublesome phenomenon connected with direct use of low-temperature geothermal water in Iceland. All the geothermal waters are in equilibrium with calcium carbonate in the reservoirs (fig. 2). By cooling of the water it will become undersaturated, but other processes such as boiling and deaeration may disturb the equilibrium and cause supersaturation. By mixing waters from two aquifers of different temperatures and salinity supersaturation may occur with subsequent precipitation of calcium carbonate. When this happens inside a production well it is difficult to amend, and the well may have to be recased or a new hole drilled. Also, calcium carbonate scaling is catalysed by increased salinity of the waters and in corrosive waters rough pipe walls may also accelerate the scaling process.

Scaling by silica may occur in a few cases, but as silica precipitation is generally not to be expected until supersaturation with respect to opaline amorphous silica is reached (see Fournier, 1981), it rarely happens in low-temperature geothermal waters.

In the four hitaveitas in Iceland where fresh water is heated by geothermal water there have in all cases been problems due to scaling of magnesium silicates (Kristmannsdóttir et al., 1989). To minimize scaling the pH is kept as low as possible by minimum deaeration and addition of geothermal steam. Yet, great care has to be taken to prevent the water from becoming too corrosive. The heating of the waters is



also kept at a minimum above the boiling temperature to keep the supersaturation of magnesium silicates in check. All heated waters are somewhat supersaturated with respect to magnesium silicates. Even if the degree of supersaturation is low precipitation will eventually occur from a supersaturated fluid. The dwelling time in the plant and distribution net has thus to be kept as short as possible. In one case an attempt was made to run a plant by mixing the heated fresh water with geothermal water in the storing tanks and distribution net, but severe scaling problems were encountered. This should indeed have been anticipated as the mixture had high pH, high concentration of magnesium and silica all adding to the supersaturation of magnesium silicates. In addition the higher total concentration of dissolved solids in the mixture would have a catalysing effect on the scaling process, as well as increased salinity.

### **TYPES OF WATER EXPLOITED IN HITAVEITAS**

As stated in previous sections hydrogen sulfide, oxygen and salinity are the most important parameters of the natural low-temperature geothermal waters in Iceland. The low-temperature waters used in Icelandic hitaveitas can be classified into seven groups by their different concentration of those three substances and the eighth group of water is the heated fresh waters:

1. Fresh geothermal water with chloride concentration  $<50$  mg/l and hydrogen sulfide  $>0,1$  mg/l.
2. Fresh geothermal water with chloride concentration  $<50$  mg/l, hydrogen sulfide  $<0,1$  mg/l and dissolved oxygen  $<0,010$  mg/l.
3. Fresh geothermal water with chloride concentration  $<50$  mg/l, hydrogen sulfide  $<0,1$  mg/l and dissolved oxygen  $>0,010$  mg/l.
4. Slightly saline geothermal water with chloride concentration  $>50$  mg/l and hydrogen sulfide  $>0,1$  mg/l.
5. Slightly saline geothermal water water with chloride  $>50$  mg/l, hydrogen sulfide  $<0,1$ mg/l and dissolved oxygen  $<0,010$  mg/l.
6. Slightly saline geothermal water with chloride concentration  $>50$  mg/l, hydrogen sulfide  $<0,1$  mg/l and dissolved oxygen  $>0,010$  mg/l.
7. Saline geothermal water with chloride concentration  $>20000$  mg/l.
8. Heated cold groundwater.

The choice of the limits partly refers to the range of composition of the waters, but is mainly based on utilisation efficiency of the waters as was discussed above.

Water in group 1 is by far the best suited for direct heating purposes and water in group 4 is also very well suited, if the salinity is not too high. As to groups 2 and 5 one has to be careful not to take up oxygen by the use of this type of water, but otherwise the water is well suited for heating. Water in group 3 can be quite suitable for direct

use without chemical treatment, but group 6 waters are of poor quality and those in group 7 are totally unfit for direct heating purposes.

In the case of heated cold waters some problems can always be expected, but at least in small plants these problems can be minimized by treatment of the water and a correct design.

## REFERENCES

- Arnórsson, S., E. Gunnlaugsson and H. Svavarsson, 1983. The chemistry of geothermal waters in Iceland. II Mineral equilibria and independent variables controlling water compositions. *Geochim. Cosmochim. Acta* 47: 547-566.
- Fournier, R. O., 1981. Application of water geochemistry to geothermal exploration and reservoir engineering. In: *Geothermal Systems: Principles and Case Histories*. Ed. by Ryback and L.J. P. Muffler. John Wiley and Sons Ltd. New York: 109-143.
- Kristmannsdóttir, H., 1986. Exploitation-induced infiltration of seawater into the Seltjarnarnes geothermal field, Iceland. *Geothermal Res. Council Trans.* 10: 389-393.
- Kristmannsdóttir, H., 1989. Types of scaling occurring by geothermal utilization in Iceland. *Geothermics*, 18: 183-190.
- Kristmannsdóttir, H., M. Ólafsson and S. Thórhallsson, 1989. Magnesium silicate scaling in district heating systems in Iceland. *Geothermics*, 18: 191-198.
- Kristmannsdóttir, H., 1990. "Water used in Icelandic Hitaveitas. Types of water and chemistry". Report (in Icelandic) from Orkustofnun, OS-90042/JHD-23 B. 15 pp.
- Ólafsson, M., 1988. "Oxygen uptake in plastic pipes used in distribution nets for Hitaveitas". Report (in Icelandic) from Orkustofnun, OS-88032/JHD-16 B.