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Gas and Chemical Monitoring of the Mutnovsky (Dachny) Geothermal Field Exploitation (Kamchatka, Russia)

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ABSTRACT

Gas and chemistry sampling of the exploitation wells of the Dachny site Mutnovsky geothermal field (Kamchatka, Russia) were performed in 1999-2000 (before the 50 MWe power plant was put into operation) and again in 2003 (after exploitation started). Sampling from five principal exploitation wells (016, 26, 029W, 4E and 5E) was performed. Gas and macroelemental analysis was performed in the Institute of Volcanology Lab, sampling method was based on ASTM E 1675-95a. Microelemental analysis based on the ICP method (IRIS, Jarell Ash Corporation).

Drilling of deep wells and geothermal exploitation may cause chemical emissions of elements including arsenic, boron, lithium, silicon over their maximum allowable concentrations. The ecological impact of the gas emission (CO_2, H_2S) was estimated too. Since exploitation started, the following variations were detected: (1) fraction of meteoric gases increase in wells 016, 029W and 4E, (2) Na/K temperatures decrease in wells 4E and 029W, (3) SiO_2 decrease in all wells.

1. INTRODUCTION

Mutnovsky geothermal field in Kamchatka is within the active volcanoes Mutnovsky and Gorely environment. Mutnovsky has the highest heat capacity of any volcano of Kurile-Kamchatka arc, and Gorely is also very active. Erupted products of both of them vary from basalt to dacite composition. The last eruption of Mutnovsky occurred on March 17, 2000; in historic activity there have been 18 reported eruptions since historical activity began in the 17 century. Historical eruptions were explosive, with known lava flows produced only in 1904 (Global Volcanism Network (V. 18, No. 8 and V. 25, No. 9). Eruptions of Gorely volcano occurred in 1828, 1832, 1855, 1929-1931, 1961, 1980-1981 and 1986. Historical eruptions were volcanic and phreatic explosions of moderate volume. Exploration of Mutnovsky geothermal field started in 1978 and has lasted for more than 25 years, during which time 92 wells were drilled for the purpose of exploration and research of the geothermal fluid.

Since 2002, five exploitation wells are under operation in the Dachny site to supply steam for the 50 MWe power plant, all condensate and separated fluids are reinjected in the north region of Dachny (Fig.1). Producing wells are of 400 – 2000 m depth. Chemical composition of the fluid depends on the depth of the well, and the geothermal reservoir is divided into two levels – steam and liquid. The boundary between the two levels is at around 900 m depth. Geochemically, water from the upper level is of Na-K-HCO3-SO4 composition with pH ~5, the deeper level is of Na-Cl-SO4 composition with pH of 7.7-8.7. Deeper wells have higher mineralization and discharge the greater amount of chemicals. Dachny site Mutnovsky geothermal field area is drained by Falshivaia and Zhirovaya rivers, where natural hot spring discharge took place.

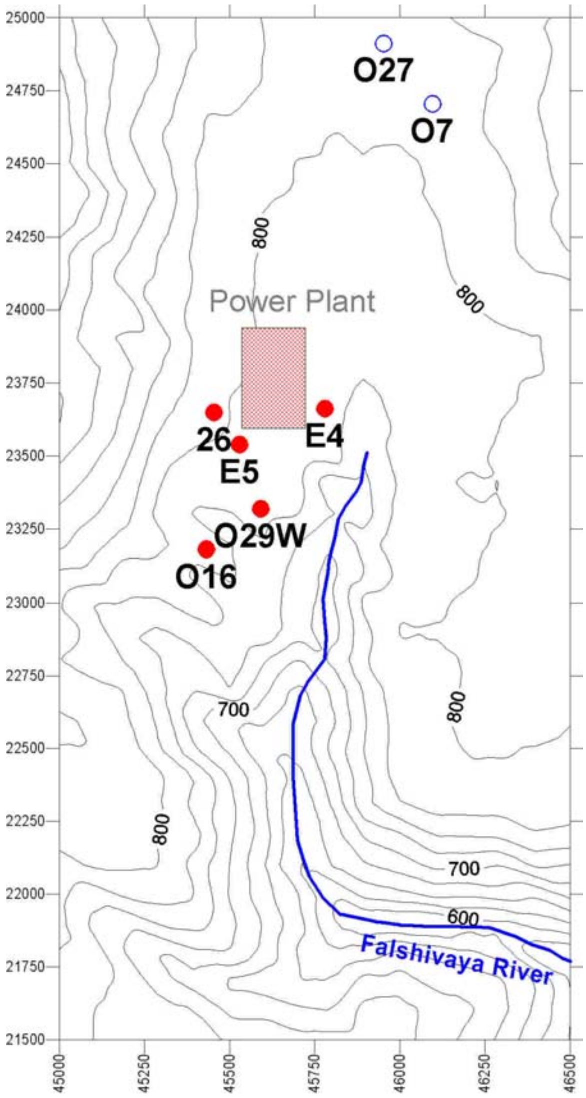

Figure 1. Schematic map of the Dachny site Mutnovsky geothermal field. Exploitation wells – filled circles, reinjection wells – empty circles.

2. METHODS OF STUDY

Analytical methods were used for characterization of geothermal fluid and estimation of chemical discharge rates from the productive wells. Gas and major elemental analysis was performed in the Institute of Volcanology Lab (RU.0001.511904), with a sampling method based on ASTM E 1675-95a. Trace elemental analysis are based on ICP method (IRIS, Jarell Ash Corporation). Sampling of wells used separators for the separation of steam and liquid phases. Samples for trace elements analysis were treated with HNO3. Samples for major components were not treated.

3. RESULTS AND DISCUSSION

Production well rates vary from 17 to 72.5 kg/s (Table 1). Results of chemical analysis are presented in Table 2 for the major and trace elements, annual calculated output of chemicals is submitted in Table 3 and annual gas emissions in Table 4. Chemical and gas composition of Mutnovsky geothermal fluids are typical of geothermal fields of the Kamchatka-Japan subduction zone which are NaCl-CO2 fluids with TDS range 1.5-15.0 g/kg and gas content 0.2-15 g/kg (Kiryukhin, et al, 2004).

Gas and chemistry transient data measured during exploitation are useful for geothermal reservoir response characterization, including thermal and hydrodynamic parameters, and boundary conditions. During the first year of exploitation, an increase of meteoric-origin gas fraction (N_2) and decrease of magmatic-origin gases fraction (H_2S) were observed in wells O16, O29W and 26 (Fig. 2). It was detected with Na/K geothermometer that temperature dropped in some of the exploitation wells (20 ^oC for well 4E, and 4.5 ^oC for well O29W).

Deeper wells in the liquid-dominated reservoir bring the greatest amount of chemicals to the environment and concentration of trace elements in the discharge water is higher than allowable by Russian federal standards. Components present in significantly high concentrations are As, B, Li, Si, Sn and sometimes Fe.

Table 1. Characteristics of the exploitation wells of the Dachny site Mutnovsky geothermal field (2003 data).

Well	Enthalpy, kJ/kg	Rate, kg/s
16	2800	17
26	2800	18
4E	1200	26.7
029W	1150	72.5
5E	1175	39

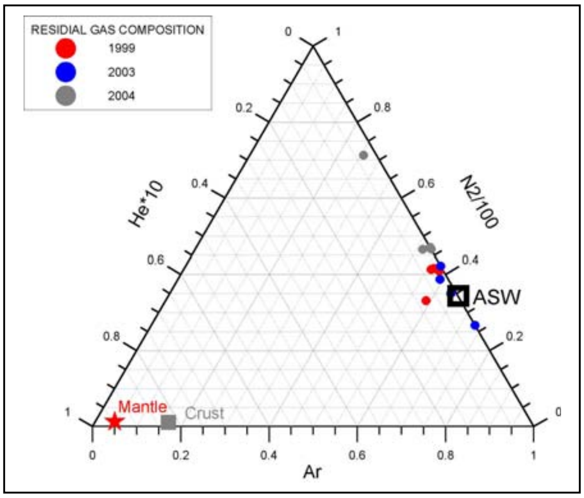

Figure 2 Transient data of relative gas content (Ar, N_2, He) in exploitation wells (26,O16, O29W, 4E) of the Mutnovsky geothermal field (Dachny).

Table 2. Chemical compositions of the fluids (in ppm) of the exploitation wells of the Dachny site Mutnovsky geothermal field (corresponding to bottomhole conditions before separation, sampling in 2003).

Well	4E	O16	26	O29W	5E
NH_4^+	2.5	6	9.0	2.7	2.0
Na^+	167.2	24.4	0.1	140.3	170.9
K^+	28.1	3.4	<0.1	25.7	28.2
Li^+	0.8	0.019	<0.01	0.8	0.9
Ca^{2+}	2.7	0.56	0.1	2.1	2.2
Mg^{2+}	0.0	0.015	0.0	0.0	0.0
Fe^{2+3+}	0.3	0.4	0.2	0.4	0.2
Al^{3+}	0.8	0.23	<0.3	0.8	0.8
Cl^-	151.7	5.7	6.4	171.8	147.4
SO_4^{2-}	160.8	45.1	1.9	113.2	199.9
HCO_3^-	61.8	30.5	18.3	45.4	26.0
CO_3^{2-}	0.0	0	0.0	0.0	0.0
F^-	2.2	0.2	0.1	2.3	3.3
B	11.0	3.9	0.1	12.9	9.2
SiO_2	144.3	9.4	<1.0	148.9	145.9
As	2.7	0.12	<0.1	3.6	1.9

Table 3. Annual chemical output (in tons) from exploitation wells of the Dachny site Mutnovsky geothermal field (2003).

Chemical component	Wells					Total
	4E	O16	26	O29W	5E	
K^+	23.6	1.8	0.0	58.7	34.7	118.9
Li^+	0.7	0.0	0.0	1.8	1.1	3.6
B	9.3	2.1	0.1	29.5	11.3	52.2
As	2.3	0.1	0.0	8.3	2.3	12.9

Table 4 Annual gas discharges (in tons) from exploitation wells of the Dachny site Mutnovsky geothermal field (sampling in 2003).

Gas	Wells					Total
	029W	26	O16	4E	5E	
CO_2	158.3	175.4	582.0	86.9	130.2	1132.7
H_2S	17.6	15.4	27.8	3.8	10.6	75.1
He	0.0	0.0	0.0	0.0	0.0	0.0
H_2	0.0	1.0	1.6	0.0	0.0	2.8
Ar	0.2	0.4	0.4	0.1	0.1	1.2
N_2	4.0	16.2	17.1	1.3	4.7	43.1
CH_4	0.3	1.4	2.7	0.1	0.1	4.5
Total	180.3	209.8	631.9	92.1	189.9	1304.1

The gas emissions from Mutnovsky geothermal power plant in Dachny are very low in comparison to those of the active Mutnovsky volcano located 10 km away. As estimated by M. Zelensky (2003) fumaroles of Mutnovsky volcano crater with temperatures up to 600^oC yield 64,605 tons of annual emission of CO_2, that is significantly greater 1,132 tons (Table 4) from exploitation wells in Dachny.

The total production of wells O16, 26, 4E, O29W and 5E is 66.4 kg/s of steam at 7 bars, which is equivalent to the 33 MWe yield from Mutnovsky power plant. That means that 2.6 kg of CO_2 per MWhr is an environmental impact from Mutnovsky power plant. This is significantly lower than the 550 kg of CO_2 per MWhr for gas-based power plants, 850 kg of CO_2 per MWhr for oil-based power plants, and 1000 kg of CO_2 per MWhr for coal-based power plants, according to typical gas emissions for various types of electric power plants currently in use in the world today. Global warming caused by growing in CO_2 in atmosphere due to industrial development makes geothermal energy use an instrument of CO_2 release reduction. Hence, CO_2 reduction in Kamchatka due to the Mutnovsky geothermal power plant reaches 245,000 tons annually, if oil-based power production is used as a reference value. The price of 1 ton of CO_2 is estimated as 5 US dollars (Guidelines, 2003) in the world market of CO_2 quotas according to Kyoto Protocol principles. That makes the potential benefit for the Mutnovsky project (at current rates) an annual amount of 795,000 – 1,450,000 US dollars depending on whether oil or gas-based power plants are used as the reference value.

4. CONCLUSIONS

1. Chemistry and gas monitoring data obtained during exploitation of the Mutnovsky geothermal field show current greenhouse CO_2 emission (1,133 tons annually) from five exploitation wells which supply steam for the 50 MWe power plant are very low compared to the active Mutnovsky volcano (64,605 tons annually), hence there is no significant negative impact for environment. Moreover, Mutnovsky (Dachny) power plant production may substitute a significant fraction of the existing oil power plant in Kamchatka in terms of CO_2 reduction (245,000 tons of CO_2 annually). The annual benefits may reach 795 – 1,450 thousands US dollars in case of CO_2 reduction laws will be implemented.

2. Significant amounts of toxic chemicals As and B are extracted, mostly from the deep liquid-dominated wells, and then are reinjected in the wells O27 and O7 at the Dachny site. Nevertheless, regular monitoring of the chemical compositions is recommended in the local rivers (Falshivaya river, Zhirovaya fish-populated river and Trudny creek) that drain the Dachny 50 MWe power plant and Verkhne-Mutnovsky 12 MWe power plant sites.

4. It is strongly recommended that regular (at least once a month) gas and fluid chemistry sampling of exploitation wells be carried out (based on ASTM E 1675-95a), and tracer flow test (TFT) measurements of steam and liquid phase rates be taken at the same time.

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