Surface gas flux measurement using the accumulation chamber developed and patented by Ineris.

Assessing surface gas emissions in a post-mining site

Surface gas emissions occur in a township overlying a former mining area of the Lorraine coal basin (Eastern France), with reported dangerous gas emissions in a public school and in dwellings. Ineris was mandated to determine the origin and the dynamics of the gas emissions. Thorough investigations were performed, with multiple findings showing that the gas emanates from subsurface rocks in the unsaturated zone located above the local aquifer. Crevasses induced by old mine subsidence are the pathways to the surface. This case study illustrates the complexity of expertizing surface gas emissions on a site affected by underground operations like mining or gas storage.

RISKS RELATED TO UNDERGROUND GAS EMISSIONS.

Gas can migrate underground through overburden strata potentially affected by former underground mining activities (e.g. dewatering, subsidence, formation of cracks or fractures). When emitted at ground surface, underground gas may lead to situations at risks for people. Related hazards as suffocation, poisoning or explosion, depend on the composition of the emitted gas, the dynamics of the emission (flow, duration) and the potential of accumulation in confined or semi-confined spaces (i.e. poorly or non-ventilated spaces, such as cellars, basements or underground networks).

Understanding underground gas production processes and migration to the surface is a fundamental step to assess post-mining risks and define mitigation measures. Ineris has deep expertise in the characterization of those processes based on a strong feedback experience. Here we detail the context and the work done in a city district as a case study.

A main fracture unearthed close to the surface.
(photo credit: GEODERIS)

LOCAL SURFACE IMPACTS OF FORMER UNDERGROUND OPERATIONS.

In this case study, the old underground mining works are located 600 meters deep. The longwall mining with roof caving method was used to extract coal causing important land subsidence with large induced tensile stress zones in the overburden. The presence of competent rock formations at shallow depth, such as Trias sandstones in the Lorraine coal basin, favored the formation of open fractures reaching surface.

In the studied area, more than 1,000 fractures were identified and mapped. The fractures have lengths extending from 10 to more than 100 m, widths from 1 to 10 cm and depths down to 10 m.

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maîtriser le risque
pour un développement durable

IN SITU MEASUREMENTS AND ORIGIN OF THE EMITTED GAS. In situ subsurface measurements undertaken inside opened surface fractures showed an O_2-depleted and CO_2-enriched gas atmosphere, with values down to 7% vol. for oxygen (O_2) and up to 8% for carbon dioxide (CO_2). No abnormal quantity of any dangerous gases usually found in post-mining voids, such as methane (CH_4) and carbon monoxide (CO), was detected.

These values of concentrations have also been measured in some cellars, suggesting that the gas migrates from the ground into the basements of the dwellings. Such concentrations are very hazardous for people since irreversible effects on human health are observed above 5% vol. for CO_2 and below 16% vol. for O_2 (normal atmospheric values: 0,04% and 20,9% vol.).

Discussion on the three possible hypotheses for the origin of the emitted gas →

Mine gas ✗	Biogas ✗	Reaction ✓
Gas from the **post-mining voids** or blackdamp from **coal seams** migrating towards the surface?	Gas produced in a **peatland** close to the city district impacted by gas emissions?	Gas produced by a **geochemical reaction** occurring in the shallow dewatered bedrocks.
But there is **no CH_4** in emitted gas whereas it is a common component of mine gas.	But there is **no CH_4** in emitted gas whereas it is a common component of peatland gas.	O_2/CO_2 abundance ratios match with **oxidation of FeS_2** coupled with **dissolution of $CaCO_3$**.
And O_2/CO_2 abundance ratios in emitted gas do not match a **dilution process** of soil gas with a deep-originated gas (mine gas).	And O_2/CO_2 abundance ratios in emitted gas do not match a **biological origin** (such as respiration process: $O_2 \rightarrow CO_2$).	Measured isotopic signature $\delta^{13}C$ (= $^{13}C/^{12}C$ ratio) of emitted CO_2 coherent with $\delta^{13}C$ of CO_2 produced by $CaCO_3$ dissolution.

Shallow bedrocks are partially dewatered following mining activities which increases the thickness of the capillary fringe and thus the pore volume where gas-water-rock reactions may occur.

Petrographic analyses on fresh cores confirmed occurrence of both FeS_2 and $CaCO_3$ in rock samples below 50 m depth.

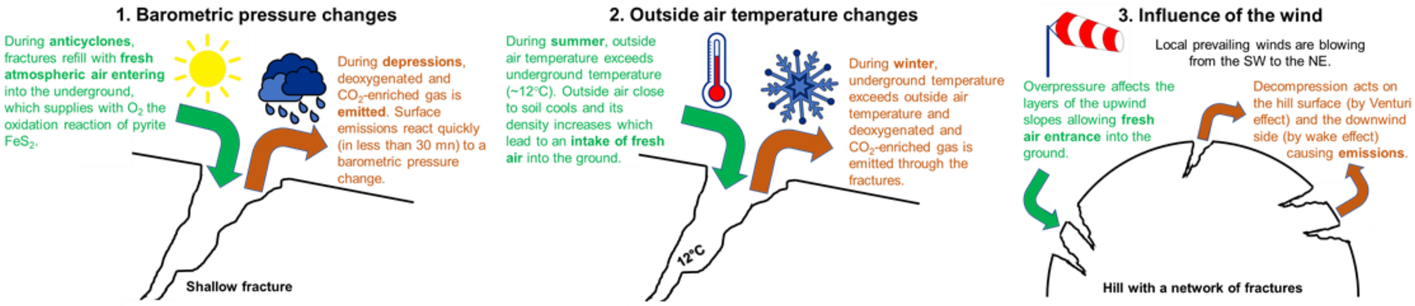
Batch experiments were run in lab conditions with core fragments. Sterilized equipment and water were used. Gas phase was monitored. Results confirmed the geochemical process.

O_2 is a reactant. FeS_2 oxidation is not limited if O_2 supply is renewed which is made possible by the fractures which allow **fresh air entrance into the ground**.

↑ Other evidence supporting the hypothesis that the gas is produced by a geochemical process occurring in the shallow bedrocks.

DYNAMICS OF THE SURFACE GAS EMISSIONS. Once ground fractures were identified as the pathways of the gas, two fractures underlying some dwellings known to be affected by gas emissions were equipped with an automated continuous gas measuring system to characterize the dynamics of the surface emissions. A similar system was also set up at 50 meters depth in a borehole drilled for correlation purposes.

These measurements showed that the dynamics of gas emissions are driven by barometric pressure changes, thermal draught and wind flow.



↑ Dynamics of the gas emissions at the surface driven by changes of barometric pressure and temperature and by the wind.