# Remote Sensor Net for Wireless Temperature and Gas Measurement on Mining Dumps

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*Abstract:* - Long-term monitoring of thermic processes and concentration of dangerous gases within old mine dumps is very important especially from the point of view of environmental protection and also human health. In Ostravian region there are several thermically active mine dumps with specially installed probes measurement temperatures and gas concentrations (CO, CH4). The paper gives an overview of two basic measurement systems applied at the mentioned dumps including description of used probes and methods of data processing. It also deals with handling and processing arisen alarm states during exceeding predefined limit values.

*Key-Words:* - sensor, monitoring, measurement system, temperature measurement, data processing, mining dump

## 1 Introduction

Underground black coal mining is plagued by a number of negative phenomena. One of them is the necessity of exploitation, transport to the surface and storing a huge amount of collateral rock from proximate surroundings of coal seams, mainly carboniferous rock (clay stone, siltstone, sandstone). Due to their character they are inconvenient for a wider industrial use.

Generally they are referred to as "barren rock" or slag and usually stored in proximate surroundings of coal factories, making wide hills called mullock tips. The amount of coal being stored together with collateral rock depends on the technology of separation and processing the product of coal factory. Various analyses of the coal dump samples declare that percentage of combustible substances usually reaches 30%, while even 50% is not an exception.

In terms of thermal process, a very adverse factor is the existence various organic substances being stored in the dumps, including plastics in recent decades. It contains almost the whole trash from coal factories and often municipal waste from the surrounding communities. Even worse is unorganized and often secret store of various waste from nearby factories, including dangerous chemicals. Documentation of stored material is thus scarce or missing, particularly for older dumps.

### 1.1 Causes of rise of thermal processes

As it was mentioned above, the coal dumps contain a high number of combustible materials (eminently with prevailing coal substances) in almost all of its volume. Nevertheless, pore space can reach up to 40 %, which prevents the air and oxygen from getting into the depths of the dump. Warming up to given temperature causes the start of the first phase of thermal process which, under certain conditions, can spread into endogenous and sometimes surface fire. Basic causes of the fire can be summed up as follows:

- external initiation
- autooxidation of a coal substance
- illegal store of chemicals

### 1.2 Risks of burning dumps

Nowadays, with rising importance of improving the quality of living environment, the burning of the dumps represent a significant negative factor and source of pollution of a wide surrounding area. Activities of thermal processes lead to a rise of risks with various hazard levels, some of them imminently threatening human lives. The most dangerous risks caused by the burning dumps are as follows:

- heat generation
- release of toxic substances, especially CO,$CH_4$
- generation and spread of fine dust
- creation of burnt-out space within the dumps

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- risk of a surface fire

## 2 Temperature and gas monitoring

The basic presumption for monitoring and evaluation thermal activities of mine dumps is retrieving the surface and underground temperatures. According the current methodology, the range and intensity are evaluated by the following approaches:

Measurement of surface temperatures
- temperature measurements of surface layer of the dump are determined for evaluation of surface affects of thermal activities. Infra thermometers are widely used in this case, when the dense grid of the points is measured and consequently the isotherms are determined. Larger areas and inaccessible ground spaces require the use of aerial photography with a color marking of warmer locations.

Measurements of subsurface temperatures
- this method is used both for determination of surface extent and mainly for subsurface analysis. Temperatures are retrieved by use of steel probes installed into required depth levels to create the needed network of sensors. These measurements use classical mercury thermometers, thermocouple probes, sensors PT100 or the probes equipped with digital sensors (SMT160/30, DS18B20) together with evaluation unit based on µ-processor.

Gas monitoring
- as it was mentioned above, thermal processes generate various gas substances. Presence of dangerous CO indicates imperfect burning of organic materials and thus running endogenous fire. Monitoring of temperatures and gases (CO, $CO_2$, $CH_4$) is eminently important for determination of extent and intensity of thermal processes within the dump and gives the feedback for realization of maintenance intervention.

## 3 Measurement systems

The most important mine dumps in Ostravian region affected by thermical activity are Hedvika and Ema. Measurement of temperatures and concentration has been carrying out there for last several years. However, the main disadvantage relies in manual measurements using classical measurement devices and sensors.

For long-term monitoring of temperatures and gas concentrations there have been two designed and successfully implemented two complex measurement systems including a large sensoric network containing both temperature and concentration sensors CO and $CH_4$. The first of them is centralized measurement system that contains particular sensors of temperature and gas (ones to tens), primary data concentrators and a central telemetric station. This station sends the data by GPRS technology to the central server data storage which is determined for data archiving and online visualization in the forms of trend lines on web pages. It also allows automatic data transfer to private own server via FTP technology. Measurement of temperatures and gas concentrations is realized in tens of probes covering affected area. The most typical spacing of the probes is 25 m.

Telemetric stations consist of universal data logger and GSM/GPRS communication module. Common battery operation is designed for multiple years of operation. Telemetric stations make it possible to set up large monitoring networks independent of external power sources and can be combined not only for temperature monitoring but also for other physical and electrical quantities. Depending on the type of I/O circuit, a single telemetric station can measure multiple input signals (temperature, gas concentrations, pressure etc). Due to these top-class features it possible to cover large areas by autonomous monitoring system, capable of performing measurements and sending data for years without human intervention.

As for temperature sensors, the system uses temperature sensors PT 100 or PT 1000 and gas sensors Figaro Engineering Inc. of series TGS 2442, TGS 2611, TGS 3870 etc. One of the main disadvantages of this system is mainly necessity of cablings connecting sensors with primary data concentrator and from concentrators to telemetric station. Block scheme of the complete measurement system is shown in Fig. 1.

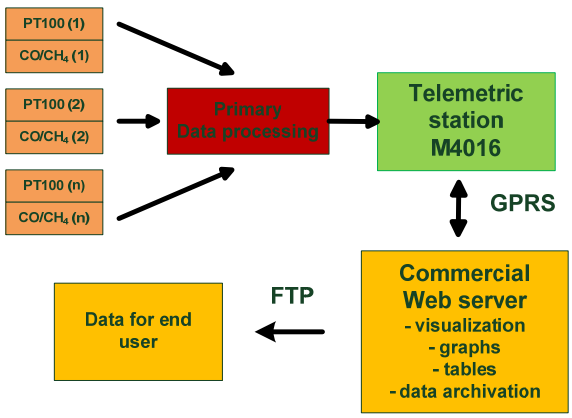


Fig. 1. Block scheme of measurement system based on telemetric station

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The photo of the telemetric station with prepared sensors is in Fig. 2.

Fig. 2. Telemetric station with temperature sensors

The second system consists of autonomous embedded measurement unit determined for implementation directly in the head of special measurement probes. This kind of system is also used for measurements of temperatures and gas concentrations (CO, $CH_4$) and its main advantage is that they may be put into operation even in faraway parts of monitored area without necessity of cablings unlike the previous system.

The concept of measurement system comes out from the need of autonomy and long-term operation without operator intervention. Also, to comply with other demands, the effort is given to minimal geometry proportions together with low-cost energy need.

The core of the system is made of µprocessor connected with temperature sensor(s) and concentration sensor(s). Currently the concept composes two digital sensors Dallas DS18B20 and one CO concentration sensor. The system is supposed to be extended by Pt 1000 and other gas sensors for close future. Consequently the processor communicates with GPRS that provides data transfer through FTP to user server where processing, archiving and data visualization by means of the dynamic charts are performed on the web pages. Block schemes of such system is in Fig. 3.

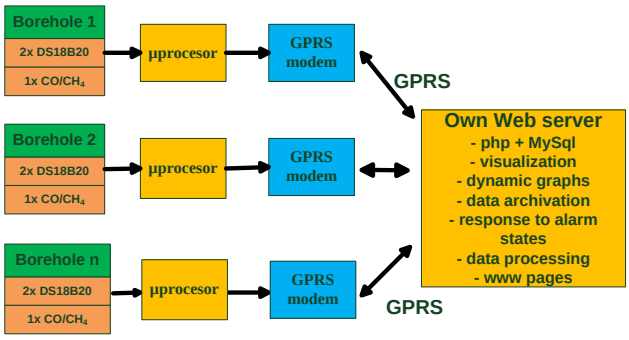


Fig. 3. Block scheme of autonomous measurement system

## 4 Using measurement systems on mining dumps

As mentioned above, the most affected places in Ostravian region are Hedvika and Ema mine dumps. The large area of these old mine dumps (heaps) is covered by installed special measurement probes that take care of long-term both temperature and concentration monitoring.

### 4.1. Mining dump Hedvika

Mine dump Hedvika is a slag dump that belongs to former factory Důl Julius Fučík. The dump is mighty, huge and spacious formation of slag landfills. The landfills of slag rock have been carried out since 1903. Transportation of the slag rock to the heap was performed by means of mine pushcarts. Photography of the Hedvika mine dump is illustrated in Fig. 4.


Fig. 4. Hedvika mining dump photo

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Fig. 5. – Special measurement probes at the Hedvika mine dump

The Hedvika mine dump is equipped with several tens of measurement probes that provide regular temperature measurements in 3 depth levels (3, 6 a 9m). The measurement started in 2001 and since that time it is performed periodically once a month, while the temperature is scanned manually using a probe. The above mentioned measurement system is installed in 12 probes together with one concentration probe. Fig. 6. shows the example of the chart representing the temperature trend line in one probe in the range of 05/2009 to 05/2010.

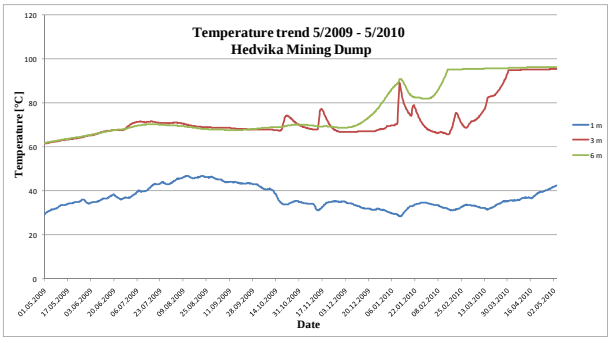


Fig. 6. Temperature trend of Hedvika mining dump

## 4.2. Mining dump Ema

The Ema mine dump has been gradually created, starting from 1920 to 1995 by storing the slag from operating mines Ema, Trojice and Petr Bezruč (Terezie). After the decommissioning and termination of storing the mass at the heap the area was partly recultivated. At these days the area of value area serves for tourist purposes only – there is marked out scenic route towards a central cone of the Ema since it is registered as a cultural sight. Thermical processes including open fires have been taking place for last decades with varying intensity. Photography of the Ema mine dump is illustrated in Fig. 7.

Fig. 7. Ema mining dump photo

Fig. 8. A view of telemetric station configuration at the Ema mine dump

The Ema mine dump is currently equipped with 5 measurement probes that take care of periodical measurements of temperature and concentrations of gases, mainly CO. This is also done by autonomous measurement system that receives the temperatures data every 4 hours and sends it to the dispatching center.

As an example, there is temperature trend line at the Ema mine dump over a given period in Fig. 9.

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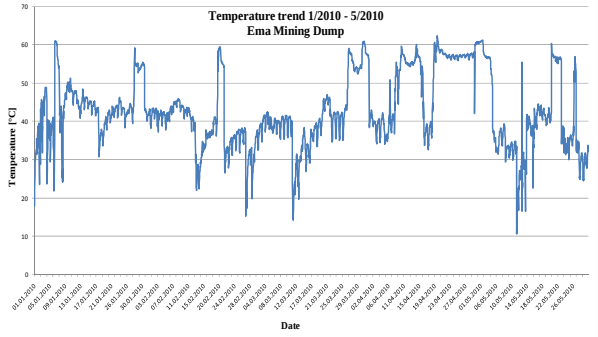


Fig. 9. Temperature trend of the Ema mine dump

## 5 Database system + www pages

All the data received from a large sensoric network of temperature and gas sensors is archived in the central database system which consequently serves as the data source for visualization on www pages. As for software solution, a combination of MySQL + PHP + SWF Chart (dynamic charts creation) has been chosen. The structure of the database system is designed so that there exists a single database for each mine dump where the particular tables correspond to particular measurement probes. The columns then contain information of GPS position of the probes, date and time of measurement and the data itself for particular depth levels.

WWW pages are powered by PHP script language and SWF Chart that is capable of creating dynamic charts linked to the data source.

## 6 Alarm states

During long-term measurements of given physical quantities it is necessary to handle possible alarm states when exceeding their given limits. In this particular case, the system must be capable of instant reaction in when either temperature or gas concentration is beyond the predefined dangerous limit. The most common solution to handle these alarm states is use of sending an alarm SMS to predefined cell phones. Operation of the system is based on GSM/GPRS modem which is connected either to central PC taking care of processing, visualization and data archiving, or by a client application run in under any host PC which is connected to the central PC. SW application providing online visualization of measured data at the web pages also contains the lines of codes that deals with sending AT command to connected GSM/GPRS modem and thus sending the alarm messages. Block scheme of such warning system is shown in Fig. 10.

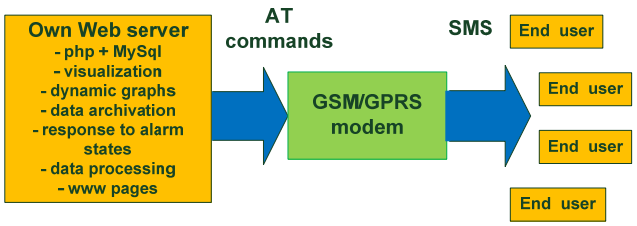


Fig. 10. Block scheme of warning system

## 7 Conclusion

The paper dealt with a description of two types of complex measurement system composed of a large sensoric network covering affected areas of old mine dumps Hedvika and Ema. It also introduced long-term data trend lines at these dumps and one of the possibilities to implement reaction to exceeding the limits. In close future the system is planned to be extended by other gas sensors. Also, for further phases of the project, the second generation of the system is on the way, covering miniaturization of the central units and charging the accumulators by renewable energy sources.

## Acknowledgment

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