Air quality and geothermal projects

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The potential release of natural gases from geothermal fluids during drilling and testing of wells or during plant operation is of concern in some European countries. The European and national environmental and mining laws cover most issues, including reporting of accidental emissions. Besides decrees implementing European directives related to air emissions and air quality, the potential impacts of the aeriform emissions of geothermal fluids are regulated mainly through best practices of operators and national/regional guidelines.

It is necessary to distinguish between the two main phases of a geothermal project when emissions may occur.

Regarding the **potential aeriform emissions to the atmosphere during drilling and testing of geothermal well**, the situation among the countries mapped in our studies and the analysis of the collected data are synthetised in Fig. 1 and Table 1. On the other hand, Fig. 2 and Table 2 synthetise the situation regarding the **potential aeriform emissions to the atmosphere during the geothermal plant operation and maintenance**.

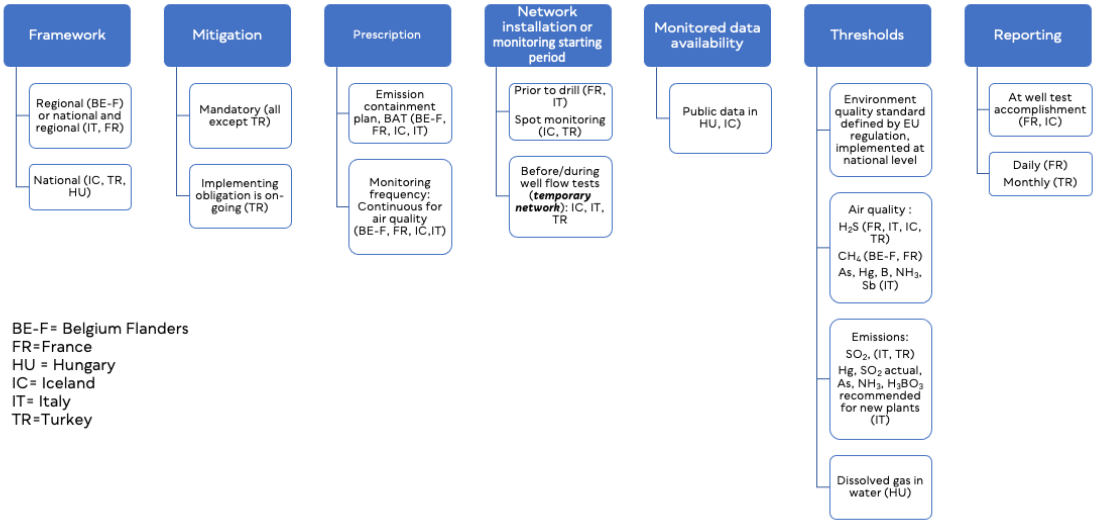

Figure 1 Regulations and solutions for public health and safety issues established at the national level in the GEOENVI participating countries to mitigate the potential impacts and risks of aeriform emissions of geothermal fluids ***during the well drilling phase, including flow test****.*

Similarities	Differences
○ Standard procedures of expert operators already foresee monitoring systems at rig sites, a Blow Out Preventer (BOP) to stop the operation and a temporary monitoring system during flow tests to mitigate accidental spills and exceedance of thresholds fixed by law; ○ EU regulation, implemented at the national level, defines environmental quality standards; ○ Belgium-Flanders, France, Iceland, and Italy require air quality monitoring; ○ Air quality thresholds (beyond those set by EU) are set in Belgium-Flanders, France, Iceland, Italy, and Turkey. Emissions are controlled in Belgium-Flanders, France,	○ For standards not set at the EU level, and although, for example, the World Health Organisation[1] establishes air quality guidelines, variable thresholds are adopted at the national level. E.g., air quality thresholds for H_2S are different in France, Italy, Iceland, and Turkey, as are those for CH_4 in Belgium-Flanders, France and Hungary; ○ Monitoring data are public only in Hungary and Iceland. Italy and Belgium-Flanders release partial data; ○ The frequency of reporting to authority is variable.

[1] http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/pre2009/who-air-quality-guidelines-for-europe,-2nd-edition,-2000-cd-rom-version

Italy, and Turkey. Usually, the gas monitoring is mandatory during drilling in the bounds of the drilling yard, whereas outside the drilling yard the gas monitoring is due during flow tests on the base of the EIA requirements.	

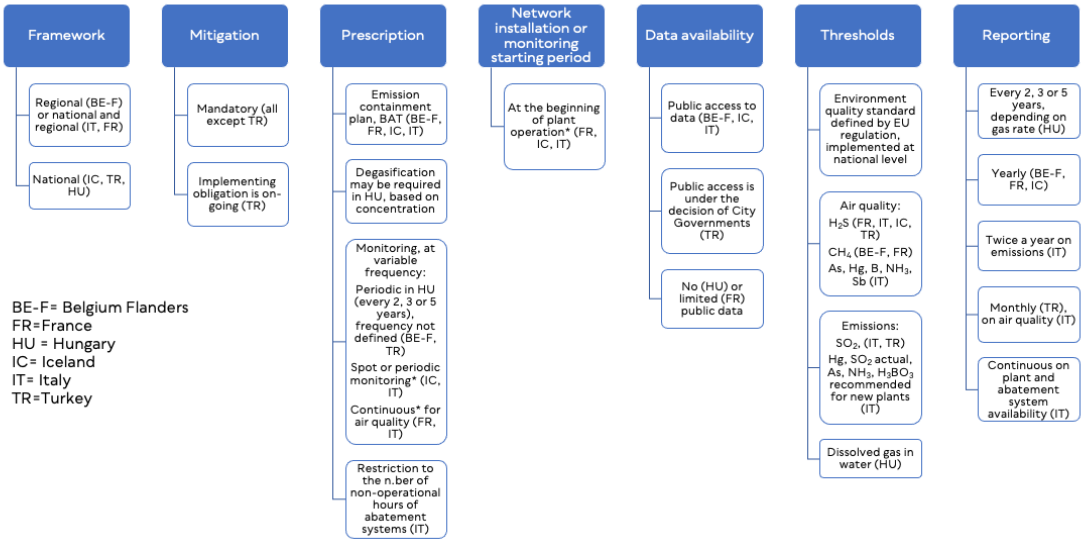

Figure 2 Regulations and solutions for public health and safety issues established at the national level in the GEOENVI participating countries to mitigate the potential impacts of aeriform emissions of geothermal fluids ***during the plant operations****.*

Similarities	Differences
○ Environment quality standard defined by the EU regulation are implemented at the national level; ○ Emission containment plan and the Best Available Technologies (BAT) are required in most countries (Belgium-Flanders, France, Iceland, Italy); ○ Permanent networks for air quality are adopted in all countries.	○ Monitoring frequency is very variable; ○ The frequency of reporting to authority is very variable; ○ For standards not set at the EU level, and although, for example, the World Health Organisation[2] establishes air quality guidelines, variable thresholds are adopted at the national level. E.g., air quality thresholds for H_2S are different in France,

[2] http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/pre2009/who-air-quality-guidelines-for-europe,-2nd-edition,-2000-cd-rom-version

	Italy, Iceland, and Turkey, as are those for CH_4 in Belgium-Flanders, France and Hungary; ○ A restriction to the number of non-operational hours of abatement systems is required only in Italy; ○ Degasification is required in Hungary (diversified for various levels of gas content); ○ Data are public only in Iceland and Italy.

1st Case study: Hungary

The emissions are strictly regulated, as geothermal fluids in the Pannonian Basin are often very rich in gas (methane). Gas analyses are required:

- during drilling;
- during workover/ cleaning of the well;
- during operation at the frequency defined in the operational license (individual).

Produced thermal waters are classified into 3 categories according to their measured gas content at 1013 millibar pressure and 20 °C temperature:

- "A" below the threshold of 0,8 l/m^3;
- "B" between 0,8-10 l/m^3;
- "C" above 10 l/m^3.

The Decree describes in detail the procedure of analyses, which can be done only by nationally accredited laboratories. The analyses are a pre-requisite to get an operational license for water wells. Degasification is compulsory in water falling into category "C", applying a MSZ-10-226 certificated degasifying unit. In category "B", the degasification has to be done under the normal operational circumstances, while in category "A" it is not required. The degasification has to be done in a way that does not cause the deterioration of water quality.

The gas content has to be regularly monitored with repeated analyses: in category "A" – every 5 years, in category "B" – every 3 years, in category "C" – every 2 years.

2nd Case study: Tuscany, Italy

The legislation on air quality and emissions provides guidelines and air quality and emission limits from plants. Regional legislation in Tuscany enforces further limits to geothermal power plants, imposing air concentration thresholds and defining emission limits, procedures for sampling and analysis of geothermal emissions, max number of non-operational hours for plant, and adoption of abatement systems (Tables 1, 2, and 3). Besides reducing emissions below the limits defined by regulation, abatement systems reduce ammonia emissions by up to 80-90%. In geothermal areas, air quality is monitored by the operator (Enel Green Power) through a system of 18 monitoring stations that constantly measure the concentration of H_2S in ambient air. The Regional Environmental Protection Agency (ARPAT) validates the measured values. Moreover, ARPAT runs: 1) a fixed station near Larderello, which monitors H_2S, O_3, NO_2, and PM10. The station belongs to the Regional Network of air quality stations and is also part of the Copernicus Atmosphere Monitoring Service (CAMS[1]); 2) two mobile laboratories which are also able to measure mercury concentration in air. All data are published through the ARPAT and the Enel Green Power websites.

Table 1: Air quality limits of reference in Tuscany, Italy, as reported in the regional guidelines

Parameter	Concentration
Hydrogen Sulphide (H_2S)	150 µg/m^3 daily average maximum air concentration
	100 µg/m^3 for 1-14 days (maximum average over the period)
	20 µg/m^3 up to 90 days (maximum average over the period)
Arsenic (As)	6 ng/m^3 yearly average
Mercury (Hg)	0.2 µg/m^3
Boron (B)	20 µg/m^3 daily average
	10 µg/m^3 > for 1-14 days (average over the period)
Ammonia (NH_3)	170 µg/m^3 daily average
	70 µg/m^3> for 1-14 days (average over the period)
Antimonium (Sb)	5 µg/m^3 daily average

Table 2: Emission limits allowed in Tuscany (Italy) plants

Equipment	H_2S kg/h	Hg g/h	SO_2 g/h
Outlet of the AMIS abatement plant	3	2	150
Natural drift cooling towers for plants ≤ 20 MW	10*	4	
Natural drift cooling towers for plants > 20 MW	20*	8	
Forced drift cooling towers for plants ≤ 20 MW	30*	10	
Forced drift cooling towers for plants between 20 and 60 MW	60*	15	
Forced drift cooling towers for plants > 60 MW	100*	20	

* Overall emission limit from the cooling tower (AMIS included)

Table 3: Maximum plant stop hours per year allowed in Tuscany (Italy) plants

Type of stop	Limit
Hours of overall non-operational plant	2% in 8760 hours / year
Hours of operation of AMIS plants / overall operational time of the facility	≥ 98%

Recommendations regarding the geothermal well drilling phase

1. **Defining air quality baseline**

Air quality should be monitored at the plant site and additional locations in the surrounding area prior to the start of any geothermal operation, to establish a baseline.

2. Enforcing air quality monitoring during well drilling

At least when drilling potentially gas-bearing formations, air quality monitoring should be enforced in the bounds of the drilling yard.

3. Enforcing air quality monitoring during well flow tests

Outside the drilling yard, gas monitoring should be enforced during flow tests.

4. Always equipping the drilling rig with tools (e.g. Blow Out Preventer) to prevent accidental gas flow at geothermal wells

5. Enforce mitigation plan to prevent accidental emissions during drilling

It should include: trained personnel (to be certified, e.g., IWCF), perform safety exercises during drilling activity, well design and implementation to face the risk. Maximum flow test overall duration or total emitted volume, to be defined case by case depending on the gas rate, should also be included.

6. Data reporting to the authority

For each drilled well, data should be provided to controlling authorities. They should include also flow test durations or total emitted volume, to be checked against what was declared in the mitigation plan. Controlling authorities should be informed of the flow test schedule to allow them to verify the operations.

Recommendations regarding the geothermal plant operation phase

1. Establishing air quality standards for pollutants currently not covered by EU regulations (H_2S, Hg, …)

Guidelines of the World Health Organization are currently a reference, but air quality standards would harmonise the situation and be applied not only to the geothermal sector.

2. Enforcing continuous or frequent air quality check

During plant operation, the air quality check should be performed at sites surrounding the plant, and their location defined in the emissions containment plan. Frequency should be decided case by case, depending on the level of risk assessed by using state-of-the-art air quality models.

3. Monitoring and abatement plan to contain emissions

In case of predictable significant emissions**,** the following list of actions and practices is recommended.

- Total reinjection or adoption of abatement system to reduce emissions

Mitigation by total reinjection or adoption of adequate abatement systems for H_2S and other aeriform pollutants should also include the maximum amount of non-reinjected gas for reinjection and the definition of the maximum number of non-operational hours for abatement systems.

- Continuous monitoring

This may also include self-monitoring of operators checked by controlling authorities

Main recommendation: Promoting Research and Innovation on strategic topics

- Further research for **zero emission plants and total reinjection**, to increase the environmental performance of some geothermal applications.
- Further understanding of **natural emissions allowing to evaluate the real contribution of the emissions at the power plant** during operation and the effect on natural emissions in the area hosting the geothermal plants. This research would set the appropriate concepts for defining the values to be considered in LCA studies and other environmental assessments and would contribute to the current debate on the matter in Europe (ETS, emission limits). This is a crucial issue to be addressed.
- The definition of Best Available Technologies (BAT) for abatement systems at European level (e.g., a BREF document from the Seville JRC, which defines BAT to be applied to enforce the IPPC regulations[3]).

[3] https://eippcb.jrc.ec.europa.eu/reference

- Further understanding of **health effects of long-term exposure** to a low concentration of hydrogen sulphide emissions. This aspect, which is of higher impact in other sectors, has created some concern also in the geothermal sector, even though monitored concentrations are well below the limits given by the World Health Organisation and short-term effects of these emissions on human health are excluded in the European context. A clear understanding of the effects of long-term exposure to a low concentration of this substance is missing at the scientific level. As evidenced in a recent review carried out in the frame of the GEOENVI project[4], this matter is particularly complex, due to the heterogeneous and sometimes conflicting results and the difficulty to distinguish the exposure among a variety of confounding factors. A large and coordinated effort and a harmonised design of studies is necessary on these aspects.

[4] https://www.sciencedirect.com/science/article/abs/pii/S0048969719359947

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This document is part of a series conducted in the framework of the GEOENVI project. Its aim is to respond to the need for harmonisation of environmental regulations and to address concerns about potential environmental effects of geothermal projects in Europe.

GEOENVI strives to facilitate the incorporation of geothermal energy in Europe's energy transition, while respecting sustainability and creating a robust strategy to answer environmental concerns. The project developed a unique Life Cycle Assessment methodology for evaluating geothermal projects.