INTEGRATED CAVE ENVIRONMENTAL MONITORING SYSTEM (ICEMS)

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Abstract: A specialized cave microclimate and hydrologic monitoring system was established in 5 show caves managed by Slovak Caves Administration in 2007. The basic goal was to set up a system which will be able to monitor selected parameters in caves continuously, with automatic data transfer to central database, remote access to data loggers in caves an with a possibility to use it also in caves without electric power supply.
ICEMS is a result of a joint research and development of two partners: Slovak Caves Administration and MicroStep-MIS. ICEMS belongs to key products of MicroStep-MIS. Cave monitoring system is a unique integrated system consisting of permanent and mobile data loggers, communication network, data collection and central database and management system. This system consists of sensors measuring different environmental parameters. At the same time the climatic conditions outside the cave are measured. Meteorological stations near cave entrances are included into monitoring system.
All the sensors are connected to the data logger which is specially designed for cave environment (high humidity, small size, watertight...). Measured values are stored locally on each logger's CF card. The system has two modes of measurement: Standard mode, Micro mode. Standard mode allows measurement every 10 or 60 minutes. Micro mode allows measurement every minute or every 10 seconds. The system further consists of sophisticated data collection, database, data processing and data presentation software. Data Collection application is designed for data collecting from datalogger network. Cave monitoring system is an open one, it can be extended or modified according to customers' requirements. The number of connected sensors can be modified too. One of the main system advantages is the ability of remote control and maintenance.

Keywords: cave microclimate, monitoring system, radon, cave environment, rock temperature, air flow, water sensors

THE PURPOSE OF MONITORING

A specialized cave microclimate and hydrologic monitoring system was established in 5 show caves managed by Slovak Caves Administration in 2007. The basic goal was to set up a system which will be able to monitor selected parameters in caves continuously, with automatic data transfer to central database, remote access to data loggers in caves and with a possibility to use it also in caves without electric power supply.

Cave microclimate monitoring is from the scientific point of view useful to have better knowledge of cave geo-systems, determination of anthropogenous influence on climate changes, on stability and regeneration possibilities of caves, especially show caves.

The main requirements on the functionality of the system were: sufficient capacity of own battery sources for at least 2 or 3 months, protection against over-voltage in case of power from the mains, protection against lightning, reliable functionality of probes in cave environment (high relative air humidity and low temperature in ice filled caves) and ranges of measurement important for caves.

SYSTEM

Integrated cave environmental monitoring system (ICEMS) is a result of a joint research and development of two partners: Slovak Caves Administration and MicroStep-MIS. ICEMS belongs to key products of MicroStep-MIS. Cave monitoring system is a unique integrated system consisting of sensors, permanent and mobile data loggers, communication network, data collection and central database and management system (Fig. 1).

System structure

- sensors
- data loggers
- communication network
- data collection and management system
- central database

System was developed, installed and is serviced by MicroStep-MIS and Slovak Caves Administration.

MicroStep-MIS develops software and hardware equipments as well as complex solution of monitoring systems, integration of environmental systems to unified networks.

SENSORS

This system consists of sensors measuring (Fig. 2):

- air temperature
- relative humidity – specially designed for high humidity in caves
- rock temperature
- wind speed and direction (2D, 3D)
- precipitation
- drip inlet
- evaporation
- global solar radiation
- CO_2
- radon Rn^{222} – designed for continous measurement of Rn^{222}
- water temperature
- water quality – conductivity, pH, NOx, Cl
- water quality – spectrometric measurement
- water level
- air pressure

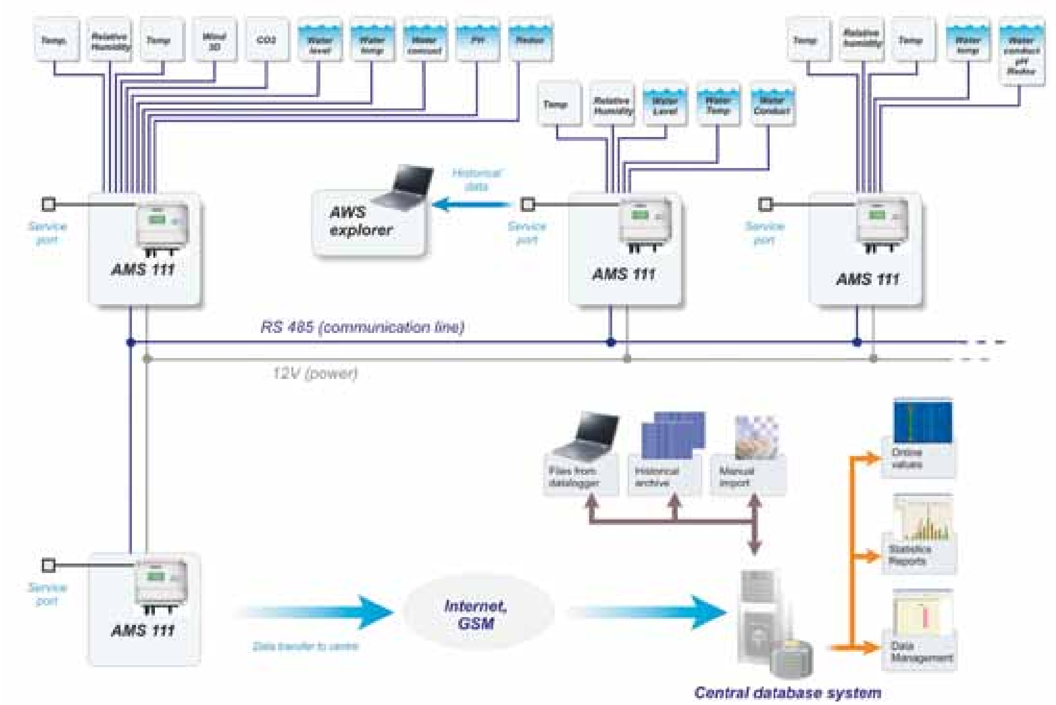


Fig. 1. Cave system overview

At the same time the climatic conditions outside the cave are measured. Meteorological stations near cave entrances are included into monitoring system (Fig. 3).

DATA LOGGER

All the sensors are connected to the data logger (Fig. 4) which is specially designed for cave environment (high humidity, small size, watertight...).

The logger is easy to maintain, with a very low consumption, flexible and easy to configure to any sets of sensors. Measured values are stored locally on each logger CF card. Storing is not limited by card capacity regarding to rich avalability of high capacity cards. Online data transmission is via RS485, WiFi, GSM / GPRS, etc. and is managed by the central system.

Cave monitoring system is equipped with effective overvoltage (lightning) protection. The system is scalable from one mobile station powered by a battery to a national monitoring for all the caves in the country with powerful central system.

Fig. 2. Different sensors and data logger in ice cave.Photo: J. Zelinka

Data logger has standard equipment as touch screen, battery, external/internal memory, communication interface (RS232, RS485, Bluetooth).

Other technical parameters of data logger used in caves:

- 22x precise differential, inputs resolution 24 bit,
- 12x digital inputs (0-20V),
- accuracy better than 1µV,
- 5 additional analog inputs.

The data logger has DC input, main battery and backup battery for memory. Data logger contains integrated

Fig. 3. Meteorological station outside the cave. Photo: J. Zelinka

Fig. 4. Data logger. Photo: J. Zelinka

RS485 data communication line and RS232 service line. It can be equipped with optional GSM modem. Data logger can be connected with PDA for file browsing via portable Bluetooth. In PDA it is possible to check current data, configure logger parameters and download, upload configuration file as well as the data files.

The data loggers inside cave are operated on 230V power. In case of 230V power loss the data logger is equipped with main battery that provides backup power and high consumption sensors are switched off automatically. When the logger is operating with power from the main battery, sensors that require large amount of power are disconnected.

The data logger has build in compact flash memory with capacity up to number of GB (similar to USB keys). The measured data can be stored in this memory for several months.

The data logger has RS232 service port. User can download data and change settings using PDA or laptop computer.

Measurement modes

The system has two modes of measurement: Standard mode and Micro mode.

Standard mode allows measurement every 10 or 60 minutes. 10 minutes measurement interval is designed for static type of system. 60 minutes measurement interval is designed for mobile type of system.

Micro mode allows measurement every 10 or 60 seconds. 10 seconds measurement interval is designed for static type of system. 60 seconds measurement interval is designed for mobile type of system.

Each data logger can operate in both modes (also simultaneously), which can be switched from remote server. There is possibility to change measurement intervals too.

Communication network

Several data loggers are installed inside each cave. They are connected via two wire RS485 communication lines. Outside of the cave is installed external data logger which has GSM module.

External data logger is connected to GPRS network and establishes VPN connection with data centre. The external data logger routes communication between interior data loggers inside the cave and the data centre. The VPN connection is secured by telecommunication operator.

Operation and collection

The system further consists of sophisticated data collection, database, data processing and data presentation software.

Data Collection application is designed for data collecting from datalogger network. Main purpose of the central database (EnviDB) is to:

- automate procedures for the data management and processing,
- integrate data from collection system,
- provide data storage for environmental data and meta-data,
- perform quality control,
- single point of access for end-user services for data provision, distribution and publication.

Historical data from old devices and data from other measurement systems e.g. meteorological institutes can be imported to the central database. EnviDB is software designed for metadata management and collected data processing.

Cave monitoring system is open one, it can be extended or modified according to customers' requirements. The number of connected sensors can be modified too. One of the main system advantages is the ability of remote control and maintenance.

The measured data are collected automatically via GPRS VPN network. The collection software is installed in the HQ building. The data are collected automatically and on-line every 10 minutes.

The downloaded data are stored in the central database.

The collection software allows view of all data loggers installed within the caves. User can see current status of communication (Fig. 5). In the messages browser user can view the latest data message downloaded from data logger and decoded values as well.

In the AWS details user can setup the micro regime and schedule automatic start and stop of micro regime (Fig. 6).

Fig. 5. Remote control status of communication

Fig. 6. Setting up the microregime measurement from the office

USER INTERFACE AND APPLICATIONS

Quality control

Before storing the data it is necessary to pre process the data – decode it from the original data logger records and modify it in into unified structure.

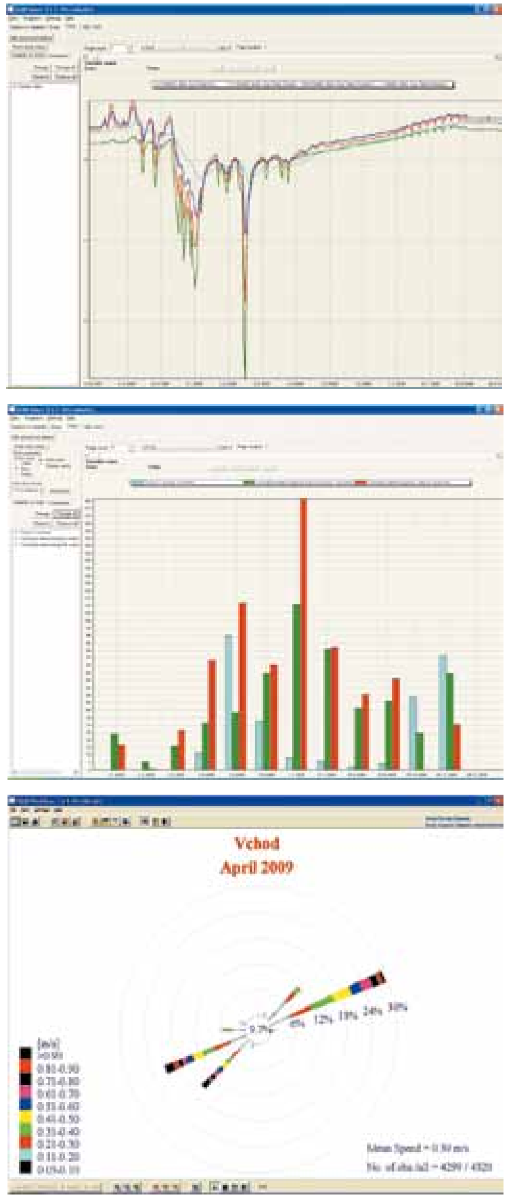
Data quality control is performed because it is crucial to ensure that only correct observations are submitted to database processing.

Wide variety of checks have been developed:

- Elimination of duplicates
- Internal consistency checks
- Comparison with global ranges
- Time line comparisons with other observations
- Manual monitoring and corrections

References

Cave monitoring systems are installed in the caves of Slovakia, Czech Republic and Slovenia.



Figs. 7, 8 and 9.Various graphical interpretations of stored data

• Five permanent and six mobile Cave Monitoring Systems are installed in Slovak Caves:

- Demänovská Ice Cave
- Demänovská Cave of Liberty
- Dobšinská Ice Cave (Fig. 10)
- Gombasecká Cave
- Domica Cave

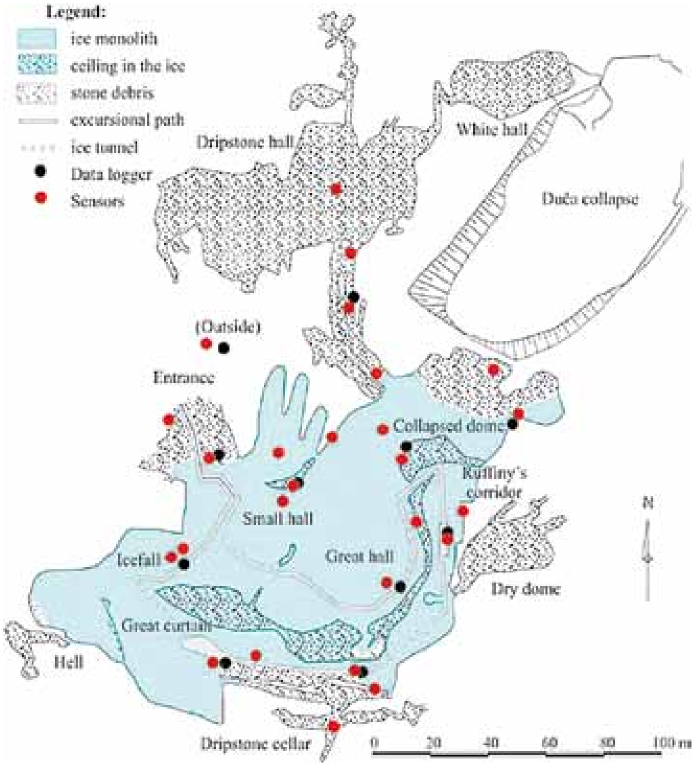


Fig. 10. Distribution of dataloggers and sensors in Dobšinská Ice Cave

Fig. 11. Radon sensor installed in Domica Cave. Photo. I. Smetanová

• One permanent and one mobile Cave Monitoring System is installed in Czech republic:

– Kateřinská Cave

• One permanent Cave Monitoring System is installed in Slovenia:

– Postojna Cave

Radon monitoring in Domica Cave

Continuous radon measurement in Domica Cave started in June 2010. This measurement is based on cooperation of four partners:

1. Slovak Caves Administration
2. Department of Nuclear Physics and Biophysics, Faculty of Mathematics, Physics and Informatics, Comenius University Bratislava
3. Geophysical Institute, Slovak Academy of Sciences
4. MicroStep-MIS, Monitoring and Information Systems

The radon sensor mobile head is measuring alpha decay of ^{222}Rn in measuring passage (Fig. 11). It was installed in Small Hall of Domica Cave. Periodic daily and non-periodic short term variations of ^{222}Rn activity concentration were registered during this short period of radon measurement. Daily average values were in range 0,8 – 2,65 kBq.m^{-3} (Fig. 12).

This measurement is a part of research of cave microclimate regime and research of impact on employees' health as well as the relationship between radon activity concentration changes and meteorological and cave microclimatic conditions study.

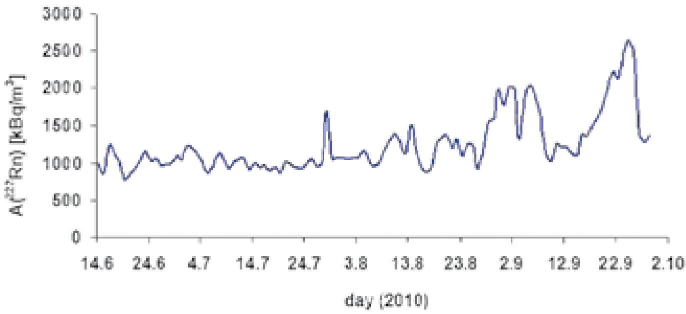


Fig. 12. 222Rn-daily average values from Domica Cave. Author: I. Smetanová

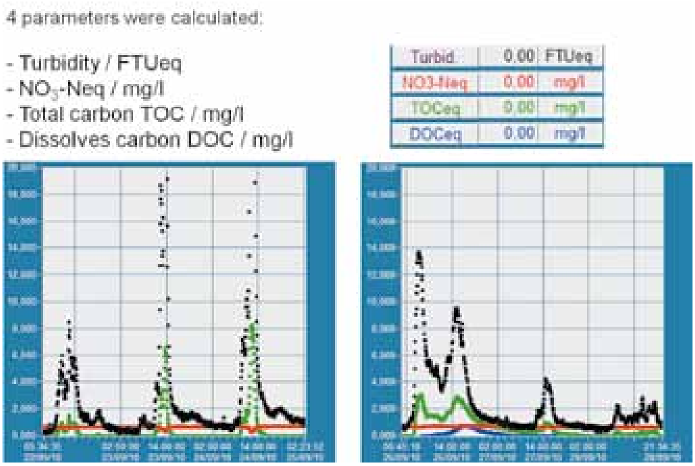


Fig. 13. Continuous water quality monitoring test in Demänovka River

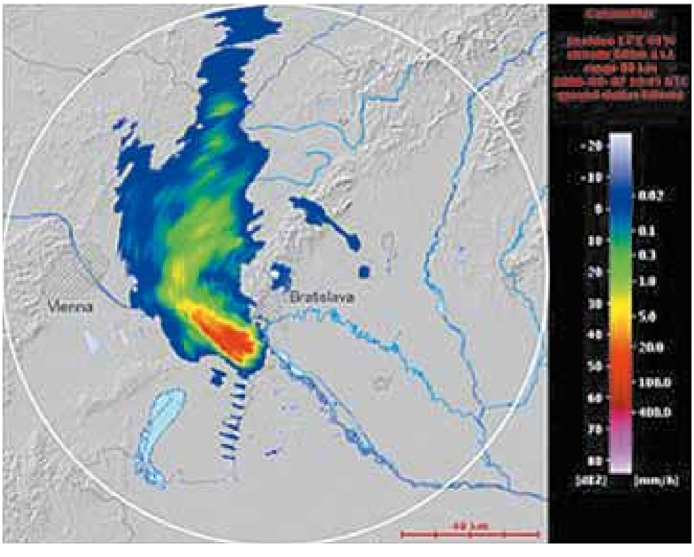


Fig. 14. Graph generated by radar

Water quality spectrometric measurement

Another part of research started in September 2010 – Continuous water quality monitoring of Demänovka River (Fig. 13). The new type of sensor – spectrometric analyser for this type of continuous monitoring was installed in Demänovská Cave of Liberty. Testing monitoring period started on September 17th 2010 and ended on October 1st 2010.

This testing proved the suitability of sensor installation in cave environment. Tested sensors were running without need of maintenance. Registered water quality was without significant changes during this period, the sample of water in Demänovka River was taken. Used type of global calibration method „RIVER" is suitable for water quality monitoring of surface water and four parameters were calculated.

Future

Further development and improvement of the ICEMS is going on. For example a new humidity sensor especially designed for humidity nearing 100 %, is under tests. Development and tests of a new drip sensor will start soon. Lightning and mini weather radar are ready to connect to ICEMS (Figs. 14 and 15). Optimization of spectrographic water quality measurement is under progress. New generation of data logger is ready for installation as well.

Fig. 15. Meteorological radar

Fig. 16. Countries with installed monitoring systems by MicroStep

Mini-portable meteorological radar is prepared for full integration to ICEMS. It is used for:

- detection of severe thunderstorms, intense rainfall, hail, down bursts, etc.
- nowcasting – prognosis from 30 up to 120 minutes
- monitoring and warning before local flash floods
- regional nowcasting with radar with respect on customer safety

Thunderstorm/lightning subsystem is used for detection of discharges by lightning sensor, integration with database of (hazardous) meteorological phenomena. Data displays, data archiving, operator alerts on significant changes/hazards, equipment status reporting and remote maintenance.

About MicroStep

MicroStep-MIS is specialized in development and manufacturing of environmental monitoring and information systems. The company‘s key activities cover: meteorology, seismology, gama radiation, air quality, marine systems, cave environment, crisis information systems. MicroStep-MIS operates worldwide (Fig. 16).

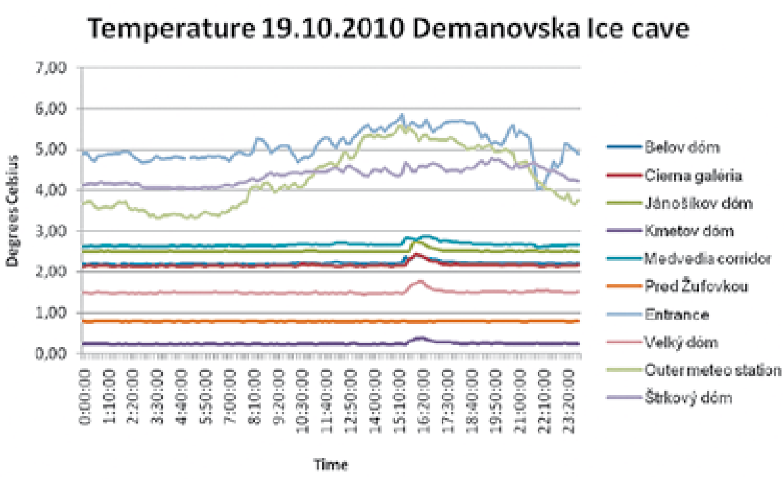


Fig. 17. Change of temperature in Demänovská Ice Cave during the visit of ISCA 6th Congress participants

At the end

Congress participants visited different Slovak caves. Here are the changes of air temperature measured during the visits to this caves (Fig. 17.)