Adaptation of datalogger equipment for CO2, temperature, and humidity measurements inside caves.

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Summary

Low-cost CO2, temperature, and humidity datalogger equipment has been adapted in a waterproof box for optimal operation in cavities with high humidity levels of +90%.

Until recently, having a datalogger with CO2 sensors in cavities with high levels of humidity was impractical due to the low operability of these sensors in extreme humidity conditions that are common in many cavities. An adaptation using a waterproof box and hydrophobic filters for these devices has been presented to protect the sensors from extreme exposure.

Tests carried out for months inside a cavity have been successful for long-term CO2 datalogger measurements. Tests of over seven months in a cavity with more than 98% RH conditions have yielded positive results, and the sensors have not been affected by this extreme humidity.

These adaptations allow the use of dataloggers in cavities, opening up broad options for measuring climate dynamics in cavities. The materials used and the adaptation of the equipment for waterproofing under extreme conditions are described, with reliable measurements for long-term indoor use.

Resumen

Adaptación de equipos dataloger de CO2, temperatura y Humedad de bajo coste adaptado en la caja estanca para su funcionamiento optimo en cavidades con altos niveles de humedad +90%.

Hasta hace poco tener un dataloger con sensores de CO2 en cavidades con altos niveles de humedad, eran poco viables por la baja operatividad que tienen estos sensores en condiciones extremas de humedad que suelen haber en muchas cavidades. Presentamos una adaptación sobre una caja estanca y filtros hidrofóbicos para estos equipos que protegen de las exposiciones extremas a los sensores.

Los ensayos realizados durante meses en interior de una cavidad están siendo viables para las mediciones a largo plazo de los dataloger de CO2. Pruebas de más de siete meses en una cavidad en condiciones de más del 98% RH ha resultado positivas y los sensores no se han visto afectados por esta humedad extrema.

Estas adaptaciones permiten el uso de los dataloger en cavidades abriendo unas amplias opciones a las mediciones de la dinámica del clima en cavidades. Se describen los materiales utilizados y la adaptación de los equipos para su estanqueidad a condiciones extremas, con mediciones fiables para periodos de larga permanencia en interiores.

Keywords: CO2 equipment for caves, cave climate, CO2 detector for caves, tourist caves.

Introduction:

Gas measurements in caves are becoming more and more common, with some surprising variations in CO2 and other gases observed throughout the year, as demonstrated in caves in Castilla la Mancha (Atienza de la Cruz et al 2019), the Castañar cave in Extremadura (Cueva S. et al 2015), and even the high levels in the Sima del Vapor in Murcia (Perez-Lopez R. et al 2016). These studies have shown the importance of understanding cave climate dynamics for both research and safety purposes.

However, the use of CO2 monitoring equipment in caves was until recently limited to direct readings during visits or costly laboratory equipment. The difficulty of installing CO2 sensors in caves is due to the high humidity and CO2 concentrations present in the cave, which can quickly deteriorate the equipment. Additionally, the energy consumption required for long-term recording limits their autonomous duration.

Recently, due to the global COVID-19 pandemic, measuring ventilation in indoor spaces using CO2 sensors has been suggested. This has led to a relaunch of the market for these devices, with new models and sensors based on NDIR (Senseair 2022) becoming more popular and easily accessible from various manufacturers. An updated table of recommended equipment for speleologists can be found on the website www.cuevashipogenicas.es, as well as details published by (Ros A. et al 2020).

For cave monitoring, data loggers are needed to record data for long periods of time that are resistant to the humid environment of caves. This factor limits the choice of equipment, as commercially available NDIR CO2 sensors are not operational at humidity levels above 85-90% and tend to malfunction quickly.

To address this issue, we have adapted a data logger under a waterproof enclosure to protect against excess humidity. Among commercial equipment, the “Carbon Dioxide Detector” model, manufactured by Eco-Deyi, stands out (see photo 1), which allows for storing records at intervals ranging from 10 seconds to 1 hour, is easy to find in the market, and is affordably priced. To reduce ambient humidity, we have protected the equipment in IP66 waterproof enclosures with ventilation holes protected by hydrophobic filters. To eliminate humidity, a USB power source has been installed inside, which produces sufficient heat, approximately ±4~7°C, to prevent moisture from affecting the CO2 sensors and electronics (see photo 2).

The temperature and humidity sensors have been installed outside the waterproof enclosure so that the measurement of these parameters is not affected by the internal power source.

To install this equipment, it is necessary to have a permanent power supply in the cave, making it particularly suitable for caves with interior power installations.

Materials:

- ECO-DEYI Carbon Dioxide Detector datalogger
- Zemper IP66 IK10 waterproof enclosure
- Hydrophobic ventilation filters
- USB power supply
- IP68 cable glands for cable sealing
- 4-pin JST SM male and female connector cable
- Other materials: power supply cable, female plug base, USB cable.

Features of the ECO-DEYI Carbon Dioxide Detector equipment:

Portable digital CO_2 meter, gas analyzer with monitor, 9999ppm, temperature and humidity sensor.

The portable CO_2 meters manufactured by ECO-DEYI are available on the market and distributed by different suppliers such as Dioxcare (the equipment distributed by this brand only allows recordings up to 30 minutes), Amazon, Aliexpress, or the manufacturer Ecodeyi.

Technical specifications:

Portable digital CO_2 meter, gas analyzer with monitor, 9999ppm, temperature and humidity sensor.

Datalogger with intervals from 10 seconds to 1 hour (some DIOXCARE models only allow up to 30 minutes).

Capacity for 999 records in PDF. ECO-DEYI has released a version 3.1 model that allows up to 20,000 records in XLS format through specific software.

CO_2 sensor:

These devices use NDIR type CO_2 sensors and depending on the manufacturing date, they may have SENSEAIR S8 or MEMSF MTP40-F1 sensors, which are similar sensors with fast response, easy calibration, reliability, and a range of 1% or 10,000 ppm.

Operational humidity ranges;

SENSAIR S8 0-95% RH non-condensed (Photo 1C)

MEMSF MTP40-F1 0-90% RH non-condensed (Photo 1B).

Precision ±40ppm ±rgd10%

Temperature and humidity sensors:

For temperature and humidity, they incorporate an external Sensirion SHT3x temperature and humidity sensor.

Temperature precision ± 1°C range

Operational temperature range -20 ~ 60°C

Humidity precision ± 2%RH ± 0 ~ 80%RH

Operational humidity range (20% ~ 80%RH)

Long-term exposure outside normal operating ranges can result in incorrect data, especially due to condensation.

Waterproof box

In order to reduce environmental conditions and stay within the operational ranges of the CO_2 sensor, the equipment has been fitted in IP66 IK10 Zemper protective enclosures, with ventilation holes protected by hydrophobic filters that limit the passage of moisture.

For this case, we have used IP66 IK10 Zemper protective enclosures, where the measuring equipment is housed.

Hydrophobic ventilation filter

Hydrophobic filters are typically made of materials such as polytetrafluoroethylene (PTFE), polypropylene, or polyethylene, which have low surface energy and do not absorb water. These materials allow air or gas to pass through the filter while blocking the passage of liquid. The use of these filters in the waterproof box limits the passage of moisture that affects the electronics of the equipment, while allowing the passage of air and ambient gases.

USB power supply

To power the equipment, a small power supply with a USB output of 5V/2A and a working current of 100~300mA is incorporated. This power supply installed inside the waterproof box generates heat of ±47°C, sufficient for the humidity to decrease to operational limits for electronic equipment.

IP68 cable glands

The cable glands allow the power cables and the external temperature and humidity sensor to be isolated from the outside and inside of the box.

Photo 1. A CO_2, temperature, and humidity datalogger (EcoDeyi) with two CO_2 sensors models: MTP40-F1 and SENSEAIR S8.

Project development

To adapt the Carbon Dioxide Detector equipment inside the IP66 protective box, holes must be made for the cable glands of the power supply wiring and external temperature probe cables, as well as holes for air and gas ventilation with protection of hydrophobic filters.

Open the measuring equipment and unsolder the temperature and humidity probe wiring to remove it and connect it again with a cable with male and female JST SM 4-pin connectors that will allow it to be removed from the box with insulated cable glands (see photo 3 D and C, photo 4 B and C).

For the power supply cable, make a hole to pass a cable gland (see photo 3 E).

Place the cable with a female socket base and connect the USB power supply (see photo 3 B) for permanent power supply of the measuring equipment.

Make several holes for the passage of air and gases protected internally with hydrophobic filters (see photo 4 A).

Program the equipment with the required data periodicity and close it. The settings of these equipment allow up to 999 hours or close to 42 days of recording, which will have to be collected and reset the counter.

Important: the recording data stops once it reaches the limit of 999 records, preserving the initial data until the end of the period of 999 records. The data is obtained directly in pdf files, and version 3.1 models require specific software for downloading in xls format (T5LTest Communication Tools).

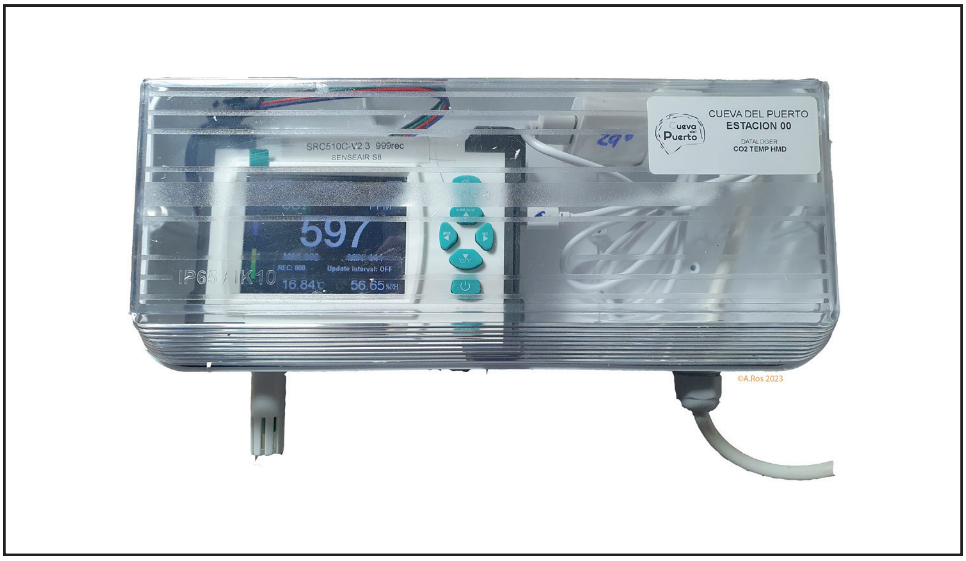


Photo 2: Carbon Dioxide Detector measuring station adapted to Zemper IP66 waterproof box.

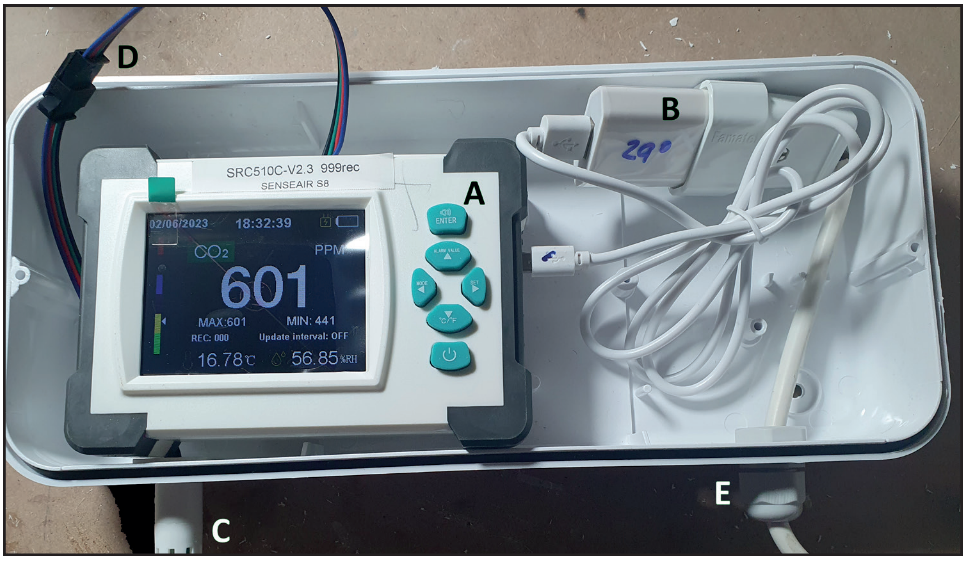


Photo 3. Detail of Carbon Dioxide Detector equipment adaptation. A EcoDeyi equipment, B USB power supply, C Temperature and humidity probe adapted on exterior of box. D Temperature and humidity probe connection. E Cable gland for electrical power supply protection.

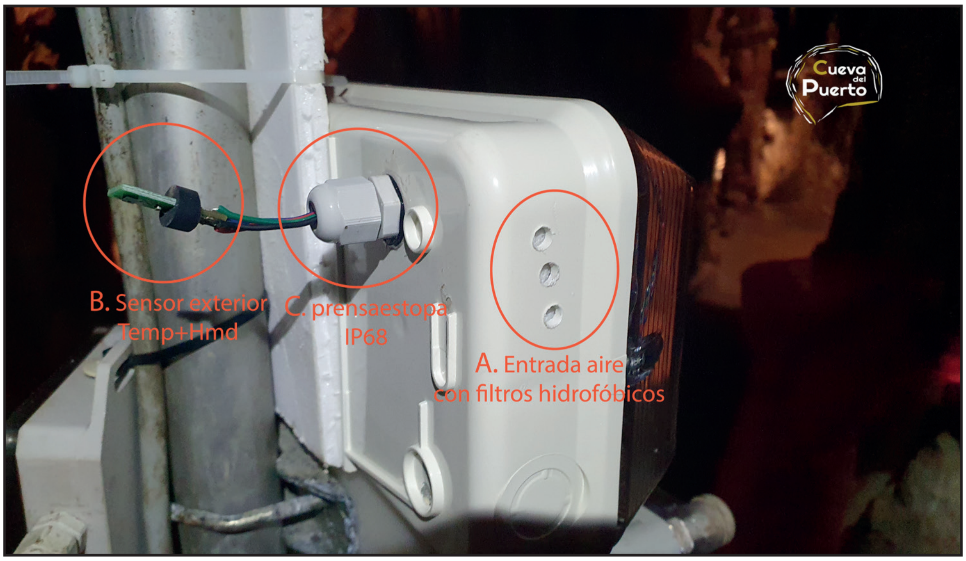


Photo 4. Detail of IP66 waterproof box and adaptations of holes A, and temperature and humidity sensor B, protected with cable gland C.

Photo 5. Carbon Dioxide Detector equipment installed inside Cueva del Puerto (seven-month operating period).

Data Report **Cueva del Puerto**

File Created Date:12/20/2022 10:43:12 Days 42. Estación **03 Sala Medusa**

Periodo : **de 30/08/2022 a 11/10/2022**

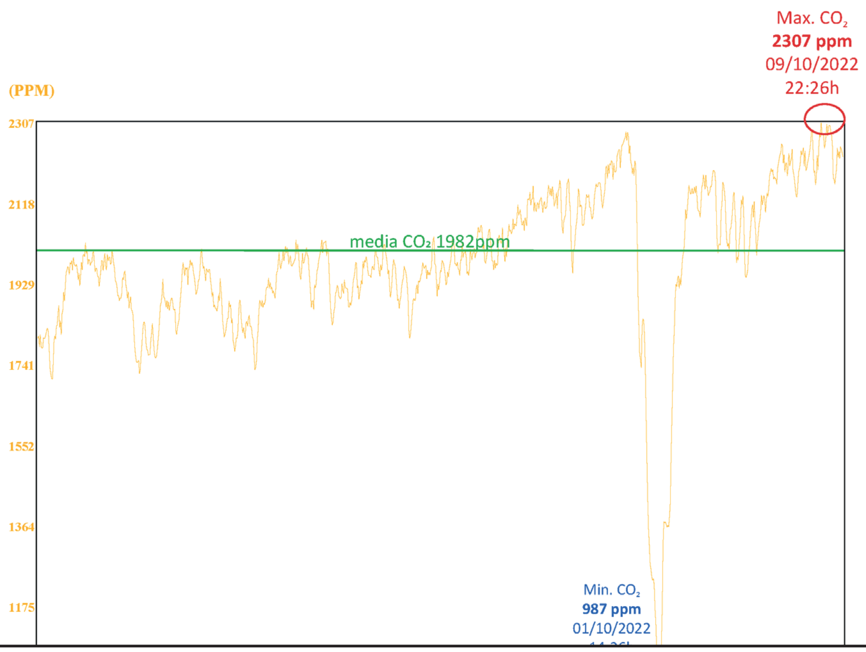
Device Information

Device	CO2 Meter	**Alarm Value**	9000PPM	**Update interval**	1 hour
Start Time	08/30/2022 11:26:46	**Stop Time**	10/11/2022 01:26:46	**Log Points**	999

Summary

Highest CO2: 2307 PPM	Highest Temp: 19.39 'C	Highest Humi: 100.00 %RH
Lowest CO2: 987 PPM	Lowest Temp: 19.12 'C	Lowest Humi: 100.00 %RH

MEDIA CO_2: 1982 PPM MEDIA Temp: 19.20°C MEDIA Humd: 100.00 %RH



Graph 1. CO2 data sheet corresponding to 42 days of records, courtesy of Cueva del Puerto, Calasparra-Spain.

Conclusions:

The use of low-cost NDIR and Sensirion sensor-based equipment for measuring CO_2, temperature, and humidity allows us to obtain results with precision for CO_2 of ±40ppm, temperature of ±1°C, and humidity of ±2%, providing important data on the cave's climate.

The operational range of CO_2 sensors in conditions of humidity greater than 90% significantly affects their operational life and the data obtained, leading to prolonged periods of blocking and malfunctioning.

The option we have implemented involves lowering the RH level inside a sealed box with openings protected by hydrophobic filters that limit the entry of moisture into the box. A small power source keeps the equipment on while also increasing the internal temperature to ±4~7°C, sufficient to reduce interior humidity to acceptable limits for sensor operability.

The temperature probe is installed outside the box to avoid being affected by the increased internal temperature. Humidity data often saturate the probe at 100% within a few hours in environments with more than 90% RH, so humidity must be measured with handheld equipment at each entry.

The tests carried out for more than seven months have surpassed those of any CO_2 equipment in these environments and are currently still functioning. Three equipment pieces have been installed inside the Cueva del Puerto (Calasparra), providing data mainly on CO_2, which has been difficult to obtain until now (photo 5).

The use of low-cost CO_2, temperature, and humidity datalogger equipment adapted to humidity-resistant boxes is an affordable option for cavities with installed energy systems (tourist caves, laboratory caves, etc.). These tools allow us to understand environmental parameter records that have been previously unknown (graph 1).

Currently, these equipment pieces can be seen in operation in the Cueva del Puerto, in Calasparra, Murcia. To visit, go to www.cuevadelpuerto.es.

Acknowledgments:

We would like to express our gratitude to Juan Olmo, Francisco del Amo, and José Angel Solanilla from Cueva del Puerto for their collaboration in the project.
We would also like to thank the team at Cueva del Puerto in Calasparra, Murcia, for allowing us to install the equipment and carry out the monitoring.
Additionally, we would like to acknowledge ECO-DEYI for providing us with information on the manufacture of their equipment at https://www.ecodeyi.com/.

Bibliography

Atienza de la Cruz C., Orozco A., Prieto S., (2019) Cavidades con aire enrarecido, revista Calar núm. 3, Edita Federación Castellano Manchega de Espeleología y Cañones, Guadalajara.

Cueva S., Fernández-Cortes A., Abella R., Álvarez-Gallego M., García E., Sánchez-Moral S., 2015 La Cueva de Castañar, Monumento Natural, Condiciones Medio Ambientales y medidas de conservación. Junta de Extremadura.

Pérez-López R., Sánchez-Moral S., Martínez-Díaz J., Cueva S., Sánchez-Malo A., Bañón E., Quiles L., Marcos A., Carballo J., Águila M. 2016 Condiciones ambientales extremas de la Sima del Vapor: temperatura, traza isotópica de CH y CO y valores de radón: Actas EspeleoMeeting Ciudad de Villacarrillo 2016.

Ros A., Llamusí, J., Fernández-Cortés A., Calaforra J.M., Gazquez F., Soto A. 2020 Equipos para la medición de la calidad del aire y el clima en cavidades para espeleólogos. Publ. Digitales www.cenm.es

Senseair 2022. Senseair S8 residential https://senseair.com/products/size-counts/s8-residential/