Case Study

Quantitative measurement of ambient oxygen & carbon dioxide levels in Tunnel Ravne, Visoko, Bosnia and Herzegovina

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Introduction

Tunnel Ravne is a network of underground passages and chambers built in ancient times by an unknown prehistoric culture. At some point in history it was deliberately blocked up with dry stone walls backed with thousands of tons of sand and gravel. Tunnel Ravne was discovered in 2005 by Dr. Sam Semir Osmanagich Ph.D., Principal Investigator. It is being explored as part of the Bosnian Pyramid Project, by the non-profit organisation, ‘Archaeological Park: Bosnian Pyramid of the Sun Foundation’.

The staff and volunteers of the Foundation are selectively reopening the tunnels and side-passages and conserving sections of the original labyrinth. It is hoped that these will eventually connect with passages beneath other prehistoric structures in the valley. The Foundation has worked in Ravne for several years and the Tunnel is visited each year by thousands of tourists, volunteers, researchers and media. A number of other sites in the area are currently under investigation—including the Pyramid of the Sun.

Context

The conditions in Tunnel Ravne are generally considered favourable. Anecdotal reports suggest that the environment may have a therapeutic effect on the human body. One of the underground locations has been designated as a ‘meditation/healing chamber’.

This is not without precedent: the curative qualities of some underground spaces are valued by practitioners of ‘speleotherapy’, an alternative treatment in which the subterranean atmosphere is used to treat respiratory illnesses including asthma.

Speleotherapists believe that the high humidity and stable temperatures found in some caves and other areas below the earth reduce dust, pollen and air pollution. This results in a non-allergenic atmosphere that eliminates irritants which cause allergic reactions.

Another factor may be the carbon dioxide (CO₂). Normal air contains about 0.04% CO₂ but below ground this may be higher. A slightly raised CO₂ level is sometimes used in a medical setting to improve breathing (a treatment called therapeutic hypercapnia).
Objectives

Subterranean environments such as tunnels, mines and caves exhibit a wide range of atmospheric conditions. Air quality is unpredictable and may be influenced by geology, layout, microclimate and ventilation; this is difficult to analyse without special devices. Qualitative reports and favourable anecdotes may indicate acceptable conditions but subjective appraisals are less convincing than scientific proof. It is therefore prudent where possible to gather supporting evidence via experiment and statistical analysis.

Normal air contains a delicate balance of atmospheric gases which are completely safe in their usual concentrations. However, any deviation from normal values and ratio (or alternatively the existence of another gas) could have implications for safe breathing.

As a personal visitor to Visoko, Bosnia, during the Spring Equinox Tour and Conference 2015, I decided to take an atmosphere analyser (with permission from my employer, Analox\(^1\)) to conduct an informal study of the air quality in the Tunnel Ravne labyrinth.

Methodology

The Foundation regularly surveys the environmental conditions within Tunnel Ravne. A number of parameters are measured and recorded including the ambient temperature, relative humidity, atmospheric pressure, negative ion count and electromagnetic fields.

To give an example, in February 2015 the temperature was stable at 11.5°C–12.0°C; humidity was 83–87% (this is high, but it helps maintain tunnel stability and generate negative ions); negative ions—in some areas—exceeded 40,000 per cubic centimetre.

Other parameters, if measured, can also give useful data. For instance, concentrations of the atmospheric gases oxygen (O\(_2\)) and carbon dioxide (CO\(_2\)) are good indicators of air quality\(^2\), and these are easy to analyse with a portable gas-detection device.

Using an Analox Aspida portable device I was able to measure the levels of O\(_2\) and CO\(_2\) in the tourist sections of Tunnel Ravne. The Aspida was set to take automatic gas readings once per minute and the data were logged over a continuous 2½-hour period.

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\(^1\) For further details, see ‘Air monitoring in the Bosnian Valley of the Pyramids - Part 1’

\(^2\) Ambient levels of CO\(_2\) and O\(_2\) are regularly monitored in Tunnel Ravne
Results

On 17 March 2015, between 09:58 and 12:35 hours, I entered Tunnel Ravne during the Spring Equinox Tour. There were approximately 20 of us in the tourist group. I set the Aspida to sample CO2 and O2 once per minute for the duration of the visit (2½ hours).

We walked from the Tunnel entrance to the farthest point of the open sections and then back again—in total a few hundred metres—stopping at various points along the way. The Aspida was held away from the body to limit exposure to human-generated CO2.

At no point in the labyrinth did the Aspida's built-in alarms announce either a significant reduction in O2 or a significant increase in CO2. (The O2 alarm switches on if the O2 level decreases to 19.5%; the CO2 alarm switches on if the CO2 level increases to 0.5%.)

The measurements taken by the device were displayed on the screen in real-time and automatically saved as a data-log for off-site analysis. After my visit I downloaded the data to a computer; it was then imported into a spreadsheet and displayed graphically:

![Graph of levels of oxygen (O2) and carbon dioxide (CO2) measured in Ravne Tunnel labyrinth on 17/03/2015 (09:58 to 12:35 hours)](image)

Conclusion

The graph above illustrates the O2 and CO2 concentrations in different areas. Readings taken during the first/last 5 minutes demonstrate a decrease/increase in O2/CO2 which corresponds to entry/exit. There are unexplained O2 spikes at 10:21, 11:01 and 11:42. O2 and CO2 levels measured during the 2½-hour visit were all within safe limits. Normal fresh air contains 20.9% O2 and 0.03% CO2; Aspida's alarm thresholds are 19.5% and 0.5% respectively. (At this threshold the alarms are for early warning, not evacuation.)

Despite its having only one entrance and no artificial ventilation the labyrinth displays a stable, consistent atmosphere. It is believed that the construction technique used—i.e. variable ceiling heights— influences the atmospheric pressure and creates air circulation.

Further investigation of Tunnel Ravne’s subterranean atmosphere may offer insight into its air circulation and perhaps explain the O2 increases that occurred 40 minutes apart. In the meantime, regular air monitoring will help maintain safety for staff and visitors.