OR Annual report 2021

Appendices

Release of geothermal water from the Nesjavellir and Hellisheidi geothermal power plants. Groundwater monitoring.

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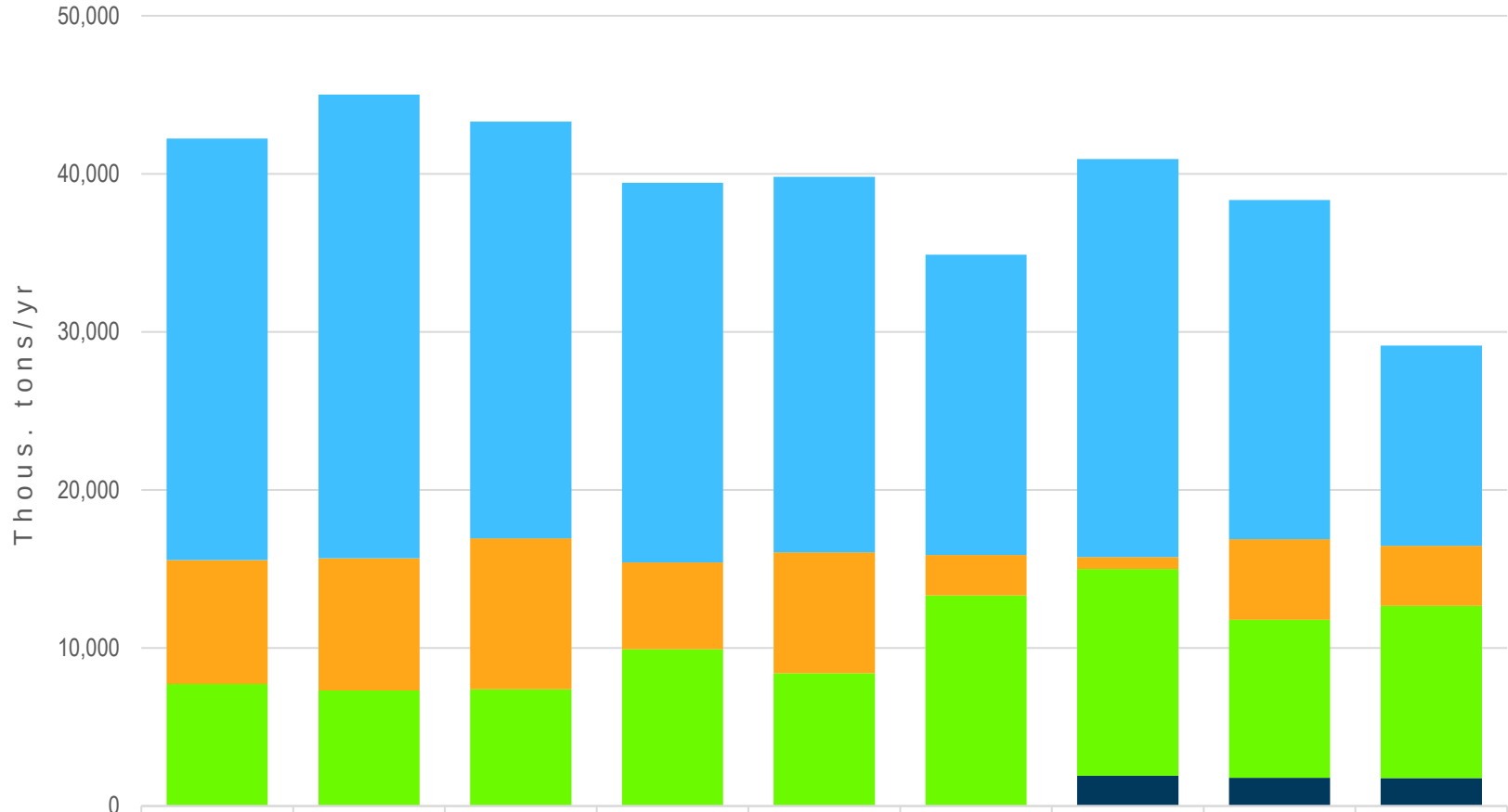
Cover photo: Gretar Ívarsson

Volume of geothermal water from the Nesjavellir Geothermal Power Plant by release route

Geothermal water (thous.m^3/year) from Nesjavellir Geothermal Power Plant 2013-2021 by release route.

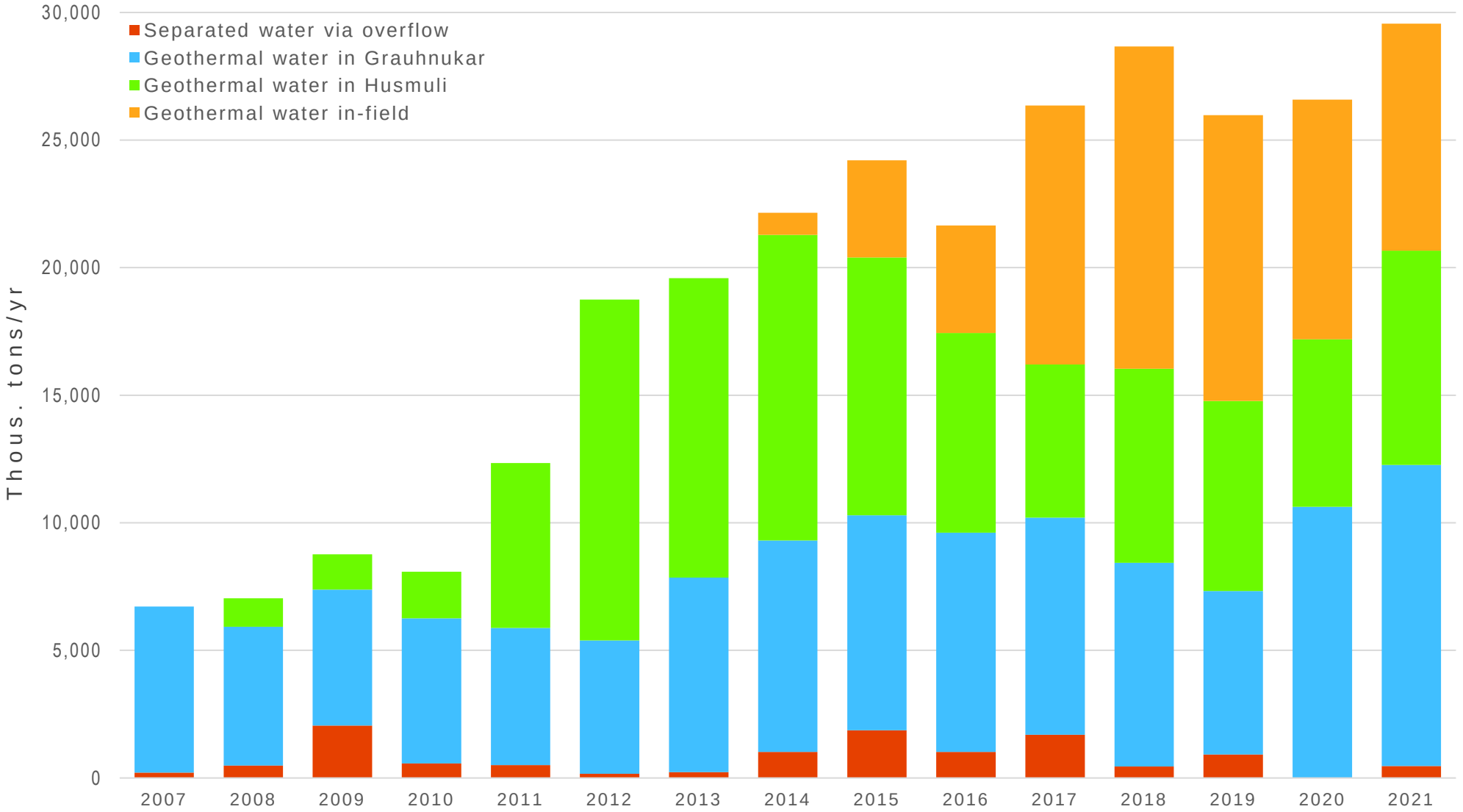
Volumes are rounded to thousands of tonnes.



	2013	2014	2015	2016	2017	2018	2019	2020	2021
Heated groundwater on surface	26,687	29,333	26,371	24,009	23,760	18,993	25,183	21,472	12,669
Geothermal water on surface	7,824	8,367	9,545	5,504	7,649	2,556	754	5,083	3,790
Geothermal water in shallow reinjection	7,730	7,317	7,388	9,917	8,395	13,328	13,086	9,997	10,895
Geothermal water in deep reinjection							1,915	1,792	1,774

Volume of geothermal water from the Hellisheidi Geothermal Power Plant by release route 2007 – 2021

Until September 2011, the largest part of geothermal water was reinjected through wells in Gráuhnúkar. Geothermal water from the plant increased when the Sleggjan plant was launched in autumn 2011, but the reinjection field at Húsmúli was then put into full operation. Since then, the geothermal water from the plant has increased. Reinjection in discontinued production wells within the production field started in 2014 and in boreholes in Threngsli in 2016.



Year	Seperated water via overflow	Geothermal water in Gráuhnúkar	Geothermal water in Húsmúli	Geothermal water in production field	Total geothermal water
	thous. tons/year	thous. tons/year	thous. tons/year	thous. tons/year	thous. tons/year
2007	215	6,502			**6,718**
2008	483	5,439	1,123		**7,045**
2009	2,050	5,335	1,382		**8,767**
2010	572	5,684	1,826		**8,082**
2011	506	5,374	6,461		**12,341**
2012	163	5,224	13,358		**18,745**
2013	233	7,620	11,733		**19,586**
2014	1,024	8,281	11,982	860	**22,147**
2015	1,870	8,422	10,107	3,803	**24,202**
2016	1,025	8,585	7,831	4,213	**21,654**
2017	1,699	8,506	6,001	10,147	**26,353**
2018	447	7,982	7,611	12,625	**28,665**
2019	919	6,409	7,445	11,206	**25,980**
2020	21	10,610	6,558	9,394	**26,583**
2021	470	11,797	8,398	8,898	**29,562**
Total	**11,697**	**111,770**	**101,816**	**61,146**	**286,429**

Volumes are rounded to thousands of tons

Geothermal fluids discharged via overflows at the Hellisheidi Geothermal Power Plant and in Hverahlid 2021

The reinjection utility is vulnerable to any operational changes and approximately 1.2% of produced geothermal water at Hellisheidi Power Plant was released via overflow. Licensors have been kept informed on the situation, on actions available at any given time and of the ongoing projects to increase the reception of the reinjection utility. Overflow in Hverahlid was inactive throughout 2021.

Date	Type of disturbance	Maximum flow [l/s]
Hellisheidi power plant		
January 19th & 20th	Maintenance	60
May 6th & 7th	Maintenance	340
August 29th	Maintenance	39
September 10th	Maintenance	54

Chemical composition of geothermal water and heated groundwater for space heating from geothermal power plants in the Hengill area

Typical concentrations (µg/L) of several trace elements in geothermal water (separated water) and heated groundwater (for space heating) from the Hellisheidi and Nesjavellir geothermal power plants and their maximum permissible concentrations (µg/L) for potable water. When the chemical content of separated water is compared to potable water standards, one can see that the concentration of arsenic in separated water from Nesjavellir was over eight times the maximum for potable water and in separated water from Hellisheidi, it was almost seven times the maximum. The concentration of selenium in separated water in Hellisheidi was also slightly over the limit. The concentration of other substances in separated water and heated groundwater is lower than the given limits for potable water.

Trace element	Unit	Max. recommended value for potable water	HELLISHEIDI			NESJAVELLIR		
			Separated water	Condensed water	Heated groundwater	Separated water	Condensed water	Heated groundwater
Arsenic (As)	µg/L	10	66.10	< 0.05	0.08	82.30	1.54	1.99
Barium (Ba)	µg/L	700	0.25	0.06	0.56	0.26	0.10	0.72
Cadmium (Cd)	µg/L	5	< 0.002	< 0.002	< 0.002	< 0.002	0.01	< 0.002
Cobalt (Co)	µg/L	*	< 0.005	< 0.005	< 0.005	0.01	0.03	0.01
Chrome (Cr)	µg/L	50	0.05	0.02	0.08	0.11	0.20	0.32
Copper (Cu)	µg/L	2,000	1.23	< 0.1	0.44	10.80	13.10	0.24
Mercury (Hg)	µg/L	1	< 0.002	< 0.002	< 0.002	0.019	< 0.002	< 0.002
Manganese (Mn)	µg/L	50	0.39	0.21	0.21	1.04	13.90	0.09
Molybdenum (Mo)	µg/L	*	8.05	0.27	0.19	5.31	0.06	0.44
Nickel (Ni)	µg/L	20	0.11	< 0.05	0.41	0.59	8.65	< 0.05
Phosphorus (P)	µg/L	5,000	< 1	1.42	45.40	< 1	2.96	46.50
Lead (Pb)	µg/L	10	0.02	< 0.01	0.03	0.40	0.37	< 0.01
Antimony (Sb)	µg/L	5	2.23	0.06	< 0.01	1.93	0.04	0.06
Selenium (Se)	µg/L	10	12.90	0.42	< 0.3	1.49	< 0.3	1.40
Strontium (Sr)	µg/L	*	< 10	< 2	10.35	< 10	< 2	19.70
Titanium (Ti)	µg/L	*	0.07	0.01	0.03	0.83	0.24	0.03
Vanadium (V)	µg/L	*	3.19	0.53	9.32	1.94	0.10	21.20
Zinc (Zn)	µg/L	3,000	1.45	0.53	5.66	10.90	85.70	1.85

** Maximum limits not specified in the potable water regulation*

Chemical composition of geothermal water (separated water) and heated groundwater (for space heating) from the Hellisheidi and Nesjavellir Geothermal Power Plants and their maximum permissible concentrations (mg/kg) for potable water

When the chemical content of separated water is compared to potable water standards, one can see that in separated water from the Hellisheidi and Nesjavellir Geothermal Power Plants, the concentration of potassium is around three times higher than permissible levels for potable water. The concentrations of sodium and fluoride in the separated water from Hellisheidi also exceeds the limit. Concentrations of aluminium in separated water from both plants are nine to ten times over the limit for potable water. Iron concentrations in condensed water in Nesjavellir is three times over the limit and is also slightly over the limit in separated water. Concentrations of other chemicals in condensate and heated groundwater from both power plants is lower than the given limits for potable water.

Chemical- and physiological factors	Unit	Max. recommended value for potable water	HELLISHEIDI			NESJAVELLIR		
			Separated water	Condensed water	Heated groundwater	Separated water	Condensed water	Heated groundwater
Acidity	pH		9.49	6.2	8.08	8.32	5.4	8.46
T (pH)	°C		21.0	37.5	18	42.3	11.8	20.6
Carbon dioxide (CO_2)	mg/kg	*	20.3	3.1	22.6	17.4	19.1	43.3
Hydrogen sulphide (H_2S)	mg/kg	*	20.8	-	0.21	43.7	39.7	0.7
Silica (SiO_2)	mg/kg	*	723.4	0.8	23.7	725.1	0.56	43.1
Sodium (Na)	mg/kg	200	213.4	0.3	5.85	171.1	0.4	18.0
Potassium (K)	mg/kg	12	39.2	0.03	0.76	32.4	0.2	2.41
Calcium (Ca)	mg/kg	100	0.54	0.21	5.10	0.43	0.13	10.62
Magnesium (Mg)	mg/kg	50	0.014	0.10	2.93	0.004	0.01	5.26
Iron (Fe)	mg/kg	0.2	0.020	0.066	0.002	0.022	0.604	0.006
Aluminium (Al)	mg/kg	0.2	1.79	0.004	0.002	1.96	0.01	0.11
Sulphate (SO_4)	mg/kg	200	16.5	1.92	3.61	12.07	2.21	15.69
Chloride (Cl)	mg/kg	*	203.5	0.2	7.25	153.5	0.8	15.95
Fluoride (F)	mg/kg	1.5	1.53	0.05	0.09	1.33	0.06	0.16

** Maximum limits not specified in the potable water regulation*

Chemical composition of groundwater in wells around the Hellisheidi Power Plant in 2021

Well			HK-07	HK-12	KH-50	KH-03	KH-12	KH-17	KH-52	KH-05	KH-06	HU-1	HK-14	HK-28
Groundwater flow			Selvogur flow			Selvogur / Thingvellir flows				Thingvellir flow				Ölfus flow
Sample no.			21-5221	21-5220	21-5289	21-5235	21-5185	21-5234	21-5288	21-5231	21-5224	21-5233	21-5223	21-5184
Date			7.9.2021	7.9.2021	7.12.2021	23.9.2021	30.6.2021	23.9.2021	6.12.2021	15.9.2021	8.9.2021	16.9.2021	8.9.2021	30.6.2021
Chemical properties	**Unit**	**Maximum value**												
Acidity	pH		7.48	8.31	7.20	6.98	7.53	7.10	6.65	7.78	6.82	7.67	8.07	7.07
T (pH)	°C		21.9	22.0	21.7	16.5	22.8	19.0	21.9	22.0	22.0	21.9	22.1	22.7
CO_2	mg/kg	*	53.0	39.5	68.6	192.7	30.0	219.0	26.4	45.0	32.9	24.0	21.1	76.1
F	mg/kg	1.5	0.098	0.083	0.103	0.195	0.113	0.136	0.071	0.092	0.063	0.093	0.065	0.265
Cl	mg/kg	*	8.85	9.25	8.84	5.43	9.89	5.55	5.43	7.75	6.68	7.89	7.55	16.80
SO_4	mg/kg	200	14.49	11.53	27.59	22.47	14.39	8.53	9.85	4.05	2.45	2.45	2.30	27.77
Ca	mg/kg	100	9.23	11.06	8.24	33.87	6.1	30.05	5.7	9.44	4.21	4.18	3.78	12.85
Fe	mg/kg	0.2	0.02	0.21	0.01	0.07	0.00	0.01	0.014	0.01	0.31	0.005	0.010	0.023
K	mg/kg	12	0.81	1.02	1.09	2.46	1.06	2.79	0.82	0.79	0.48	0.75	0.71	4.68
Mg	mg/kg	50	9.86	5.41	16.24	12.86	3.46	12.30	2.81	5.83	3.80	2.47	2.78	4.34
Na	mg/kg	200	9.49	9.15	9.19	22.54	8.21	29.36	5.30	7.26	4.95	5.60	6.17	28.53
SiO_2	mg/kg	*	29.45	22.51	44.48	61.23	32.00	68.98	21.35	28.66	15.54	23.13	16.03	92.96
Al	µg/kg	200	6.94	114.00	3.71	4.67	10.20	5.20	1.68	0.74	2.16	1.08	10.10	8.85
As	µg/kg	10	0.09	< 0.05	0.07	0.06	0.36	0.12	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.31
Ba	µg/kg	700	0.36	1.52	0.63	1.09	0.92	2.27	1.34	0.21	0.83	0.46	0.23	0.71
Cd	µg/kg	5	0.012	0.004	0.0352	< 0.002	0.00399	0.0469	0.0236	0.011	0.013	0.0039	0.00379	< 0.002
Co	µg/kg	*	0.02	0.12	0.015	< 0.005	0.006	0.015	0.025	0.01	0.05	0.007	0.012	0.016
Cr	µg/kg	50	1.71	5.43	0.25	0.79	0.48	0.89	0.87	0.69	2.78	0.46	3.31	0.49
Cu	µg/kg	2,000	1.83	1.22	3.32	0.17	0.17	4.97	1.84	0.255	2.94	0.29	0.77	1.88
Hg	µg/kg	1	< 0.002	0.003	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Mn	µg/kg	50	0.95	6.46	0.82	1.55	0.18	2.12	2.06	1.00	2.81	0.245	0.56	7.78
Mo	µg/kg	*	0.79	0.47	0.15	0.34	0.26	0.16	0.21	0.19	0.09	0.15	0.13	5.48
Ni	µg/kg	20	0.10	2.86	1.39	2.98	< 0.05	1.50	0.90	0.26	0.24	< 0.05	< 0.05	4.87
Pb	µg/kg	10	0.13	0.05	0.2	< 0.01	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.9
P	µg/kg	5,000	48.8	32.8	57.9	77.8	46.5	72.8	2.9	62.7	7.50	47.4	19.5	90.3
Sb	µg/kg	5	0.142	0.078	0.0594	0.013	1.8	0.0203	0.134	0.035	0.031	0.021	0.035	0.035
Se	µg/kg	10	0.85	0.473	0.466	0.494	0.597	0.455	0.422	< 0.3	< 0.3	< 0.3	< 0.3	0.747
Sr	µg/kg	*	21.1	21.8	20.6	67.0	14.5	67.6	13.0	15.4	8.9	8.2	8.6	37.5
Ti	µg/kg	*	0.114	8.00	0.158	0.019	0.122	0.088	0.046	0.035	0.203	0.031	0.156	0.198
V	µg/kg	*	16.5	23.6	3.0	17.8	9.3	12.8	1.8	11.9	2.8	7.2	4.8	46.6
Zn	µg/kg	3,000	67.5	12.3	92.2	2.1	6.2	120.0	68.6	39.1	23.3	23.6	11.2	23.6

* *Maximum value not specified in Icelandic regulation*

The impact of the Hellisheidi Power Plant on groundwater is closely monitored in surveillance wells at and around the plant. Samples are collected to analyse overall chemical content and trace elements. in addition to measuring their temperature. conductivity and acidity. The concentration of dissolved solids is far below the limits set for potable water.