DELIVERABLE 2.1

D2.1 Fluid data of geothermal sites (type C)

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1. EXECUTIVE SUMMARY

The main objective of the work package 2 of the REFLECT project is to characterise relevant fluid properties and their reactions for saline fluids (type C). One of the specific goals was to collect fluid samples from several saline fluids from geothermal sites across Europe, determine their properties, and thus contribute to the Fluid Atlas (WP3). Additionally, the REFLECT team will compare those field data with data from lab experiments performed at near natural conditions.

Samples of type C fluids were taken from several sites in Germany, Austria, Belgium and the Netherlands. The samples were analysed for major and minor ions, dissolved gases and isotopes.

2. SAMPLING AND ANALYSIS OF TYPE C FLUIDS

In June 2020 and from April through July 2021, thermal water samples have been taken from seven geothermal or hydrothermal sites in the Netherlands, Belgium, Germany and Austria. Figure 1 shows the locations of the conducted sampling campaigns. This deliverable reports on the sampling campaigns and the results obained from data analysis.

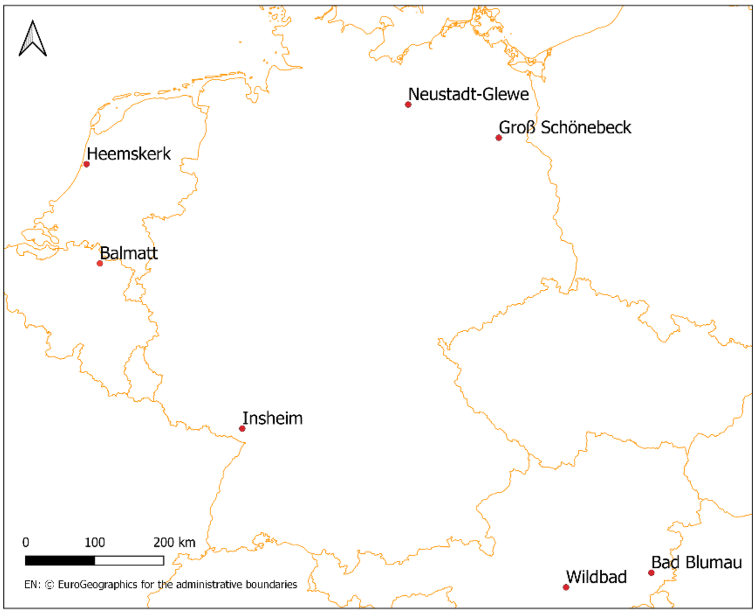

Figure 1: Overview of location of conducted sampling campaigns

2.1 SAMPLING AND ANALYSIS OF THERMAL WATER SAMPLES FROM NEUSTADT-GLEWE, GERMANY

At Neustadt-Glewe one thermal water sample was taken by GFZ on June 02, 2021 and sent to Hydroisotop for analysis of main cations, anions, heavy metals, DOC, gases and isotopes (^{18}O, ^{2}H, $^{18}O-SO_4$, ^{2}H, ^{13}C-DIC, $^{13}C-CO_2$, $^{13}C-CH_4$, $^{13}C-C_xH_y$, $^{2}H-CH_4$, $^{34}S-SO_4$, $^{34}S-H_2S$, $^{2}H-CH_4$). There was too little H_2S in sample 363469 to conduct the $^{34}S-H_2S$ measurement. The analytical results are presented in Table 1 and Table 2.

Table 1 **Hydrochemical composition of thermal water samples from Neustadt-Glewe, Germany.**

Lab-No.	unit	363469
Location		**Neustadt-Glewe**
		Gt-Neustadt-Glewe
		02.06.2021
Spec. electr. conductivity (25 °C) Lab.	µS/cm	218000
pH value Lab.		5,5
Temperature Lab.	°C	24,3
Alkalinity (pH 4,3) Lab.	mmol/l	1,5
Main cations and anions		
Sodium (Na^+)	mg/l	74000
Potassium (K^+)	mg/l	890
Calcium (Ca^{2+})	mg/l	7900
Magnesium (Mg^{2+})	mg/l	1400
Ammonium (NH_4^+)	mg/l	71,6
Hydrogen carbonate (HCO_3^-)	mg/l	91,8
Chloride (Cl^-)	mg/l	130000
Sulphate (SO_4^{2-})	mg/l	460
Nitrate (NO_3^-)	mg/l	15
Heavy metals and trace elements		
Antimony	mg/l	0,042
Barium (Ba^{2+})	mg/l	4,2
Fluoride (F^-)	mg/l	2,8
Iodide (I^-)	mg/l	< 1
Lithium (Li^+)	mg/l	22,3
Silicon	mg/l	9,8
Strontium (Sr^{2+})	mg/l	400
Aluminium	mg/l	0,028
Arsenic	mg/l	< 0,005
Lead	mg/l	< 0,5
Chromium total	mg/l	< 0,02
Iron total	mg/l	84,8
Copper	mg/l	< 0,01
Manganese total	mg/l	13,5
Nickel	mg/l	-
Uranium	mg/l	< 0,0001
Zinc	mg/l	4,76
DOC	mg/l	31,7

Table 2 **Analytical results of dissolved gases and stable isotopes of thermal water samples from Neustadt-Glewe, Germany.**

Dissolved gases		
Hydrogen	Nml/kg	0,206
Oxygen	Nml/kg	0
Nitrogen	Nml/kg	3,6
Carbon dioxide	Nml/kg	122
Methane	Nml/kg	8,35
Ethane	Nml/kg	0,3243
Propane	Nml/kg	0,0375
Butane	Nml/kg	0,0031
Pentane	Nml/kg	0,0004
Helium	Nml/kg	< 0,0735
Argon	Nml/kg	0,08
Sum Gases	Nml/kg	135
Stable isotopes		
Oxygen-18 ($\delta^{18}O$)	‰	-2,03
Deuterium (δ^2H)	‰	-27,7
Deuterium-excess	‰	-11,46
Carbon-13 ($\delta^{13}C$-DIC)	‰	-11
Sulphur-34 ($\delta^{34}S$-SO4)	‰	16,6
Oxygen-18 ($\delta^{18}O-SO_4$)	‰	12,3
Carbon-13 ($\delta^{13}C-CO_2$)	‰	-10,9
Carbon-13 ($\delta^{13}C-CH_4$)	‰	-43,9
Deuterium (δ^2H-CH_4)	‰	-226
Carbon-13 ($\delta^{13}C-C_2H_6$)	‰	-32,1
Carbon-13 ($\delta^{13}C-C_3H_8$)	‰	-28,2
Carbon-13 ($\delta^{13}C$-i-C_4H_{10})	‰	-23,4
Carbon-13 ($\delta^{13}C$-n-C_4H_{10})	‰	-26,6

2.2 SAMPLING AND ANALYSIS OF THERMAL WATER SAMPLES FROM GROß SCHÖNEBECK, GERMANY

In order to gain information about the increased methane content (about 65 vol-%) in the gas samples of the Groß Schönebeck production well (GrSk05/05) collected in February 2021 as compared to previous samples in 2010-2018 (10-14 vol-%), three gas samples were sampled by GFZ on 02 March 2021 at the valve at the wellhead when releasing the pressure from the wellhead. Main gas composition was measured by GFZ indicating again predominantly CH_4 (63,9-64,2 Vol-%) followed by N_2 (30,9 – 31,2 vol.-%) with minor amounts of H_2 (3,4 vol-%) and CO_2 (0,01-0,04 vol-%).

Potential reasons for the increased methane content could be either microbial activity or contribution of fluid / gas from a different source within the reservoir. To determine the origin of methane, therefore, isotope analyses were performed. The samples arrived at Hydroisotop on March 13th 2021 for the analysis of higher hydrocarbons (C2-C5) and their isotopic composition (^{13}C-CO_2, ^{13}C -CH_4, ^{13}C-C_xH_y and ^2H-CH_4). Results are summarized in Table 3. Together with the measured high amounts of higher hydrocarbons (ethane, propane etc.) they indicate a rather thermogenic source of the hydrocarbons.

Table 3 Analytical results of dissolved gases and stable isotopes of thermal water samples from Groß Schönebeck, Germany.

Lab-No.	unit	358676	358677	358678
Location		**Groß Schönebeck**	**Groß Schönebeck**	**Groß Schönebeck**
		Großschb 1	Großschb 2	Großschb 3
Hydrocarbons and stable isotopes				
Ethane	vpm	32000	32600	33600
Propane	vpm	17500	18300	18600
i-Butane	vpm	12100	13200	13500
n-Butane	vpm	6840	8030	8300
i-Pentane	vpm	3700	5240	5900
n-Pentane	vpm	1100	1650	1900
Ethene	vpm	< 1000	< 1000	< 1000
Propene	vpm	< 100	< 100	< 100
1-Butene	vpm	< 100	< 100	< 100
Carbon-13 ($\delta^{13}C$-CO_2)	‰	-16,9	-18,3	-16,0
Carbon-13 ($\delta^{13}C$-CH_4)	‰	-48,6	-46,8	-49,6
Deuterium (δ^2H-CH_4)	‰	-190	-190	-189
Carbon-13 ($\delta^{13}C$-$C2H_6$)	‰	-28,4	-28,7	-28,9
Carbon-13 ($\delta^{13}C$-C_3H_8)	‰	-22,8	-23,0	-23,5
Carbon-13 ($\delta^{13}C$-i-C_4H_{10})	‰	-26,3	-27,0	-27,8
Carbon-13 ($\delta^{13}C$-n-C_4H_{10})	‰	-20,7	-21,5	-21,8

To better clarify the question of the source of methane, additionally, two downhole water samples from two different depths (1500 and 4000 m) were taken by GFZ on 09th and 10th of June 2021 and sent to Hydroisotop for analysis of main cations and anions, heavy metals, trace elements and isotopes (^{13}C-CH_4) in July 2021. The analytical results of hydrochemical parameters are compiled in Table 5, the ^{13}C measurements of the separated gas phase are presented in Table 4.

The water sample composition resembles those of earlier measurements of samples collected in Groß Schönebeck (e.g. Regenspurg et al., 2010). However, since the well had not been in operation for a while a depth differentiation between the sample from 4000 m and the one from 1500 m is obvious. This was already visible by the black precipitate observed in the 4000 m sample, whereas the sample at 1500 m showed da reddish precipitate of presumably iron oxides. It should be noted that the nitrate content of the water samples is unusually high (compare Table 5) since reducing conditions are expected. This could have been caused by air contact of the sample and subsequent oxidation. Furthermore, Table 5 shows a reduced silicon content in sample 365871 compared to sample 365870. Given the high temperature of the well, the higher silicon content is more plausible.

Table 4 Analytical results of stable isotopes of additional gas samples from Groß Schönebeck, Germany.

Lab-No.	unit	367042	367043	367044
Location		**Groß Schönebeck**	**Groß Schönebeck**	**Groß Schönebeck**
		grsk 0405 1500m 255mbar	grsk 0405 4000m 515mbar	grsk 0405 4000m 728mbar
Stable isotopes				
Carbon-13 ($\delta^{13}C-CH_4$)	‰	-50,2	-48,3	-45,3

Table 5 Hydrochemical composition of thermal water samples from Groß Schönebeck, Germany.

Lab-No.	unit	365870	365871
Location		Groß Schönebeck	Groß Schönebeck
		grsk tp 6/2021 A (4000 m)	grsk tp 6/2021 A (1500 m)
Main cations and anions			
Sodium (Na^+)	mg/l	37700	37300
Potassium (K^+)	mg/l	3400	3190
Calcium (Ca^{2+})	mg/l	47800	48200
Magnesium (Mg^{2+})	mg/l	139	287
Chloride (Cl^-)	mg/l	162000	165000
Sulphate (SO_4^{2-})	mg/l	83,7	134
Nitrate (NO_3^-)	mg/l	228	209
Heavy metals and trace elements			
Antimony	mg/l	0,068	0,196
Barium (Ba^{2+})	mg/l	64,5	9,65
Bromide (Br^-)	mg/l	333	318
Fluoride (F^-)	mg/l	2,1	< 1
Iodide (I^-)	mg/l	17,4	< 10
Lithium (Li^+)	mg/l	220	227
Silicon	mg/l	18,2	1,7
Strontium (Sr^{2+})	mg/l	2100	2250
Aluminium	mg/l	2,76	2,91
Arsenic	mg/l	0,028	< 0,005
Lead	mg/l	1,99	1,21
Copper	mg/l	1,22	0,055
Manganese total	mg/l	4,35	206
Nickel	mg/l	< 0,01	< 0,01
Uranium	mg/l	< 0,0001	< 0,0001
Zinc	mg/l	2,68	110

Water samples were also shipped to the REFLECT partners at University of Neuchatel for microbial analysis and to the organic geochemistry group at GFZ. Results from these analyses will be reported separately.

2.3 SAMPLING AND ANALYSIS OF THERMAL WATER SAMPLES FROM HEEMSKERK, NETHERLANDS

On 10th of May 2021, two thermal water samples were taken by TNO before and after the heat exchanger at the geothermal site Heemskerk in the Netherlands. The samples sent to Hydroisotop were analysed for their hydrochemical composition, heavy metal and dissolved organic carbon (DOC) content and stable isotopes (^{18}O, ^{2}H, ^{13}C-DIC). Analytical results are presented in Table 6. It should be noted that the pH measured in the laboratory diverges from previously observed pH values which in the past have not been reported below 5,4. Concentrations of major ions had initially been reported too low but re-measurement of the samples yielded values in ranges that had previously been recorded. However, the concentraton of Lithium is much higher than expected. In order to resolve these uncertainties, the site Heemskerk was sampled again by TNO on March 29th 2022.

Table 6 Hydrochemical composition of thermal water samples from Heemskerk, Netherlands.

Lab-No.	unit	363150	363151	382314
Location		**Heemskerk**	**Heemskerk**	**Heemskerk**
		HEK-GT-before HE	HEK-GT-after HE	HEK-GT before HE
		10.05.2021	10.05.2021	29.03.2022
Spec. electr. conductivity (25 °C) Lab.	µS/cm	240000	239000	236000
pH value Lab.		4,4	4,7	5,6
Temperature Lab.	°C	22,5	22,5	24,2
Alkalinity (pH 4,3) Lab.	mmol/l	< 0,1	0,29	1,92
Main cations and anions				
Sodium (Na^+)	mg/l	89000	95000	93000
Potassium (K^+)	mg/l	810	820	1300
Calcium (Ca^{2+})	mg/l	9500	9600	9500
Magnesium (Mg^{2+})	mg/l	1200	1300	740
Ammonium (NH_4^+)	mg/l	163	160	155
Hydrogen carbonate (HCO_3^-)	mg/l	-	17,8	117
Chloride (Cl^-)	mg/l	160000	170000	170000
Sulphate (SO_4^{2-})	mg/l	390	400	390
Nitrate (NO_3^-)	mg/l	< 1	< 1	< 1
Heavy metals and trace elements				
Antimony	mg/l	< 0,002	< 0,002	-
Barium (Ba^{2+})	mg/l	5,3	5,9	9
Fluoride (F^-)	mg/l	6,7	7,5	< 1
Iodide (I^-)	mg/l	4,3	5,5	5,25
Lithium (Li^+)	mg/l	31,1	43,5	26,9
Silicon	mg/l	9,37	10,8	9,82
Strontium (Sr^{2+})	mg/l	440	450	310
Aluminium	mg/l	< 0,01	0,017	-
Arsenic	mg/l	0,018	0,013	0,248
Lead	mg/l	2,6	2,8	2,22
Iron total	mg/l	124	103	131
Copper	mg/l	0,22	0,17	< 0,005
Manganese total	mg/l	10,3	10,5	12,8
Nickel	mg/l	0,1	0,089	0,042
Uranium	mg/l	< 0,0001	< 0,0001	< 0,005
Zinc	mg/l	21	23	46,9
DOC	mg/l	30,2	23,4	26,5
Stable isotopes				
Oxygen-18 ($\delta^{18}O$)	‰	-1,16	-0,73	-
Deuterium ($\delta^{2}H$)	‰	-22,9	-20,8	-
Deuterium-excess	‰	-13,62	-14,96	-
Carbon-13 ($\delta^{13}C$-DIC)	‰	-3,7	-4,6	-

At this sample the pH of 5,6 is in the expected range and the Lithium content is also lower than in the previous measurements. A gas sample was also taken by TNO and sent to Hydroisotop (see Table 7). The gas volumes are likely too high since at the sampling point the as is already partially degassed and only a gas-water mixture could be sampled by TNO.

Table 7 Composition of gases at Heemskerk, Netherlands.

Lab-No.	unit	382314
Location		**Heemskerk**
		HEK-GT before HE
		44649
Gases		
Hydrogen	Nml/kg	1,29
Nitrogen	Nml/kg	201
Carbon dioxide	Nml/kg	281
Methane	Nml/kg	2880
Ethane	Nml/kg	55,7
Propane	Nml/kg	5,6
Butane	Nml/kg	0,73
Pentane	Nml/kg	< 0,03
Ethene	Nml/kg	< 0,03
Helium	Nml/kg	4,8
Argon	Nml/kg	0,66
Oxygen	Nml/kg	0,66

2.4 SAMPLING AND ANALYISIS OF THERMAL WATER SAMPLES FROM BALMATT, BELGIUM

One sample of thermal water was taken from the production well at Balmatt, Belgium on May 17th 2021 and sent to Hydroisotop for analysis of main cations and anions and heavy metals. Analytical results are presented in Table 8. It can be seen in Table 8 that the nitrate content is remarkably high. However, all meaurements had to be conducted from the same sample bottle, which had been acidified, presumably with HNO_3 which can be expected to be the source of the high nitrate content.

Table 8 **Hydrochemical composition of thermal water samples from Balmatt, Belgium.**

Lab-No.	unit	365761
Location		**Balmatt**
		production well
		17.05.2021
Main cations and anions		
Sodium (Na^+)	mg/l	54300
Potassium (K^+)	mg/l	3450
Calcium (Ca^{2+})	mg/l	9040
Magnesium (Mg^{2+})	mg/l	627
Chloride (Cl^-)	mg/l	115000
Sulphate (SO_4^{2-})	mg/l	318
Nitrate (NO_3^-)	mg/l	1050
Heavy metals and trace elements		
Antimony	mg/l	0,039
Barium (Ba^{2+})	mg/l	1,5
Iodide (I^-)	mg/l	< 10
Lithium (Li^+)	mg/l	122
Silicon	mg/l	37
Strontium (Sr^{2+})	mg/l	602
Aluminium	mg/l	1,26
Arsenic	mg/l	< 0,005
Lead	mg/l	0,023
Iron total	mg/l	74,58
Copper	mg/l	0,013
Manganese total	mg/l	6,98
Nickel	mg/l	< 0,01
Uranium	mg/l	< 0,0001
Zinc	mg/l	2,75

2.4 SAMPLING AND ANALYSIS OF THERMAL WATER SAMPLES FROM INSHEIM, GERMANY

Two thermal water samples were taken by Hydroisotop at the production and injection wells in Insheim on 18th of June 2020. The samples were analysed for their hydrochemical composition, heavy metal and dissolved organic carbon (DOC) content, dissolved gases and stable isotopes of water and gas components (^{18}O, ^{2}H, ^{34}S-H_2S, ^{34}S-SO_4, ^{18}O-SO_4, ^{13}C-DIC, ^{13}C-CO_2, ^{13}C-CH_4, ^{2}H-CH_4). Analytical results are presented in Table 9 and Table 10.
Table 9 shows nitrate in both water samples and a positive redox potential when reducing conditions would be expected in a deep geothermal well. On-site measurements showed no oxygen present. It is however possible that air contamination during sampling caused some ammonium to oxidize to nitrate.

Table 9 **Hydrochemical composition of thermal water samples from Insheim, Germany.**

Lab-No.	unit	324459	324460
Location		**Insheim**	**Insheim**
		production well	injection well
		18.06.2020	18.06.2020
Temperature at sampling	°C	18,1	19
Spec. electr. conductivity (25 °C) at sampling	µS/cm	140400	140500
Spec. electr. conductivity (25 °C) Lab.	µS/cm	138600	138600
pH value at sampling		4,9	4,9
pH value Lab.		4,9	5,2
Dissolved oxygen content	mg/l	<0,1	< 0,1
Redox potential	mV	93	125
Base capacity (pH 8,2)	mmol/l	25,5	36,6
Alkalinity (pH 4,3) on site	mmol/l	2,9	2,7
Alkalinity (pH 4,3) Lab.	mmol/l	2,46	2,46
Main cations and anions			
Sodium (Na^+)	mg/l	29000	30000
Potassium (K^+)	mg/l	4000	4300
Calcium (Ca^{2+})	mg/l	7100	7500
Magnesium (Mg^{2+})	mg/l	70	72
Ammonium (NH_4^+)	mg/l	39,2	39,9
Hydrogen carbonate (HCO_3^-)	mg/l	150	150
Chloride (Cl^-)	mg/l	61000	63000
Sulphate (SO_4^{2-})	mg/l	140	150
Nitrate (NO_3^-)	mg/l	1,6	1,2
Heavy metals and trace elements			
Antimony	mg/l	0,33	0,23
Barium (Ba^{2+})	mg/l	26	26
Bromide (Br^-)	mg/l	181	205
Fluoride (F^-)	mg/l	< 1	< 1
Iodide (I^-)	mg/l	< 1	< 1
Lithium (Li^+)	mg/l	167	180
Molybdenum	mg/l	-	< 0,001
total phosphate	mg/l	-	0,96
Ortho-phosphate (PO_4^{3-})	mg/l	-	0,96
Silicon	mg/l	73,4	72,4
Strontium (Sr^{2+})	mg/l	130	160
Sulphide total (H_2S, HS^-, S^{2-})	mg/l	< 0,1	< 0,1
Aluminium	mg/l	< 0,005	< 0,005
Arsenic	mg/l	16	18
Lead	mg/l	1,6	1,7
Iron total	mg/l	26,3	28,4
Copper	mg/l	0,024	0,13
Manganese total	mg/l	30,7	30,6
Nickel	mg/l	< 0,001	< 0,001
Uranium	mg/l	< 0,0001	< 0,0001
Zinc	mg/l	8,8	9,5
DOC	mg/l	1,5	5,1

Table 10 **Analytical results of dissolved gases and stable isotopes of thermal water samples from Insheim, Germany.**

Lab-No.	unit	324459	324460
Location		**Insheim**	**Insheim**
		production well	injection well
		18.06.2020	18.06.2020
Dissolved gases			
Hydrogen	Nml/kg	< 0,3749	< 0,3469
Oxygen	Nml/kg	< 0,01	< 0,01
Nitrogen	Nml/kg	67,7	44,9
Carbon dioxide	Nml/kg	660	631
Methane	Nml/kg	16,87	13,18
Ethane	Nml/kg	0,1994	0,1499
Propane	Nml/kg	0,0165	0,0104
Butane	Nml/kg	0,0082	0,0035
Pentane	Nml/kg	0,0082	0,0014
Helium	Nml/kg	1,12	0,972
Argon	Nml/kg	0,35	0,3
Sum Gases	Nml/kg	746	691
Stable isotopes			
Oxygen-18 ($\delta^{18}O$)	‰	-1,49	-
Deuterium ($\delta^{2}H$)	‰	-44	-
Deuterium-excess	‰	-32,08	-
Carbon-13 ($\delta^{13}C$-DIC)	‰	-3,6	-
Sulphur-34 ($\delta^{34}S$-SO4)	‰	14,4	-
Sulphur-34 ($\delta^{34}S$-$H^{2}S$)	‰	12,9	-
Oxygen-18 ($\delta^{18}O$-SO_4)	‰	7,2	-
Carbon-13 ($\delta^{13}C$-CO_2)	‰	-4,6	-4,5
Carbon-13 ($\delta^{13}C$-CH_4)	‰	-34,1	-34,8
Deuterium ($\delta^{2}H$-CH_4)	‰	-148	-148

2.5 SAMPLING AND ANALYSIS OF THERMAL WATER SAMPLES FROM BAD BLUMAU, AUSTRIA

At the geothermal site Blumau in Austria five thermal water samples were taken by Hydroisotop at the production and injection well, as well as after the heat exchanger on 29th of June 2020. Besides the hydrochemical composition, dissolved gases, the heavy metal content, DOC and stable isotopes (^{18}O, ^{2}H, ^{13}C-DIC) were analysed. Analytical results are presented in Table 11 and Table 12. Additionally, three thermal water samples were taken by the operator on 09th of March 2021 and sent to Hydroisotop for DOC measurements (Table 13).

Table 11 **Analytical results of dissolved gases and stable isotopes of thermal water samples from Bad Blumau, Austria.**

Lab-No.	unit	347619	347621	347623
Location		**Bad Blumau**	**Bad Blumau**	**Bad Blumau**
		GB1	heat central after HE	GB 2
		29.06.2020	29.06.2020	29.06.2020
Temperature at sampling	°C	42,2	36,7	37,8
Spec. electr. conductivity (25 °C) at sampling	µS/cm	19850	19910	19870
Spec. electr. conductivity (25 °C) Lab.	µS/cm	-	-	20000
pH value at sampling		6,98	7,02	6,96
pH value Lab.		7,6	-	7,6
Dissolved oxygen content	mg/l	< 0,1	< 0,1	< 0,1
Redox potential	mV	-133	-117	-75
Alkalinity (pH 4,3) Lab.	mmol/l	126	-	128
Main cations and anions				
Sodium (Na^+)	mg/l	5500	-	6155
Potassium (K^+)	mg/l	139	-	140
Calcium (Ca^{2+})	mg/l	22,2	-	23,7
Magnesium (Mg^{2+})	mg/l	3,6	-	3,3
Ammonium (NH_4^+)	mg/l	-	-	7,9
Hydrogen carbonate (HCO_3^-)	mg/l	7663	-	7902
Chloride (Cl^-)	mg/l	3650	-	4726
Sulphate (SO_4^{2-})	mg/l	524	-	535
Nitrate (NO_3^-)	mg/l	< 0,5	-	< 0,5
Nitrite (NO_2^-)	mg/l	-	-	< 0,01
Heavy metals and trace elements				
Antimony	mg/l	-	-	0,026
Barium (Ba^{2+})	mg/l	-	-	0,34
Boron	mg/l	-	-	0,08
Bromide (Br^-)	mg/l	-	-	12,4
Fluoride (F^-)	mg/l	-	-	8,9
Iodide (I^-)	mg/l	-	-	1,2
Molybdenum	mg/l	-	-	0,003
Ortho-phosphate (PO_4^{3-})	mg/l	-	-	< 0,5
Selenium	mg/l	-	-	< 0,001
Strontium (Sr^{2+})	mg/l	-	-	1,4
Sulphide total (H_2S, HS^-, S^{2-})	mg/l	2,9	0,7	0,4
Aluminium	mg/l	-	-	0,029
Arsenic	mg/l	-	-	0,146
Lead	mg/l	-	-	0,01
Cadmium	mg/l	-	-	< 0,0002
Chromium total	mg/l	-	-	0,002
Cobalt	mg/l	-	-	< 0,001
Iron total	mg/l	0,09	0,09	0,09
Copper	mg/l	-	-	< 0,001
Nickel	mg/l	-	-	< 0,001
Mercury	mg/l	-	-	< 0,0002
Zinc	mg/l	-	-	< 0,001
Tin	mg/l	-	-	< 0,001
DOC	mg/l	7,2	9,2	9,2

Table 12 **Analytical results of dissolved gases and stable isotopes of thermal water samples from Bad Bluman, Austria.**

Dissolved gases				
Hydrogen	Nml/kg	< 0,3412	-	< 0,3735
Oxygen	Nml/kg	< 0,1	-	< 0,01
Nitrogen	Nml/kg	1,33	-	0,32
Carbon dioxide	Nml/kg	673	-	740
Methane	Nml/kg	0,38	-	0,4512
Ethane	Nml/kg	0,0041	-	0,0052
Propane	Nml/kg	0,0007	-	0,0007
Butane	Nml/kg	< 0,0014	-	< 0,0015
Pentane	Nml/kg	< 0,0014	-	< 0,0015
Ethene	Nml/kg	< 0,0007	-	< 0,0007
Propene	Nml/kg	< 0,0007	-	< 0,0007
Helium	Nml/kg	< 0,3412	-	< 0,3735
Argon	Nml/kg	0,038	-	0,038
Sum Gases	Nml/kg	675	-	741
Stable isotopes				
Oxygen-18 ($\delta^{18}O$)	‰	-	-	-8,23
Deuterium ($\delta^{2}H$)	‰	-	-	-59,6
Deuterium-excess	‰	-	-	6,24
Carbon-13 ($\delta^{13}C$-DIC)	‰	-	-	-1

Table 13 **Analytical results of additional DOC measurements on thermal water samples from Bad Blumau, Austria.**

Lab-No.	unit	358627	358628	358629
Location		**Bad Blumau**	**Bad Blumau**	**Bad Blumau**
		BL2	Heizzentrale	BL1
		09.03.2021	09.03.2021	09.03.2021
DOC	mg/l	9,6	9,4	7,3

2.6 SAMPLING AND ANALYSIS OF THERMAL WATER SAMPLES FROM WILDBAD-EINÖD, AUSTRIA

On 29th and 30th of April 2021 five thermal water samples were taken by Hydroisotop from five different springs/wells located at Wildbad-Einöd. The samples were analysed for hydrochemical composition, heavy metals and dissolved organic carbon (DOC) content. Analytical results are presented in Table 14.

It can be noted that the bromide content of sample 361625 is much lower than the bromide content in the other four springs. Since the chloride content in all springs is the same order of magnitude and Cl/Br ratios are expected to be similar in the same

Table 14 Hydrochemical composition of thermal water samples from Wildbad-Einöd.

Lab-No.	unit	361621	361622	361623	361624	361625
Location		**Wildbad**	**Wildbad**	**Wildbad**	**Wildbad**	**Wildbad**
		Georgsquelle	Mariaheilquelle	Ignazheilquelle	Michaelsheilquelle	Hallenbadquelle
		29.04.2021	29.04.2021	29.04.2021	29.04.2021	30.04.2021
Temperature at sampling	°C	23,5	25	25,4	25,4	21
Spec. electr. conductivity (25 °C) at sampling	µS/cm	2270	2790	2850	2860	2220
Spec. electr. conductivity (25 °C) Lab.	µS/cm	2300	2810	2870	2880	2240
pH value at sampling		6,2	6,1	6,1	6,1	6,3
pH value Lab.		6,4	6,3	6,3	6,3	6,5
Temperature Lab.	°C	23,2	22,9	23,2	22,7	17,4
Dissolved oxygen content	mg/l	< 0,1	< 0,1	< 0,1	< 0,1	0,2
Redox potential	mV	272	205	201	153	303
Base capacity (pH 8,2)	mmol/l	7,4	7,45	12,8	13,3	11,6
Alkalinity (pH 4,3) on site	mmol/l	14,6	17,5	17,6	17,5	15,1
Alkalinity (pH 4,3) Lab.	mmol/l	14,8	16,9	17,1	17,1	14,6
Main cations and anions						
Sodium (Na^+)	mg/l	94	130	140	140	86
Potassium (K^+)	mg/l	33	4,7	48	48	31
Calcium (Ca^{2+})	mg/l	370	460	460	460	370
Magnesium (Mg^{2+})	mg/l	48	64	63	63	55
Ammonium (NH_4^+)	mg/l	< 0,05	0,25	0,12	1,29	0,07
Hydrogen carbonate (HCO_3^-)	mg/l	901	1030	1040	1040	889
Chloride (Cl^-)	mg/l	54	78	88	79	55
Sulphate (SO_4^{2-})	mg/l	500	730	720	730	520
Nitrate (NO_3^-)	mg/l	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2
Nitrite (NO_2^-)	mg/l	< 0,01	0,02	< 0,01	< 0,01	< 0,01
Deviation cation to anion sum	%	1,96	1,58	1,61	1,92	1,86
Heavy metals and trace elements						
Bromide (Br^-)	mg/l	0,16	0,24	0,23	0,21	0,02
Fluoride (F^-)	mg/l	1,4	2,3	2,4	2,4	1,5
Iodide (I^-)	mg/l	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1
Lithium (Li^+)	mg/l	0,51	0,7	0,72	0,73	0,47
Silicon	mg/l	15,8	19,9	20,5	20,8	14,4
Strontium (Sr^{2+})	mg/l	5	7,9	8	8,1	5,2
Iron total	mg/l	0,99	1,2	2	1,7	0,04
Manganese total	mg/l	1,3	0,84	0,83	0,84	0,26
DOC	mg/l	1,1	0,21	0,2	0,17	0,15

3. METHODS

The analytical methods, procedures and errors are compiled in Table 15.

Table 15 Analytical methods of analysed parameters.

Parameter	Unit	Laboratory	Procedure	Analytical Method	Error
Physico-chemical parameters					
pH		Hydroisotop	DIN EN ISO 10523 (C5): 2012-04	electrode	
Temperature	°C	Hydroisotop	DIN 38404-C4: 1976-12	pH meter	
Spec. electr. conductivity (25 °C)	µS/cm	Hydroisotop	DIN EN 27888 (C8):1993-11	electrode	
Alkalinity (pH 4,3)	mmol/L	Hydrosiotop	DIN 38409-H7:2005-12	titration, pH meter	

Parameter	Unit	Laboratory	Procedure	Analytical Method	Error
Base capacity (pH 8,2)	mmol/L	Hydroisotop	DIN 38409-H7:2005-12	titration, pH meter	
Dissolved oxygen content	mg/L	Hydroisotop	DIN ISO 17289 (G25): 2014-12	electrode	
Redox potential	mV	Hydroisotop	DIN 38404-C6: 1984-05	electrode	
Main cations and anions					
Na, K, Ca, Mg, NH_4	mg/L	Hydroisotop	DIN EN ISO 14911 (E34): 1999-12	IC	
HCO_3	mg/L	Hydroisotop	calculated by alkalinity	titration	
Cl, SO_4, NO_3	mg/L	Hydroisotop	DIN EN ISO 10304-1 (D20): 2009-07	IC	
NO_2	mg/L	Hydroisotop	Merck Spectroquant 1.14776: 2017-01	photometer	
Deviation cation to anion sum	%	Hydroisotop	calculated		
Heavy metals and trace elements					
F, Br, I, ortho-PO_4	mg/L	Hydroisotop	DIN EN ISO 10304-1 (D20): 2009-07	IC	
Mn total	mg/L	Hydroisotop	Merck Spectroquant 1.14770: 2017-02	photometer	
Fe total	mg/L	Hydroisotop	Merck Spectroquant 1.14761: 2017-01	photometer	
Cr total	mg/L	Hydroisotop	DIN EN ISO 17294-2 (E29)	ICP-MS	
Li, Ba, Sr	mg/L	Hydroisotop	DIN EN ISO 14911 (E34): 1999-12	IC	

Parameter	Unit	Laboratory	Procedure	Analytical Method	Error
U, As, Pb, Cu, Ni, Zn, Sb, Ba, B, Mo, Se, Co, Sn	mg/L	GBA	DIN EN ISO 17294-2 (E29)	ICP-MS	
Si	mg/L	Hydroisotop	Merck Spectroquant 1.14794: 2016-07	photometer	
Phosphate total	mg/L	GBA	DIN EN 1189-D11	photometer	
Sulphide total (H_2S, HS, S)	mg/L	Hydroisotop	Merck Spectroquant 1.14779: 2016-09	photometer	
Mercury	mg/L	GBA	DIN EN ISO 12846 (E12)	AAS	
Dissolved organic carbon					
DOC	mg/L	Hydroisotop	DIN EN 1484 (H3): 1997-08	infrared	
Dissolved gases					
H_2, CO_2, CH_4, Ar_2, N_2, He_2, O_2	Nml/kg	Hydroisotop	QMA 504-2/15: 2007-04	Gaschromatography GC-TCD	
Methane, Ethane, Propane, Pentane, Butane, Ethene, Propene, Butene	Nml/kg	Hydroisotop	QMA 504-2/15: 2007-04	Gaschromatography GC-FID	
Stable Isotopes					
Oxygen-18 ($\delta^{18}O$-H_2O)	‰$_{VSMOW}$	Hydroisotop	QMA 504-2/23: 2012-02	Cavity-Ringdown-Spectrometry (CRDS)	1σ= ± 0,15 ‰
Deuterium ($\delta^{2}H$-H_2O)	‰$_{VSMOW}$	Hydroisotop	QMA 504-2/23: 2012-02	Cavity-Ringdown-Spectrometry (CRDS)	1σ= ± 1,5 ‰
Deuterium-excess	‰$_{VSMOW}$	Hydroisotop	calculated		
Deuterium ($\delta^{2}H$-CH_4)	‰$_{VSMPW}$	Hydroisotop	QMA504-2/4	Isotope ratio mass spectrometry (IRMS)	1σ= ± 10 ‰

Parameter	Unit	Laboratory	Procedure	Analytical Method	Error
Oxygen-18 ($\delta^{18}O-SO_4$)	‰VSMOW	Hydroisotop	QMA504-2/29: 2015-03	Isotope ratio mass spectrometry (EA-IRMS)	1σ= ± 0,5 ‰
Sulphur-34 ($\delta^{34}S-SO_4$)	‰V-CDT	Hydroisotop	QMA504-2/28: 2015-03	Isotope ratio mass spectrometry (EA-IRMS)	1σ± 0,5 ‰
Sulphur-34 ($\delta^{34}S-H_2S$)	‰V-CDT	Hydroisotop	QMA504-2/28: 2015-03	Isotopenverhältnis-Massenspektrometrie (EA-IRMS)	1σ= ± 0,5 ‰
Carbon-13 ($\delta^{13}C$-DIC)	‰VPDB	Hydroisotop	QMA 504-2/6: 2012-02	Isotope ratio mass spectrometry (IRMS)	1σ= ± 0,3 ‰
Carbon-13 ($\delta^{13}C-CO_2$)	‰VPDB	Hydroisotop	QMA 504-2/6: 2012-02	Isotope ratio mass spectrometry (IRMS);	1σ= ± 0,3 ‰
Carbon-13 ($\delta^{13}C-CH_4$)	‰VPDB	Hydroisotop	QMA504-2/16	Isotope ratio mass spectrometry (IRMS)	1σ= ± 1,5 ‰
Carbon-13 ($\delta^{13}C-C_2H_6$), Carbon-13 ($\delta^{13}C-C_3H_8$), Carbon-13 ($\delta^{13}C$-i-C_4H_{10}), Carbon-13 ($\delta^{13}C$-n-C_4H_{10})	‰VPDB	Hydroisotop	QMA504-2/16	Isotope ratio mass spectrometry (IRMS)	1σ± 0,5 ‰

4. CONCLUSION

Sampling of type C fluids from seven different sites has been accomplished. For four geothermal sites analyses are finished and for one site analyses are still in progress. Table 16 gives an overview of the analytical progress.

Table 16 Overview of the analytical progress for type C fluid sites.

sampling site	water chemistry	metals	DOC	isotopes	gases
Neustadt-Glewe, Germany	completed	completed	completed	completed	completed
Groß-Schönebeck- Germany	completed	completed	-	completed	completed
Heemskerk, Netherlands	completed	completed	completed	completed	-
Balmatt, Belgium	completed	completed	-	-	-
Insheim, Germany	completed	completed	completed	completed	completed
Bad Blumau, Austria	completed	completed	completed	completed	completed
Wildbad-Einöd, Austria	completed	completed	completed	-	-

5. REFERENCES

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