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GAS EMISSION AND GAS UTILISATION IN THE ABANDONED MINING AREA OF THE RUHR DISTRICT

Erwin KUNZ

Deutsche Montan Technologie GmbH, Am Technologiepark 1, D-45307 Essen, Germany. Kunz@dmt.de

(8 figures)

ABSTRACT. As in other coal mining areas of Europe also in the Ruhr district problems with gas outflows on the surface may occur, when mines are closed and the ventilation system is shut down. The gas volume, which remains in the coal measures in the abandoned area, causes diffuse gas inflows on the surface. This depends on the permeabilities of the remaining roadway system, the filled shafts and the rock layers, both in the area of the filled shafts and outside of it. The problems of safety and their control are described on concrete examples.
However the mine gas is also an energy source the utilisation of which is supported in Germany by a new law since the year 2000. The gas is exhausted and utilized at ten locations at the moment (electrical power so far about 39 MW). For example the location Kurl is explained in more detail. Further development of gas utilisation schemes, especially by boreholes, is intended.

Keywords: Ruhr district, abandoned mines, gas emission, safety, utilisation

Zusammenfassung. Wie in anderen Kohlerevieren in Europa, so können mit der Schließung von Bergwerken und der Einstellung der technischen Belüftung auch im Ruhrrevier Ausgasungsprobleme an der Tagesoberfläche auftreten. Die im stillgelegten Bereich im Gebirge verbliebenen Restgasmengen verursachen in Abhängigkeit von den Durchlässigkeiten der verlassenen Grubenbaue und der Gebirgsschichten diffuse Gasaustritte an der Oberfläche, die sowohl im Bereich der verfüllten Schächte als auch außerhalb davon festgestellt werden. Die sicherheitlichen Probleme und ihre Beherrschung werden beispielhaft beschrieben.
Das Grubengas ist jedoch auch ein Energieträger, dessen Nutzung in Deutschland durch das EEG aus dem Jahr 2000 gefördert wird. Das Gas wird bereits an zehn Standorten abgesaugt und verwertet (bisherige Leistung elektrisch ca. 39 MW). Als Beispiel wird der Standort Kurl näher erläutert. Der weitere Ausbau der Verwertung, insbesondere über Bohrlöcher, ist geplant.

Schlüsselbegriffe: Ruhrgebiet, stillgelegte Bergwerke, Gasaustritte, Sicherheit, Nutzung

1. Gas emissions in the area of coal deposits

In coal deposits three zones can basically be distinguished with respect to gas emissions: the non-mined area, the area of active mining and that of abandoned mining.

In the non-mined zone of the Ruhr district (Fig. 1) natural methane emissions are very low. They seem to be zero in the Lower Rhine area due to the low gas contents in the upper parts of the Carboniferous and the gas-free layers of the overburden.

They reach maximum values between 0,08 and 15,5 g/(m^2 .d) in the Westphalian area (Thielemann, 2000, p. 222), where we have an accumulation of methane below the overburden, gas storage in some layers of the overburden and tectonic faults, which pass from the Carboniferous up to the surface.

The limiting factor for natural emissions and the cause of these low flow rates is the low permeability of the seam-bearing Upper Carboniferous and of the Permian, Cretaceous and partly Tertiary sediments of the overburden. Thielemann (2000, p. 223) illustrates the low values in comparison with the flow rates in the worked Carboniferous and overburden with high permeability. These low natural emissions do not present any danger at the surface, but they also cannot be utilised.

The procedures of coal bed methane (CBM) technology are concerned with the utilisation of methane stored in the coal in non-mined deposits by boreholes (Gayer & Harris, 1996). These procedures have been applied with success in a number of deposits (e.g. San Juan Basin). In the Ruhr field it has not been possible to achieve a profitable result from a few tests, because the produced quantity of gas remained below the threshold of cost effectiveness.

In the area of active mining large quantities of the gas stored in the rock are released. They are partly diluted to harmless concentrations by the mine ventilation and conveyed into the atmosphere through the shafts. The gas is

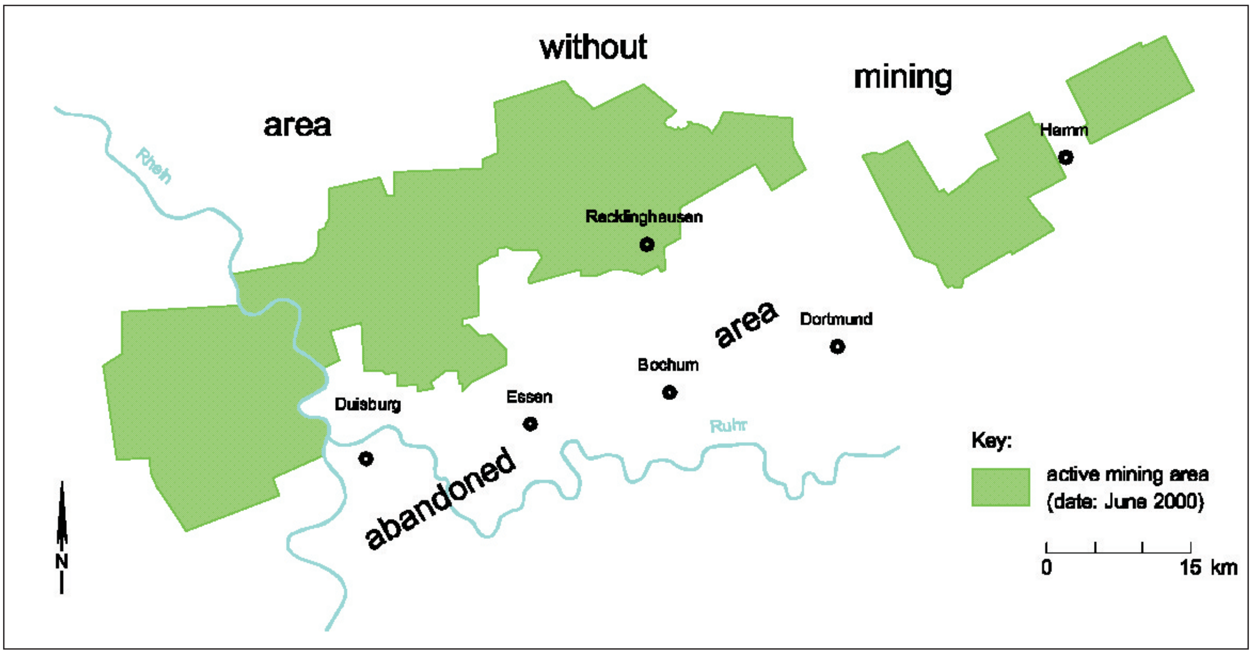

Figure 1: Actual situation of mining in the Ruhr district (June 2000).

partly sucked directly by the gas drainage system through boreholes and, because it contains 25-60 % methane, it is passed on for further utilisation. According to Lange (2000) almost 80% of the methane taken up by the gas extraction system is put to further use today at Deutsche Steinkohle: generation of heat and warm water at the mines, generation of steam and electricity at the mines, delivery of gas to public services of some cities and other industrial users and long-distance heating supply.

The third zone of gas emissions in the Ruhr district is the zone of abandoned mines. The emissions arise in particular on the surface of backfilled shafts and also in the surroundings of the shafts, if there are flow ways for the gas like old tubes, lines, conduits, tunnels etc. But gas emissions were also found outside the shaft locations on the surface above intensive mining, especially when the abandoned roadways and longwalls are near the surface and the thickness of the overburden is small. The hazards arising from this and the possibilities of further utilisation will be considered more closely in the present paper.

2. Methane emissions from backfilled shafts

The abandoned shafts of the hard coal mines, although backfilled, are the most important flow paths between the mine workings and the atmosphere. Depending on the nature of the backfilling and the properties of the filling column, of the connection of the shaft support to the rock and of the surrounding rock itself, the gas flows differ considerably in volume and distribution at the surface. In addition the methane content of the outflowing gas mixture depends on the gas content in the relevant part of the deposit.

At a number of shafts so-called gas degasification pipes with explosion-proof protection caps are installed. These pipes are either used to vent the shaft covering plate or they are connected directly with the mine workings in the depth.

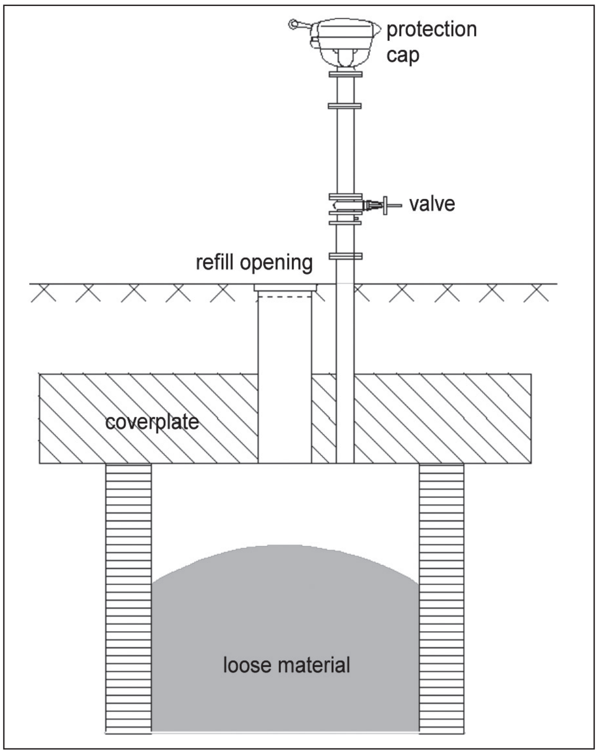

Figure 2: Shaft filled with loose material, closed with a coverplate and provided with a refill opening and a degasification pipe.

Figures 2-4 show the three backfilling arrangements most frequently used in the Ruhr district. Originally all shafts were filled with loose material (normally tailings) and secured by a cover plate with an opening for refill. If substantial gas flows were expected from a shaft, it was equipped with a degasification pipe (Fig. 2).

Since about 1975 the shafts to be abandoned are backfilled with a material which is enduringly stable in position (mostly concrete). This prevents the risk of the filling column slumping, which would involve major risks for the environment with respect to stability and gas emissions. To provide enduringly stable backfilling, one has the alternatives of full backfilling and partial backfilling (Figs. 3 and 4). In addition, in contrast to backfilling with loose material without positional stability, there is the possibility of installing degasification pipes which provide a direct connection with the abandoned mine workings.

Measurements conducted on the degasification pipes of numerous shafts in the Ruhr district filled with loose material have shown that at low atmospheric pressure an average of up to 10,5 m^3/h gas mixture escapes. The concentrations of methane in the gas flow lies in the wide range between 0 and 80 %. At high atmospheric pressure, on the other hand, air penetrates into the shaft.

From the desgasification pipes in shafts with enduringly stable filling and with a direct connection to the mine workings, an average of up to 11,9 m^3/min = 714 m^3/h gas mixture is exhausted (methane concentrations also between 0 % and 80 %), depending on the atmospheric pressure. The penetration of air into the workings at high atmospheric pressure is prevented by a non-return flap or a gate valve.

Long-term measurements carried out at a standard mine with an area of 10 km^2 allow to calculate a volume of several hundred thousand m^3 pure methane flowing per year through the degasification pipe of a shaft with a connection to the workings of that abandoned mine. But it was a mine with high gas contents in the seams. Lower gas contents respectively residual gas contents after closure will certainly cause lower volumes.

The pressure difference with the underground workings caused by a fall in atmospheric pressure on the surface, not only pushes gas out of the degasification pipes, but also pushes it through the filling material in the shafts or through the annular space between the shaft and the rock into the atmosphere. A circular gas emission protection zone is therefore generally established around the shafts and this is kept clear, if possible, of any buildings. This gas emission protection zone normally has a radius of 25 m around the mid-point of the shaft.

Fig. 5 shows that in some cases the gas outlets on the surface can also be beyond the radius of 25 m. The spread of the gas depends on the permeabilities in the

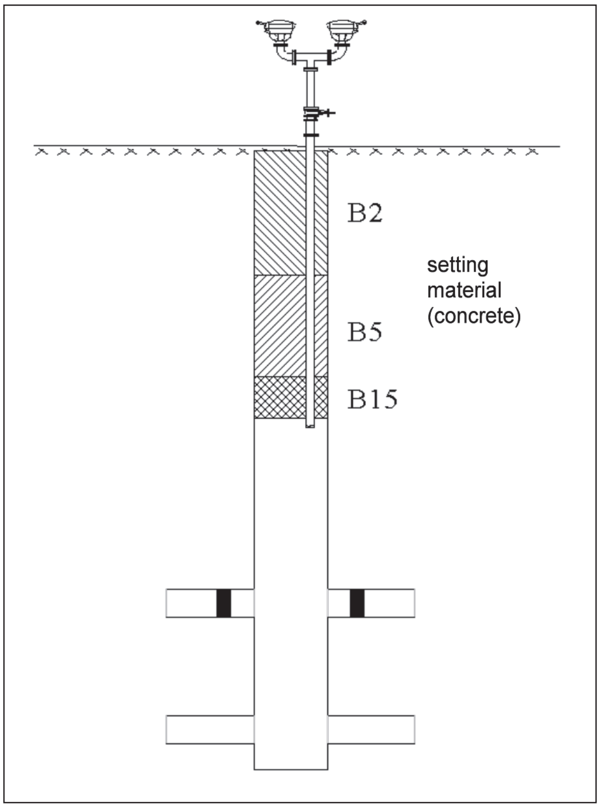

Figure 3: Partial filling of a shaft of long-term stability with a degasification pipe.

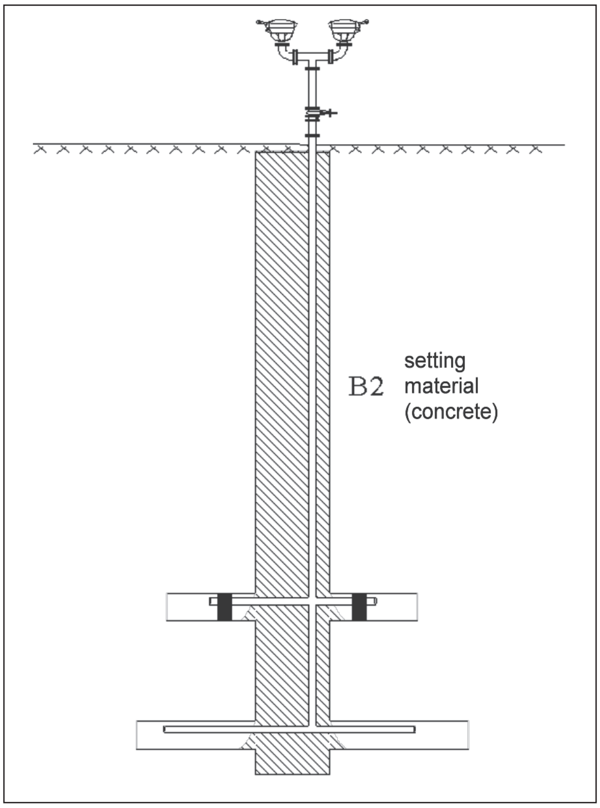

Figure 4: Complete filling of long-term stability with a degasification pipe.

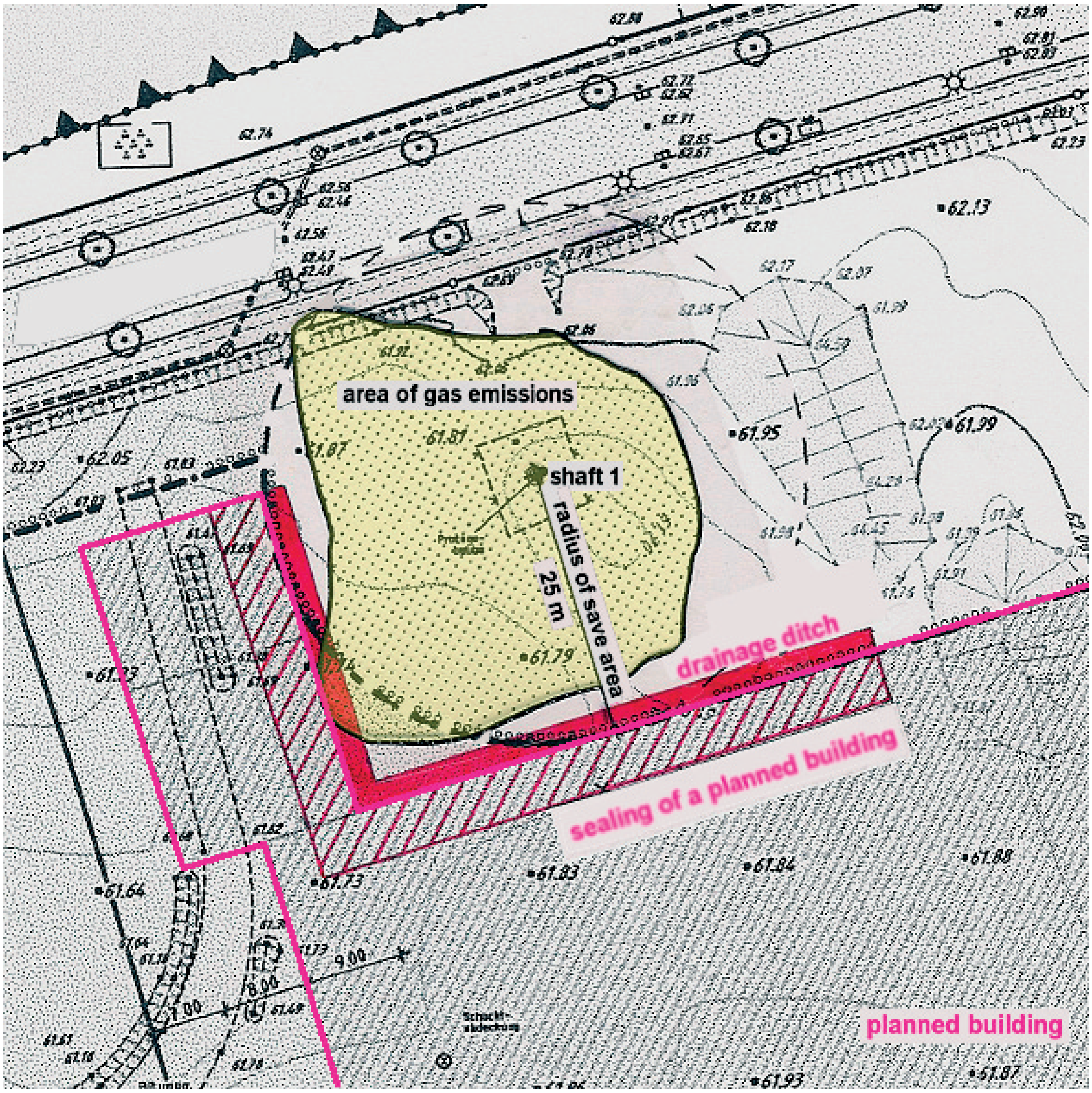

Figure 5: Area of gas emissions around an abandoned and filled shaft and protection of a planned building (Ickern).

soil, especially in the man-made filling. The gas is spread in a particular long distance by horizontal pipes, cable ducts, passages for the miners, air ducts or other hollow structures.

To protect buildings from gas inflows, measures adapted to each individual case are taken, e.g. building seals, horizontal areal drainage, vertical ring drainage etc. (Fig. 5). Drainage and ventilation systems can also be installed in existing buildings, such as old mine buildings which are to be preserved and used.

3. Methane emissions at the surface

Gas emissions at the surface can also be a hazard for people and buildings outside the shaft locations in the abandoned area of the Ruhr district. At exposed points in buildings, e.g. in ground drains or inspection shafts in the basement rooms, at pipe penetrations through the outside walls or at cracks in the floor or in outside walls, small volumes of ignitable gas mixtures were measured at low atmospheric pressure in a number of cases.

If only a few buildings are affected, individually adapted protective measures are taken as for the shaft locations. But if many buildings in densely built-up areas are affected, it will be less expensive and simpler to undertake a general measure. One example of this is what was done in Dortmund, where five boreholes with a depth of approximately 20 metres are connected to a gas exhausting station through a collective gas pipeline (Fig. 6). Fig. 7 shows the rock sequence of the overburden (Quaternary, Cretaceous) and the uppermost part of

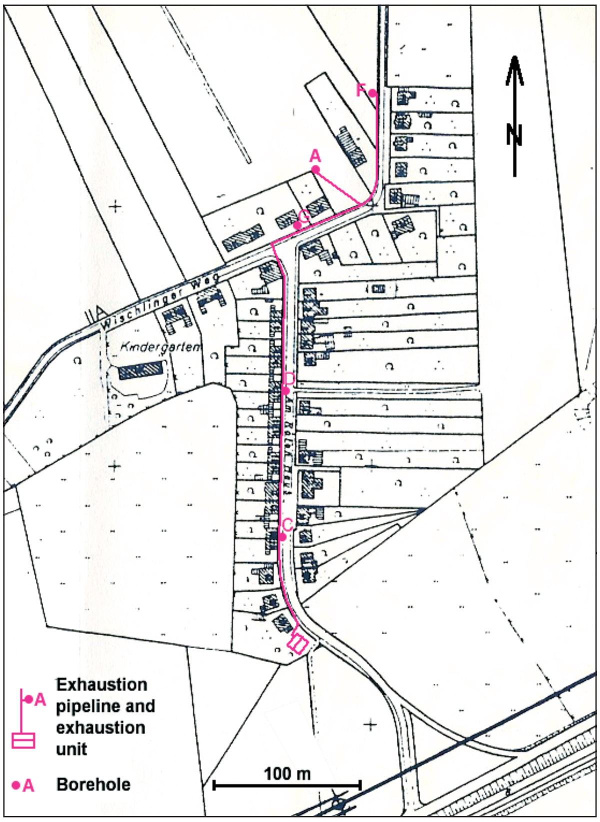

Figure 6: Gas drainage in a district of Dortmund (Marten).

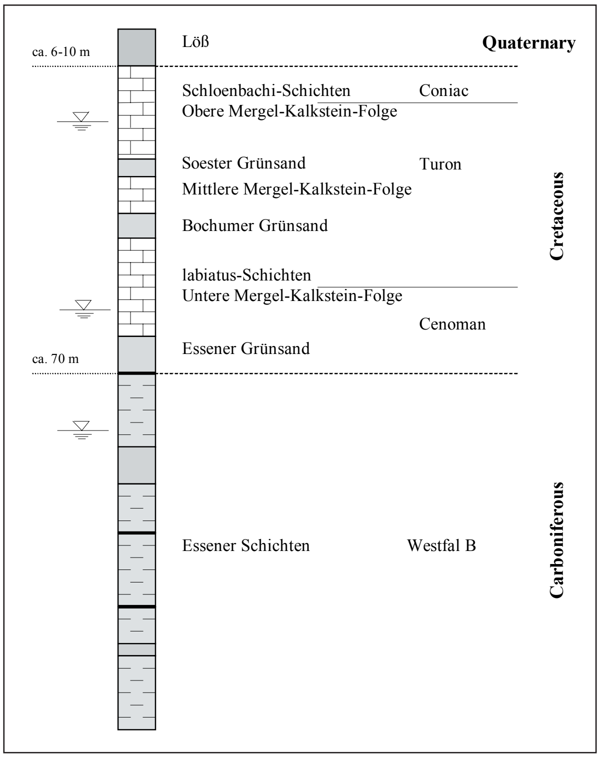

Figure 7: Rock sequence in a district of Dortmund (figure 6, borehole D).

the Carboniferous. The boreholes were drilled through the Quaternary into the “schloenbachi-Schichten” (Coniacian, Upper Cretaceous), which consist of marl and limestone. These rocks form a cleavage reservoir where, if not saturated with water, gas can be stored.

The gas migrates along unknown paths from the Carboniferous into the Cretaceous and is stored both in the “labiatus-Schichten” (Fig. 7) and the “schloenbachi-Schichten”. The reservoir rocks are sealed by the “Grünsand” resp. by the loess of the Quaternary.

By subjecting the “schloenbachi-Schichten” to suction, the gas is taken up before it can pass into the buildings. For example, in the first half of 2001 around 300 000 m³ of methane with an average methane content in the gas mixture of 58% was extracted. Utilisation is in preparation.

4. Gas utilisation

The first utilisation plants of power generation from mine gas in the abandoned area of the Ruhr district were taken into operation in 1997 in Herne and in 1998 in Lünen. Up to April 2002, 43 approvals had been granted (one of which is in the Aachen district) (Weiss, 2002). About 15 locations with an installed electrical capacity of approximately 60 MW were developed by the middle of 2002.

This sharp rise in the utililsation of mine gas was encouraged by the Renewable Energies Act (EEG) which was passed in the year 2000. In this, mine gas was included into the catalogue of regenerative energy sources whose utilisation helps to protect earth’s atmosphere.

The plant at the Kurl 3 shaft can be taken as an example of a developed location (Fig. 8). There are at present three mobile power plants in operation. The under-pressure applied is approximately 80 to 100 hPa and the methane content in the gas extracted is approximately 60 %. In the first year of operation about 20.8 GWh electricity was generated (Röhner, 2002).

Figure 8: Gas utilisation plant at Kurl 3 in Lünen.

For some areas of the deposit, calculations were made of the gas volumes still present in the deposit after mine closure. The calculation of the residual gas volume requires:

a) as much information about the original gas content as possible,
b) the superposition of the ground plans of the workings in the different seams,
c) the determination of the residual gas content for each constellation of superposition,
d) the determination of the residual coal volume for each constellation of superposition,
e) the determination of the residual gas volume for each constellation of superposition,
f) the addition of the residual gas volume of all constellations of superposition.

This calculation was done for the first time as part of research projects of the State of Nordrhein-Westfalen. For example, in the Maximilian Graben (part of the former Westfalen Mine), approximately 1.400 million m³ methane is calculated before mining and approximately 675 million m^3 methane (approx. 48 %) after mining. Even if only a fraction of this quantity can be recovered, it will be possible to operate plants with several MW capacity over a number of decades. The condition for this, however, is that the level of the mine water may not rise substantially.

5. Conclusions

The experiences in the abandoned mining area of the Ruhr district shows, that the gas emissions from the deposit don't stop when the mines are closed. They continue in very different flow rates and concentrations depending on the residual gas content in the coal, the permeability of the rocks and the penetration of air into the backfilled shafts.

The most important pathways for the gas are the old shafts, though they are backfilled. Some shafts, where stronger gas streams were expected, are provided with degasification pipes, in order to ensure a secure drainage. Anyway in a series of cases additional measures for the protection of people and buildings were necessary (sealing, drainage, ventilation).

In some parts of the abandoned zone of the Ruhr district gas emissions also occur outside the shaft locations. This is, of course, first of all a problem of safety and similar measures have to be taken like at the shaft locations, but adapted individually. In two cases until now the gas has to be continuously sucked out of boreholes by pumps.

Since 1997 until the middle of 2002 at about 15 locations, mostly at shafts with a degasification line into the old roadways, gas utilisation was installed. This boom was encouraged by law.

In the scope of research projects for some areas of the deposit the residual gas volume after mining was calculated. First results indicate that utilisation plants can be operated over a number of decades. The condition for this, however, is that the level of the mine water may not rise substantially.

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