# Impact of mine closure and access facilities on gas emissions from old mine workings to surface : examples of French iron and coal Lorraine basins

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# Impact of mine closure and access facilities on gas emissions from old mine workings to surface: examples of French iron and coal Lorraine basins

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## Abstract

Closure methods and techniques of mine shafts located in the iron Lorraine basin, in the Lorraine and in North-East coal basins are quite different.

For the first, they are associated with adits. Some are closed by a simple grid to avoid entrance in mine workings but gas entrance and exit are allowed.
Coal shafts are secured and can be equipped with a vent to enable mine gas outflow in specific conditions.

Measurements stations were installed on mine accesses to monitor mine gas parameters (oxygen, carbon dioxide and methane volumetric content, radon volumetric activity, flow velocity, gas temperature and differential pressure) and external parameters (temperature and barometric pressure).

The results show that gas flow can be regulated mainly by temperature gradient between external atmosphere and mine workings (in iron mines) or by barometric pressure (in coal mines).
Gas emissions from iron mines may require extra securing protocol that prevents population exposal to noxious gas.

## 1. Introduction

Scientific publications show that gas flows from old mines are regulated by various parameters. Grabowski and Pokryszka (2003) highlighted the link between external temperature and direction and intensity of gas flow from adits of an old iron mine located at Moyeuvre-Grande town (Lorraine iron basin East of France). The atmospheric pressure does not have any significant influence. On the contrary, Hall and al. (2006), Burrell and Whitworth (2000) have written that old coal mines are affected by atmospheric pressure possibly leading to dangerous situations (noxious gas exposure).
Indeed, a drop in atmospheric pressure leads usually to an outflow of mine gas. The closing of mine accesses, mine gas characteristics and gas flow mechanisms are important to understand and prevent a dangerous situation.
This paper deals with different French old mines that have already flooded:

- Two coal basins: in Lorraine (East of France) and in the North and Pas-de-Calais region (North of France).
- One iron basin located in Lorain.

The risks encountered with gas mine depend on the exploited ore but usually consist of explosion, inflammation, intoxication, radiation exposure or asphyxia.

The risks of explosion and inflammation are usually related to coal mines.
Some basins were safely closed because mine shafts configuration and treatment made possible gas emission control. It is not always the case.
The different data collected and their interpretations are presented hereafter.

# 2. Context of coal basins and iron-ore basin

## 2.1 The Lorraine and North and Pas-de-Calais coal basins

### 2.1.1 The Lorraine coal basin

This basin presents variations in surface altitude (200 to 400 m NGF in La Houve concession). Coal extraction was made from shafts due to the depth of the coal seams (more than one hundred meters). The number and the location of the shafts are known. At the end of the exploitation in late 1990's, early 2000's, dewatering was stopped and the accesses were closed (with concrete plug or flag). Some were equipped with a vent[1] to enable mine gas exit in specific conditions. Some parts of the basin are under gas capture stations influence. This is not the case in "La Houve" concession. Two accesses were instrumented: one shaft (Barrois) and one venting borehole (SDEC OUEST 1).

**Figure 1: Photographs of the vent SDEC OUEST 1 (left) and BARROIS shaft with a vent (right).**

### 2.1.2 The North and Pas-de-Calais coal basin

This basin does not present significant variations in altitude. Coal extraction was made from shafts due to the depth of the coal seams (only one adit is known). The number of the shafts is high (near 600) but their location is not always known. The majority of the accesses are filled and closed and some shafts can be equipped with a vent. Some boreholes can have been drilled in the basin and a great part of the

[1] A vent or a venting borehole (when not put on a shaft) is a pipe of a given height and diameter which passes through the plug or the floor of a shaft and which is in connection with the old mine workings. It is fitted with a flame arrestor and a non-return valve. The non-return valve should inhibit any intake of atmospheric air and is set to only open if the difference in pressure between inside of the pipe and outside exceeds 220 Pa (for Lorraine coal basin).

basin is under the influence of gas capture stations. Dewatering was stopped after the end of exploitation.

## 2.2 The Iron Lorraine basin

This study only concerns the north basin. This basin is a part of the iron basin of Briey-Longwy-Thionville (see Fig. 2) which is divided in three main parts, separated by main faults. These parts are hydraulically independent and dewatering was stopped at different dates.

Iron mine shafts are associated with adits. The iron north basin presents variation in surface altitude (from 355 to 441 m NGF for shafts and from 210 to 330 m NGF for adits). Some mine shafts and adits are closed by a simple grid to avoid human entrance in old workings but gas entrance and exit are allowed. Generally, shafts are located on plateau (they usually constitute topographically high points) while adits are located on hillsides (they usually constitute topographically low points).

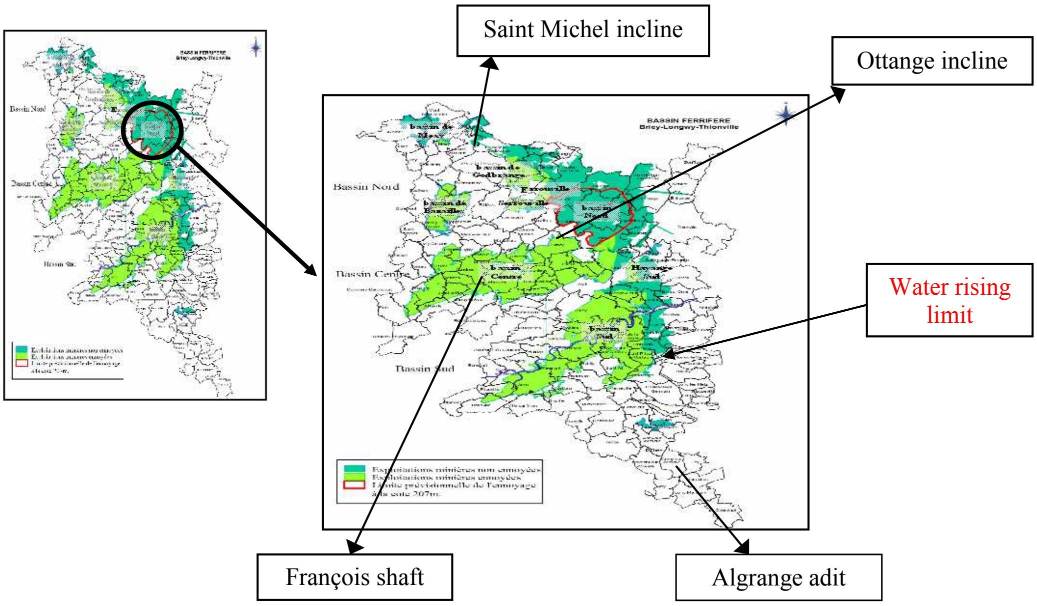


**Figure 2: Position of selected instrumented openings in the north part of the iron-ore basin of Lorraine.**

For the north basin, dewatering was stopped at the end of 2005 (Contrucci and Lagny, 2008) and overflowing at 207 m NGF occurred in March 2008. Several accesses were instrumented (see Fig. 3 and § 3).

**Figure 3: François shaft (left) and Algrange adit (right).**

These accesses are open and protected only by a grid at the entry. They do not show any significant resistance to gas outflow or inflow.

## 3. Monitoring

A monitoring system was installed in order to understand gas flow mechanisms and to evaluate mine gas composition and its intensity and evolution with time for the different old mines.
At each site, several parameters were measured:

- External parameters such as barometric pressure and atmospheric temperature.
- Gas parameters such as gas velocity and flow direction, $O_2$, $CO_2$, and $CH_4$ gas content, radon volumetric activity, gas temperature, differential pressure[2].

Fig. 4 shows a typical measurement station.

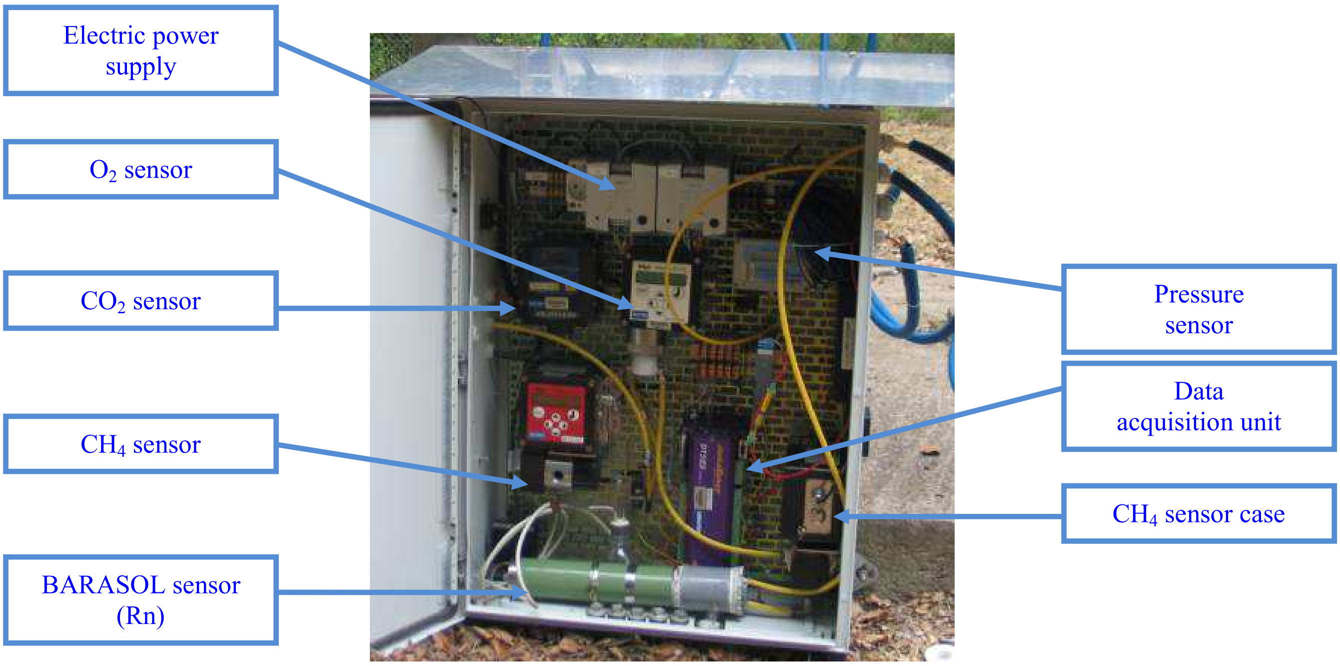


**Figure 4: Monitoring station.**

## 4. Results and discussion

### 4.1 Coal basins

A monitoring station was installed at Barrois shaft location in October 2007. However the station had to be dismantled the next day for technical improvements.
The recorded measures are shown on Fig. 5.
It can be observed a differential pressure build-up which induced the gas outflow. $CH_4$ content is close to 100 % volume, $CO_2$ content is almost 3% volume and radon volumetric activity is near 2000 Bq/m$^3$.

[2] Difference between mine pressure and atmospheric pressure; if positive, the gas should flow out from the mine; if negative, atmospheric gas flows in the mine.

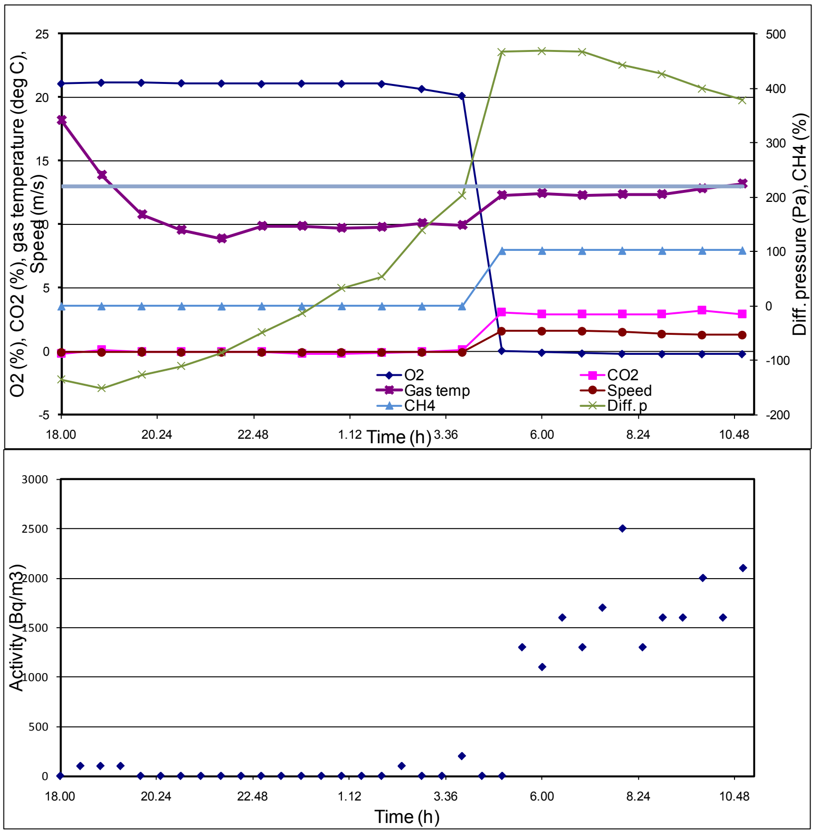


**Figure 5: Variations in gas and radon content at Barrois shaft from 09/10/2007 to 10/10/2007.**

Figure 6 shows that the variations in differential pressure levels are opposite to the variations in barometric pressure. During the investigated period, the differential pressure variations hit approximately 450 Pa.

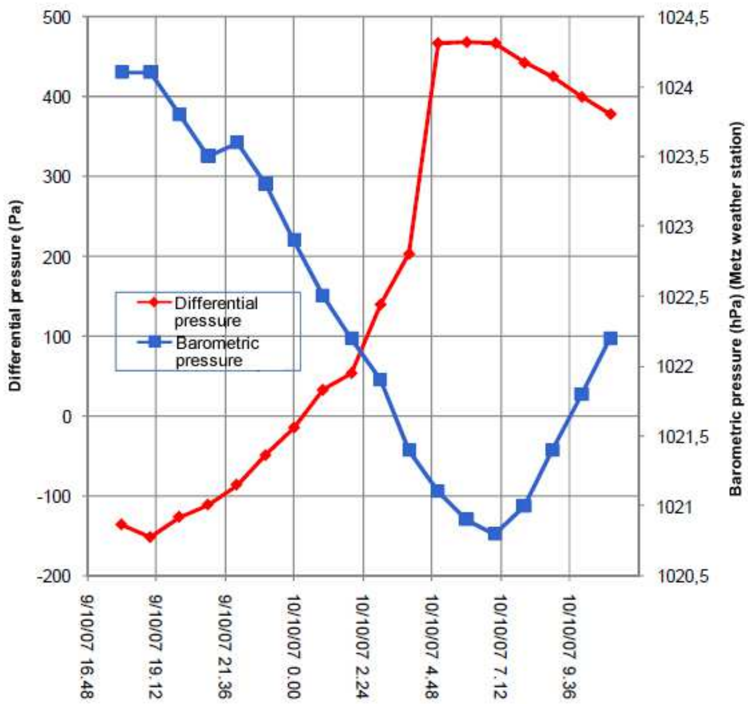


**Figure 6: Variations in differential pressure (measured at Barrois shaft) and in barometric pressure.**

This behaviour is typical and has already been observed in other coal basins where the mine voids represent a significant volume and where the accesses between mine and daylight are essentially closed shafts which are not under gas capture influence. This is the case of the east part of the North and Pas-de-Calais coal basin. We can observe for all accesses (equipped with a vent) and for venting boreholes that the differential pressure shows variations that are the opposite of those of the barometric pressure (Lagny, 2005). The absolute pressure measured at the top of the vents is therefore practically constant, except when a severe barometric depression passes through. This behaviour may be illustrated by Fig. 7 which shows ten minutes data acquisition intervals monitoring of the barometric pressure and of the differential pressure on a decompression borehole S11 (called Taffin) at the Vieux Condé concession over a period of ten days. We can observe that the variations in the barometric pressure induce differential pressure fluctuations between -550 and +2000 Pa.

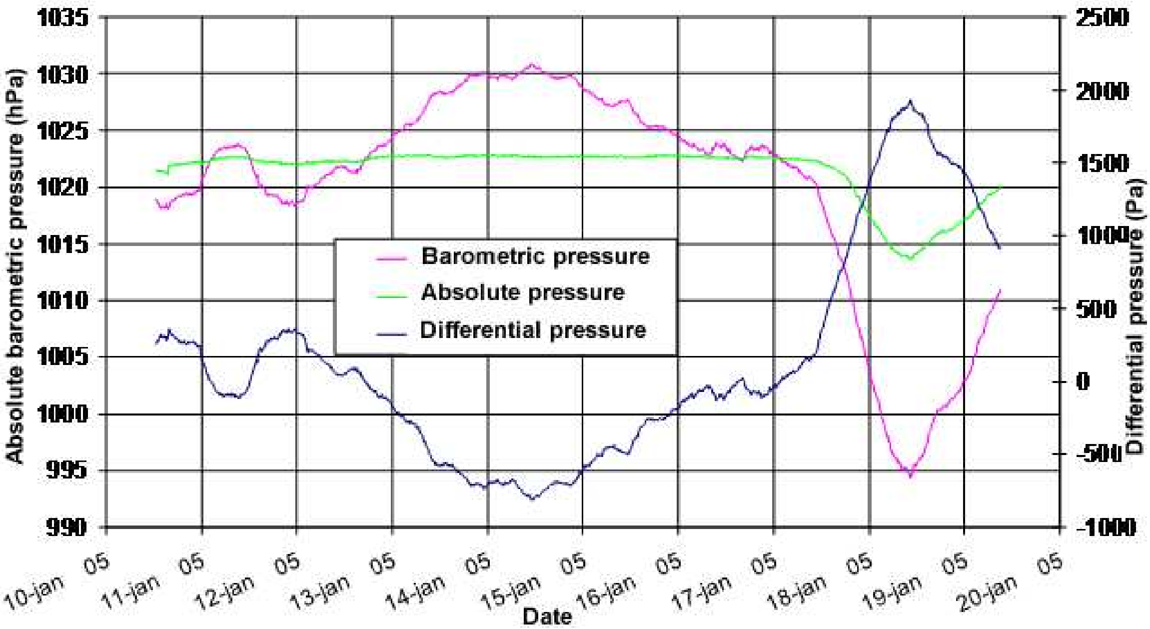


**Figure 7: Barometric pressure, differential pressure and absolute pressure over time on the S11 boreholes at the Vieux Condé concession.**

The old mine voids that make up a closed system (shafts that are mostly closed off and/or filled-in and a lack of clearly open floor-surface accesses) operate as follows: the variations in barometric pressure lead to fairly significant differential pressure variations. As a result, the barometric pressure serves as the main parameter driving mine gas towards the surface.

In the Lorraine coal basin, rising of water resulted in the filling of mine voids. The last stage of flooding immediately leads to a fall in differential pressure that then vanishes.

A progressive fall in mine gas content (methane and carbon dioxide) is observed while the oxygen content is increasing. The variations of atmospheric pressure have no more effect on the differential pressure. Mine gas exit is stopped at the instrumented accesses.

## 4.2 Iron basin

Fig. 8 and Fig. 9 are parts of the plots of the data registered at François shaft.

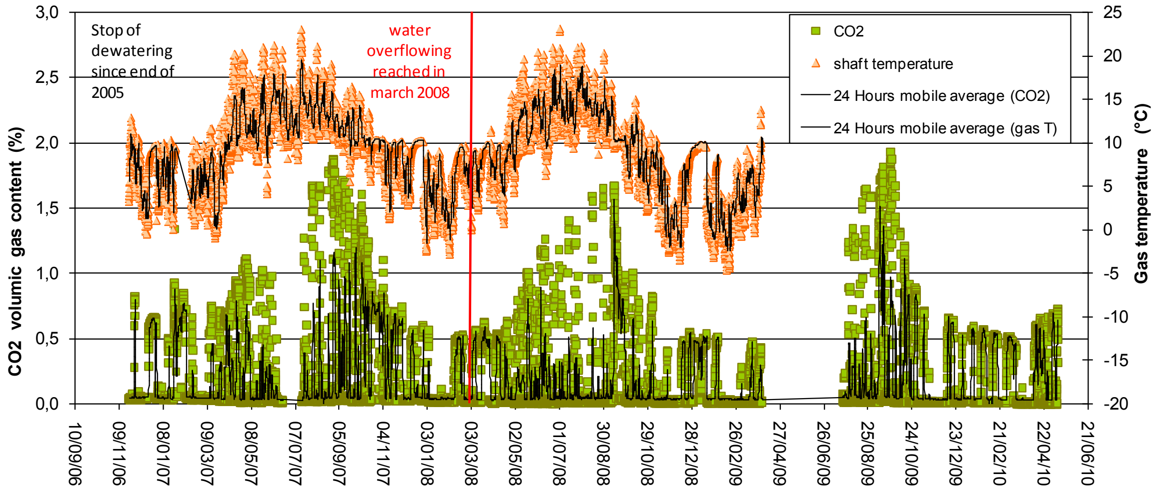


**Figure 8: $CO_2$ volumic gas content and temperature recorded at François shaft.**

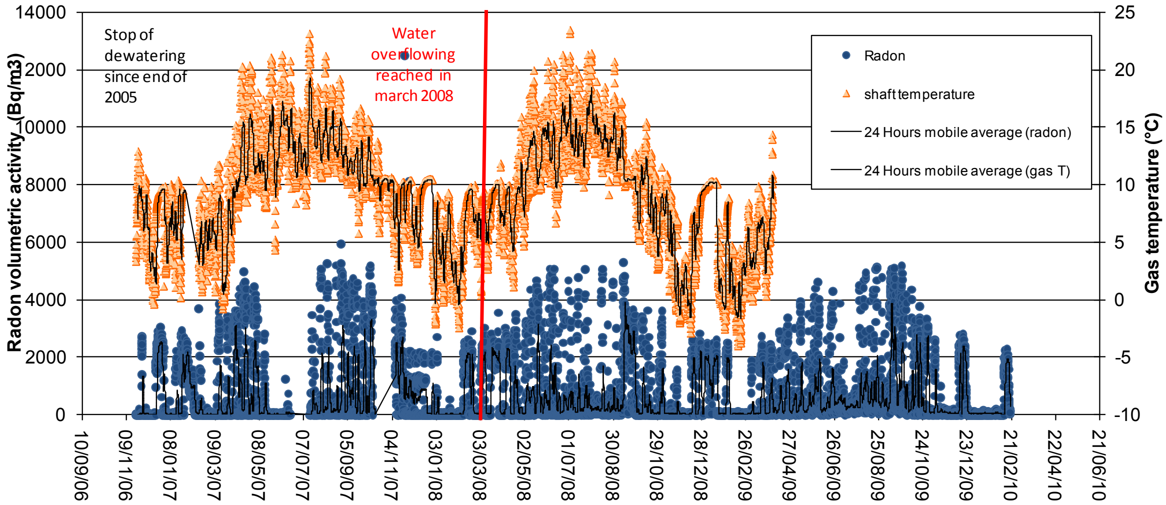


**Figure 9: Radon volumetric activity and temperature recorded at François shaft.**

Gas shaft temperature change, is influenced by seasons. $CO_2$ volumic gas content presents seasonal variations like radon volumetric activity which can reach respectively 2 % and 5000 Bq/m$^3$.

Water overflowing did not change shaft gas flow behavior and characteristics. Similar remarks can be made on Algrange adit, but a small decrease in $CO_2$ gas content can be observed with dewatering. On the contrary, radon volumetric activity is stable and stays around 9000 Bq/m$^3$.

According to the season and for each access, gas flow direction is changing due to the variations of atmospheric temperature. Noxious gas is emitted to the surface through the grids of the accesses and preferentially during summer conditions for François shaft, Algrange adit and Ottange incline.

# 5. Conclusions

## 5.1 Coal basins

For all instrumented accesses (equipped with a vent and for venting boreholes), the differential pressure shows variations that are the opposite of those of barometric pressure (Lagny, 2005). This behavior is typical and has already been observed in other coal basins where the mine voids represent a significant volume and where the accesses between mine and daylight are essentially the shafts like in the North and Pas-de-Calais and Lorraine coal basins. On the studied area, uncontrolled outflow of mine noxious gas was avoided thanks to the shaft closure and venting boreholes realisation.

These shafts and the boreholes are usually isolated by an enclosure or an enclosing wall to prevent human intrusion. A notice warns people of the danger eventually encountered.

## 5.2 Iron basin

The way of closure in the iron basin is not the same as in coal basins.

The rising of water does not have a significant effect on the gas flow and on the influence of external temperature.

This observation highlights that natural thermal convection plays a significant role in the creation of the gaseous flow between the mining reservoirs and the surface. This phenomenon is due to the temperature difference between the external atmosphere and the old workings.

In the old workings, the temperature is usually almost constant (it is estimated between 12 and 14°C, in this case), contrary to the atmospheric temperature, whose value varies according to the annual seasonal cycle. Also, a surface topography over the mining reservoir and the closure way of the accesses seem to facilitate thermal convection.

During summer, a part of the atmospheric air in contact with the upper old workings (openings badly closed or exploitation fractures) is subjected to a progressive cooling. An increase in the bulk density, due to the effect of cooling, causes gas migration towards the lowest parts of the old emerged mine workings.

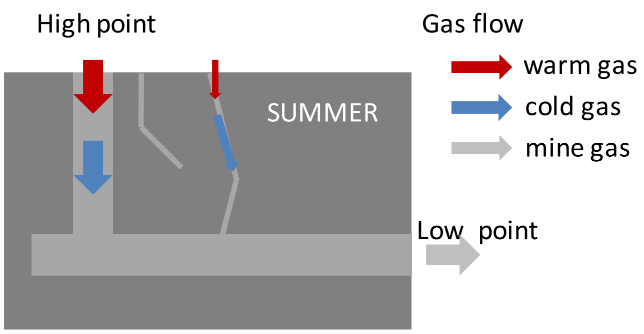


**Figure 10: Gas flow exchange during summer.**

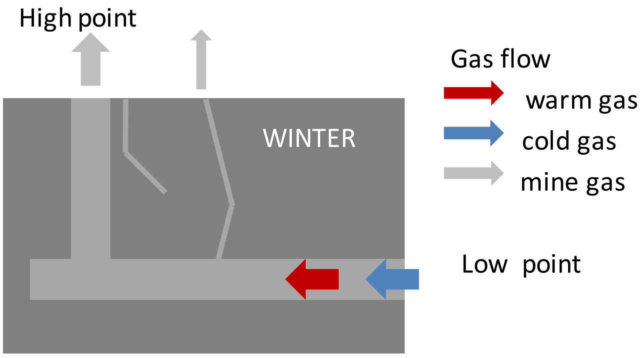


**Figure 11: Gas flow exchanges during winter.**

For G7 adit located at Moyeuvre-Grande town in Moselle department (East of France), during summer, under-oxygenated and noxious gas is emitted (Grabowski and Pokryszka, 2003). It was necessary to put a deflector (Fig. 12) which deflects the gas flow and an enclosure to avoid human exposure to this gas due to its composition (Tauziède, 2003).

**Figure 12: Deflector and enclosure set up at G7 adit exit.**

## References

Burrell R. and Whitworth K., 2000: The influence of minewater recovery on surface gas and water discharges in the Yorkshire Coal Field. Proceedings of the 7th International Minewater Association Congress, Ustrom, Poland 2000, p81-90.

Grabowski D. and Z. Pokryszka, 2003: Emissions gazeuses à partir des vides miniers dans le bassin ferrifère lorrain. Colloque Après-mines 2003, 5-7 février 2003, Nancy.

Hall J., Younger P. and Glendinning S., 2006: Is minewater a source of hazardous gas ? IAEG 2006 Paper number 349.

Contrucci I. and Lagny C., 2008: Suivi des effets de l'ennoyage du bassin ferrifère nord sur son activité gazeuse et son activité microsismique au cours de l'année 2007. Programme EAT DRS-03. Rapport INERIS, référencé DRS-08-95102-04893A du 17 avril 2008.

Lagny C., 2005: Modélisation de la pression du réservoir post-minier et des débits de gaz passant par les exutoires du secteur Est du bassin houiller du Nord et du Pas-de-Calais. Rapport INERIS référencé DRS-05-45883/R05 du 29 septembre 2005.

Tauziède C., 2003: Mise en sécurité de la galerie G7 à Moyeuvre-Grande (57). Résultats de l'installation d'un déflecteur d'air. Compléments d'observations le 25 août 2003. Rapport INERIS référencé DRS03-45405/R03 du 26 août 2003.

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