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INDOOR AIR QUALITY: THE SAMPLES OF ILGARINI AND MANTAR CAVES[1]

MAĞARALARDA İÇ ORTAM HAVA KALİTESİ: ILGARİNİ VE MANTAR MAĞARALARI ÖRNEĞİ

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ABSTRACT

Caves provide natural attractions for tourism and other socio-economic activities as tourists are most of the time motivated to visit natural attractions to appreciate the wonders of nature. However, visiting caves may cause some important health problems such as inhalation of some harmful gases and increased levels of carbon (IV) oxide (CO2) which may exceed the critical level during such visits. In literature there is big gap about caves air conditions which were located in Turkey. In this paper, Ilgarini and Mantar caves were selected because of potentially high touristic activities. The aim was to measure the caves' temperature, relative humidity and the amount of CO2 that would influence the air quality. To achieve the stated objectives, the Ilgarini and Mantar caves were visited during August 2012. The measurements were made by means of a portable air measurement apparatus in various corners of the caves 20 metres apart. The results have revealed that the indoor temperatures, relative humidity and the amount of CO2 changed considerably in comparison with the values obtained outside the caves. These results may seem to infer that when touristic activities take place especially during visits, the indoor air quality may change giving rise to some health problems such as headache, dizziness, throat and nose irritation, sneezing, coughing, tears, due to the effect of the increasing amount of CO2.

Keywords; Caving, Air quality, Ilgarini and Mantar Caves.

ÖZ

Bu çalışmanın amacı rekreasyon ve turistik etkinlikler açısından büyük önem taşıyan Ilgarini ve Mantar Mağaraları'nın iç ortam hava kalitesini sıcaklık, nem ve CO2 değerleri açısından ölçmektir. Bu amaçla anılan mağaralara 2012 yılının Eylül ayında bir ziyaret gerçekleştirilmiştir. Ziyaret sürecinde Portatif Hava Kalitesi Ölçüm Cihazı yardımı ile mağaraların farklı bölümlerinde ölçümler gerçekleştirilmiştir. Her 20 metrede gerçekleştirilen ölçüm sonuçları mağaraların iç ortamlarının dışarıya göre sıcaklık, nem ve CO2, bakımından büyük farklılıklar gösterdiğini ortaya koymuştur. Bu sonuç, anılan mağaralara özellikle grup halinde yapılacak ziyaretlerde bazı sağlık sorunlarının yaşanma olasılığının var olduğu biçiminde yorumlanabilir. Nitekim mağaralara gruplar halinde yapılan ziyaretler, mağara içerisindeki iç ortam hava kalitesinin düşmesine, buna bağlı olarak baş ağrısı, baş dönmesi, boğaz ve burun tahrişi, burun akıntısı, öksürük ve göz akıntıları gibi rahatsızlıklara sebep olabilmektedir. Bu durum özellikle astım vb. hastalığı bulunan ziyaretçiler için önemli büyük bir önem taşımaktadır.

Anahtar sözcükler: Mağaracılık, İç Ortam Hava Kalitesi, Ilgarini, Mantar Mağaraları

[1] This study has been presented as an oral presentation during the I. Eurasia International Tourism Congress: Current Issues, Trends, and Indicators (EITOC-2015) which is held between 28-30 May, 2015. The manuscript has been reviwed and tanslated into English.

1. INTRODUCTION

It is know that in caves the air is often unventilated and unhealthy because of the low oxygen level, in some terms content of saturated with toxic gases (i.e. SO_2 ammonia) and some temporary sources trace gas like radon. Poor indoor air quality causes headache, dizziness, fatigue, loss of concentration, and odor disorders when it is over 1000 ppm whereas it causes irritation in the throat and nose, sneezing, cough, and eye watering when it is over 1500 ppm (Ercan, 2012). This is the reason patients who are suffer from asthma should not be in this kind of places.

On the other hand caves have an important place in humanity's socio-cultural development (Yazgan & Kadanalı, 2012). Recently, they have gained importance in terms of recreation and tourism activities and speleotherapy as well (James, 2006; Yeşil, Yeşil & Yılmaz, 2008; Arpacı, Zengin and Batman, 2012).Indoor air quality changes is not always cause negative impact. If all the precaution and definition complete with ongoing monitoring it would be safe for all visitors.

Caves can be defined as natural underground spaces among rocks extended to a size that allows people to go in. The formation of caves takes thousands of years, and they have become an important element of tourism in Turkey with their unique visual richness (İşçen, 1992 qtd. in Ulusan & Batman, 2010).

It is known that there are 40.000 caves in Turkey. Kastamonu is one of the gifted city in Turkey by mother nature in terms cave. Cide and Pınarbaşı within the provincial borders of Kastamonu. Some of these caves are both nationally and internationally important (Kalem, 2001). According to speleologists, the triangle formed by Pınarbaşı, Azdavay, and Cide is one of the most important regions in Turkey in terms of caves (The Scientific and Technological Research Council of Turkey [Türkiye Bilimsel Araştırmalar Kurumu - TÜBİTAK], 2009). There are Mantar and Ilgarini caves in this region within the borders of Küre Mountains National Park (KMNP). They have a high potential not only in terms of recreation and tourism but also in terms of bio-speleology (Anatolian Speleological Society, 2008).

During visits to the caves, visitors are not checked by any means. Moreover, in many caves, precautions are taken only to preserve natural structure. There are also certain neglects that may threaten human health in the caves which are open to visit. One such neglect is the poisonous gases that may exist in the indoor air of caves. No notice is given to visitors about their potential harms to human health. In addition, CO_2 amount in the indoor cave air may increase to a great extent during crowded group visits, which may harm the human health. For instance, Osborne (2001) claims that the sudden death of Australia's first geologist Thomson Wellington at the age of 30 while working in caves stemmed from high amount of carbon dioxide existing in the indoor cave air (Osborne, 2001, p. 10).

Despite all these adversities, there is scarcely any scientific study dwelling on the threats and possible results that people may experience during cave visits. Furthermore, there is no national study (conducted for Turkey) focusing on gases (poisonous) that pose potential threats for human health and critical CO_2 rates that increase due to breathing during the visits of people who are not expert in speleology. In this sense, this study seeks to analyze the indoor air quality in Ilgarini and Mantar caves which have a high potential to attract a lot of visitors. The study analysis focuses on the change of indoor air quality depending on the exterior environment in terms of CO_2, temperature, and relative humidity. Also, an attempt is made to provide comparison criteria for possible concerns as to whether potential visitors will experience any health issues.

2. LITERATURE REVIEW

National (Turkish) literature indicates that the attention towards caves is basically concentrated on the attraction power of special interest tourism (Sever, 2008; Yeşil, Yeşil & Yılmaz, 2008; Albükrek, Aytan, Taylan, Usuloğlu & Sıvacıoğlu, 2012; Arpacı, Zengin & Batman, 2012; Aydoğdu, 2012; Öcal & Özcan, 2013; Özşahin & Kaymaz, 2014). However, there is no study specifying the appropriate level of the indoor air quality, which gases pose a threat to human health, and particularly the threshold values for CO_2 amounts during the visits of crowded groups to the caves.

Besides this, there are many studies in the international literature regarding the indoor air quality of caves (Osborne, 2001; Smith & Telling, 2004; Sanna, Arca, Ventura, Zara, & Duce 2007; Linan, Vadillo & Carrasco, 2008; Badino, 2009; Whitaker, Jones, 1999; Baldini & Baker, 2009; Freitas, 2010; James, 2010; Kim, Kong, Choi, Lim, Yu, Cho and Yeon, 2012). In addition, there are a lot of studies regarding air quality in city centers, parks, forests, closed areas, and so on (Sevik et al., 2015; Cetin et al.,, 2015).

These studies mainly focus on the amount of carbon dioxide in the air as well as relative humidity and temperature. For instance, James (2010) conducted a study regarding Undara Lava Tubes and Bayliss caves located in McBride volcanic area of Queensland state of Australia. He states that temperature (^{0}C), relative humidity, carbon dioxide (CO_2), and radon, which make a total of four components, are important determiners for indoor air quality (James, 2010, p. 77). The researcher states that the gases in the air of Bayliss caves are limited to CO_2, oxygen (O_2), and radon (James, 2010, p. 77).

Osborne (2001) conducted a set of studies starting from 1977 to early 2000s regarding the indoor air quality of caves in Australia and also measured carbon dioxide condensation in the air (Osborne, 2001). Osborne also informs that carbon dioxide condensation measurements in Wellington caves were initiated by Fraser in 1958. There was 13.5% of carbon dioxide and 20% of oxygen in the CO_2 measured by Fraser (Osborne, 2001).

Sanna et al. (2007) states with reference to Badino that temperature, relative humidity, carbon dioxide, and air circulation are determiners for the control of micro environment within caves (Badino 1995 qtd in. Sanna et al., 2007, pp. 511-512).

Kim et al. (2012) conducted a study titled "*A study on the changes of air quality the Baekryong cave in Pyeonchang*" and stated that the most important components determining indoor air quality within caves for people and microbiological sustainability are temperature, relative humidity, and carbon dioxide.

It is possible to say that analyzed studies particularly focus on the levels of temperature, relative humidity, and carbon dioxide inside the caves for determining the indoor air quality of the caves that are open to visit. On the other hand, it is acknowledged that temperature and relative humidity rates do not have an impact on human health as much as carbon dioxide. It is possible to say that indoor air quality of caves is determined by the amount of carbon dioxide in the air (Osborne 2001; Fernandez-Cortez, Calaforra and Sanchez-Martos, 2006; James, 2010).

The decrease in temperature leads to decrease in the number of red blood cells in the blood. This causes hemorrhage in the eye retina and slowing of blood supply in the entire body. It even causes embolisms (infarcts) and death if it is not intervened at advanced stages (Çalışkan & Sarış, 2008).

Berberoğlu and Motör (2005) state that there are standards specifying the maximum limits permitted for polluters related to indoor air quality in many countries around the world (See Table 1) (Berberoğlu and Motör, 2011). Various resources assert that indoor air quality, which is highly important for human health, should have a temperature of 19–23°C, a relative humidity rate of 40–60%, and a CO_2 amount of 1000 ppm for it to be deemed good (Arishidani et al. 1996; WHO, 2000; Berberoğlu & Motör, 2011).

Table 1: The Limit Rates Recommended in the Standards Concerning IAQ (Indoor Air Quality) in Various Countries

Countries	CO_2 (ppm)	Relative humidity (%)	Temperature (°C)
USA	1000	30-60	20-25
Germany	5000	30-70	20-26
Hong-Kong	800-1000	40-70	20-25.50

CO_2 is among the primary gases to have a rapid change in its composition due to human metabolic activities in closed areas. The air breathed in from the normal atmosphere includes O_2 at a rate of 21% and CO_2 at a rate of 0.033% whereas it has O_2 at a rate of 16-17% and CO_2 at a rate of 4% (40000 ppm) while it is being breathed out from the lungs. This change is particularly influential on environments where there are collective activities (Bulgurcu et al., 2003). This leads to constant increase in CO_2 amount in closed areas (Yıldız & Altınöz, 2011). Due to the increase in the amount of CO_2 in the environment, people experience fatigue, imperceptions, and sleepiness (Coşkun et al., 2005).

The influence of relative humidity on human health is associated with temperature. If relative humidity is very high (e.g. over 70%) the metabolism cannot intake adequate moisture to cool down over the skin. Thus, one feels irritated due to gradually increasing heat in the human body. The highness of relative humidity increases the risk of heart attack when the temperature is 26 °C (Çalışkan and Sarış, 2008). However, it is very unlikely that such health problems occur inside the caves as sudden temperature decreases were detected inside the caves. As a matter of fact, this is a problem stemming from the increase in both temperature and humidity.

In the previous studies, temperature rates within the caves were measured and given as statistical data. Relative humidity was generally found to be 100 or close to 100. CO_2 rates change depending on factors such as measurement point, the distance to cave entrance, in-cave air circulation, height, and width (Fernandes-Cortes et al., 2006; Sanna et al., 2007; James, 2010; Kim et al., 2012).

3. METHOD

The research material consists of Ilgarini and Mantar caves. These caves were selected because both of them are within the borders of KMNP, which is an important visiting option these caves that close to each other for cave lovers on nature, climbing.

The study is a cross-sectional study which aims at measuring the indoor air quality of Ilgarini and Mantar caves in terms of CO_2, temperature (°C) and relative humidity. Measurements were performed via Portable Air Quality Measurement Device during the study. Initially, the rates in the exterior environment were measured. Afterwards, the measurements were repeated once in 20 meters starting from the cave entries. At the end of the measurements, temperature levels were obtained as °C; CO_2 levels were obtained as ppm; and relative humidity levels were obtained as %. Evaluations were made based on the measurement results. Previous research indicates that in general, CO_2, temperature and relative humidity rates are taken into consideration in indoor air quality measurements (Osborne, 2001; Coşkun, Mutlu & Yüce, 2005; Linan et al., 2008; James, 2010). In the light of this information, the elements and gases that should exist in the air were excluded from the study, which constitutes the limitation of the study.

The Ilgarini cave is the most important cave within KMNP. It is located in the Yamanlar village on the extension of the Sorkun plateau. The distance of the cave to Pınarbaşı district centre is 36 km. It is accessible via car until Sümenler village Kazla neighbourhood Top square. It is possible to reach the cave on foot within 2 hours from the Sorkun plateau (778 m) through the path in steep, rocky and virgin forests. It is also accessible from Derebucağı village either on foot or via a mule car. However, it is strictly recommended to take a guide (İmat, İbret & Altınözü, 2012). The altitude of the cave is 1250 m. There are 1-million-year-old stalactites and stalagmites in 10-million-year-old cave formation. Moreover, there are remains of storied tombs and chapels from Roman and Byzantium periods within the cave (Kalem, 2001). Ilgarini is the 4th deepest cave in Turkey with a depth of 850 m inside. In addition, it is one of the best examples of cave travertines in Turkey (Ayaz, 2002).

Map 1: The locations of Ilgarini and Mantar caves

Ilgarini cave is comprised of two sections, which are horizontal fossil section and vertical active section. There are remains of houses and cisterns in the entry section which are assumed to belong to the Roman – Byzantium period. Moreover, there is a man-made road at the head of vertical section consisting of 24 spirals which are made of cobbled stones. Later on this road, there is a well with a depth of 52 meters and a diameter of 30 meters. Afterwards, one reaches a siphon similar to a lake whose bottom is covered by white travertines. Fossil branch is covered with travertines and very beautiful chandelier-shaped cave formations (TÜBİTAK, 2009).

Figure 1: A scene from the Ilgarini cave

The Mantar cave is on the path leading to Ilgarini. Though it is not as well-known as the Ilgarini cave, it is an important cave for recreation and tourism due to both its location and cave formations it has inside.

Entrance to the Mantar cave is through a sinkhole under a dense plant cover. The cave has two big halls that were formed in the north and south. There are big stalagmites in the hall facing the south. It was named after the mushroom-shaped stalagmites in the southern hall. The Mantar cave presents a visual feast to its visitors with its travertines.

4. FINDINGS AND DISCUSSION

Caves are formations of karstic melting that are formed in a very long time. They contain various forms of karstic accumulation shapes (Öcal & Özcan, 2013). Caves have undertaken many important functions throughout the history of humanity and survived through several ages. Especially in the early ages, caves undertook an important role for providing shelter to people. However, their functions dramatically changed depending on socio-economic developments.

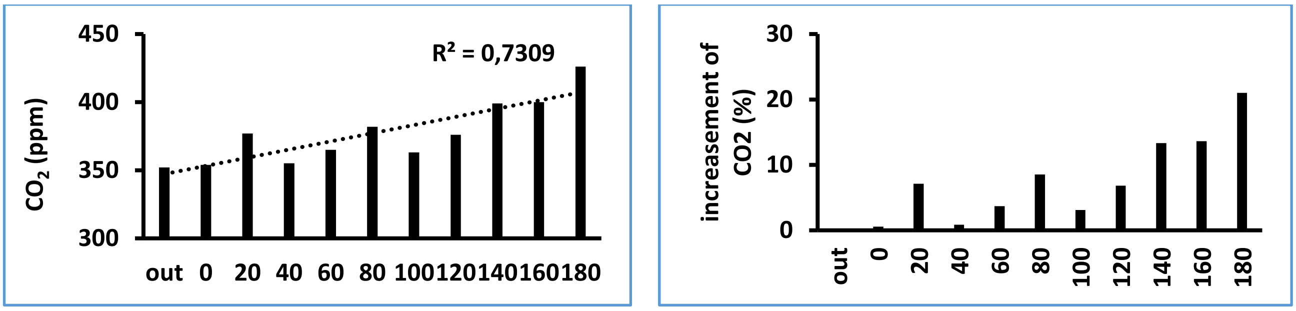
Table 2. The Ilgarini Cave and Indoor Air Rates in the Horizontal Gallery

Rates/Environment	**Exterior Environment**	**Entrance**	**20 m**	**40 m**	**60 m**	**80 m**
Temperature (°C)	18.6	17.1	14.4	12.3	11.8	11.9
CO_2 (ppm)	352	354	377	355	365	382
Humidity (%)	88.4	96.7	96.8	100	100	100
Rates/Environment	Exterior environment	100 m	120 m	140 m	160 m	180 m
Temperature (°C)	18.6	11.2	11.3	11.4	11.6	11.9
CO_2 (ppm)	352	363	376	399	400	426
Humidity (%)	88.4	100	100	100	100	100

Nowadays, caves have become important areas of interest not only for speleologists but also for touristic activities. In Turkey, many caves are visited by thousands of tourists and nature lovers. Though it does not date back to long ago, the number of caves who are open to mass tourism is approximately ten (Altınok, 2008). The Ministry of Culture and Tourism (MCT) states that there are nearly 40,000 caves in our country 30 of which are open to tourism. (MCT, 2015).

Observation of Ilgarini cave listed in Table 2 is summarized as below in Figure 2a, Figure 2b and Figure 3 versus CO_2 level change, temperature and humidity respectively. According to Figure 1b CO_2 level

Maximum % 21 percentage is increased through the horizontal far distance. This increase is directly proportional with respect to 0.73 R^2 value as shown in Figure1a. On the contrary temperature is not changed after 60 m as seen in Figure 2



Horizontal Distance from entrance (m)
(a)

Horizontal Distance from entrance (m)
(b)

Figures 2. CO_2 Levels at Different Locations of the Ilgarini Cave

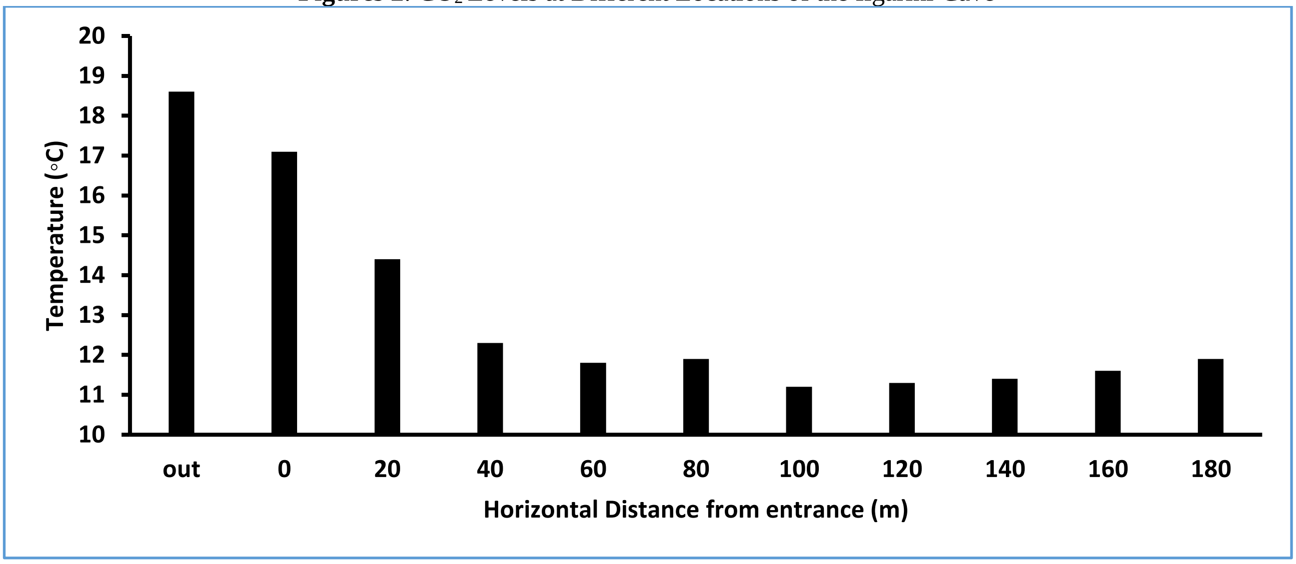


Figure 4 Temperature Levels at Different Locations of the Ilgarini Cave

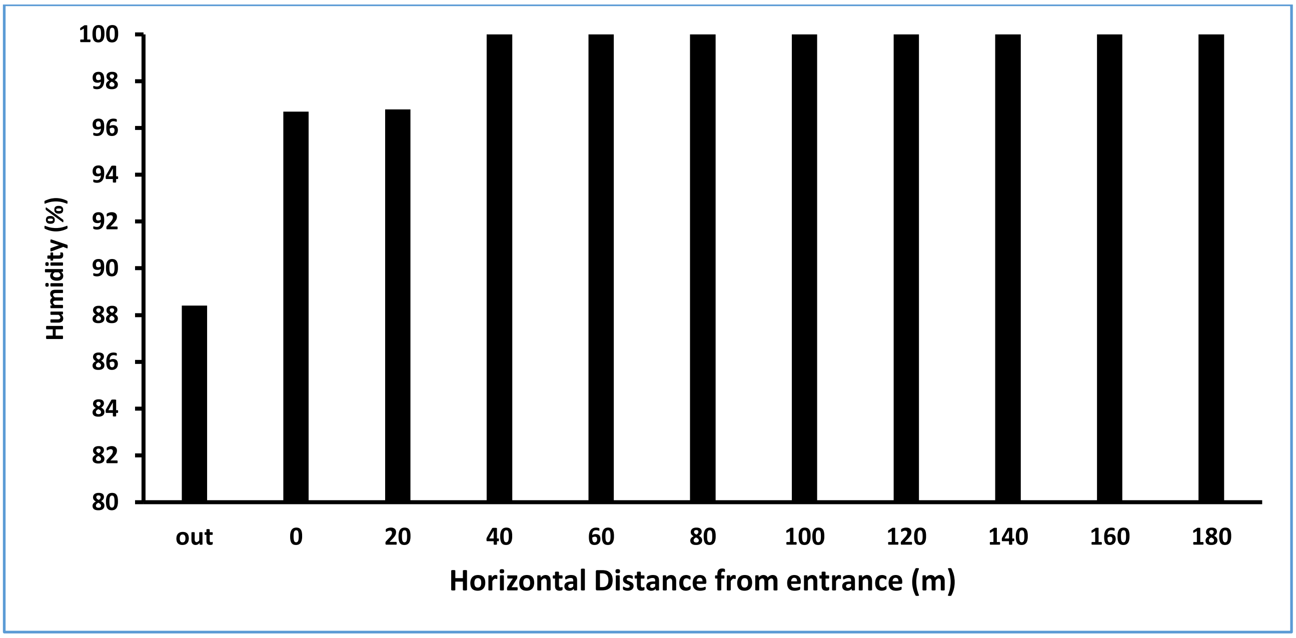


Figure 5 Humidity Levels at Different Locations of the Ilgarini Cave

It is know that in case of caves microcliment conditions are described with consistent temperature and humidity (Yeşil, Yeşil & Yılmaz, 2008). In Ilgari cave humidity and temperature values are not changed as much as CO_2 level inside the cave.

As emphasized above, the region surrounding Küre Mountains is highly rich in caves. In addition, caves within KMNP have the potential to be visited by nature lovers. The above mentioned caves are not among those which are open to visit. Therefore, they were determined as research subjects to provide a source for potential amateur speleologists to obtain information regarding indoor air quality.

4.1. Measurements in the Ilgarini Cave

The Ilgarini cave starts with a wide gallery as a structure. It is comprised of two big branches, one of which is horizontal and the other is going deep downwards. Table 1 shows temperature, CO_2, and humidity rates in the horizontal gallery which were obtained through the measurements that were repeated once in 20 meters following the exterior environment and entrance.

Table 1 shows that temperature was 18.6 °C in the exterior environment while it dropped a bit inside the cave. However, it changed between 17.1 °C and 11.8 °C. The amount of CO_2 did not change considerably. The rate of 352 ppm that was detected outside reached 426 ppm at most inside. These rates indicate that air circulation occurs inside the cave. There is an open way to the sky nearly 100 meters after the cave's entrance with a wide gallery. This can be the basic reason for air circulation inside the cave.

The most remarkable rates inside the cave belong to humidity. Starting from 40 meters, the humidity was measured 100% inside the cave. The observations made inside the cave easily show water particles hanging in the air under the light.

The main big branch of the Ilgarini cave goes deep downwards. For visitors without professional equipment, it is not possible to go further from the section where there are remains that are reached after more than 20 turns and stepping down more than 180 stairs. The measurements made in this section reveal a temperature of 5.8 °C, 630 ppm of CO_2, and a humidity rate of 100%. These rates, again, indicate that there is air circulation in this section of the cave. What is remarkable in this section is the sudden decrease in temperature.

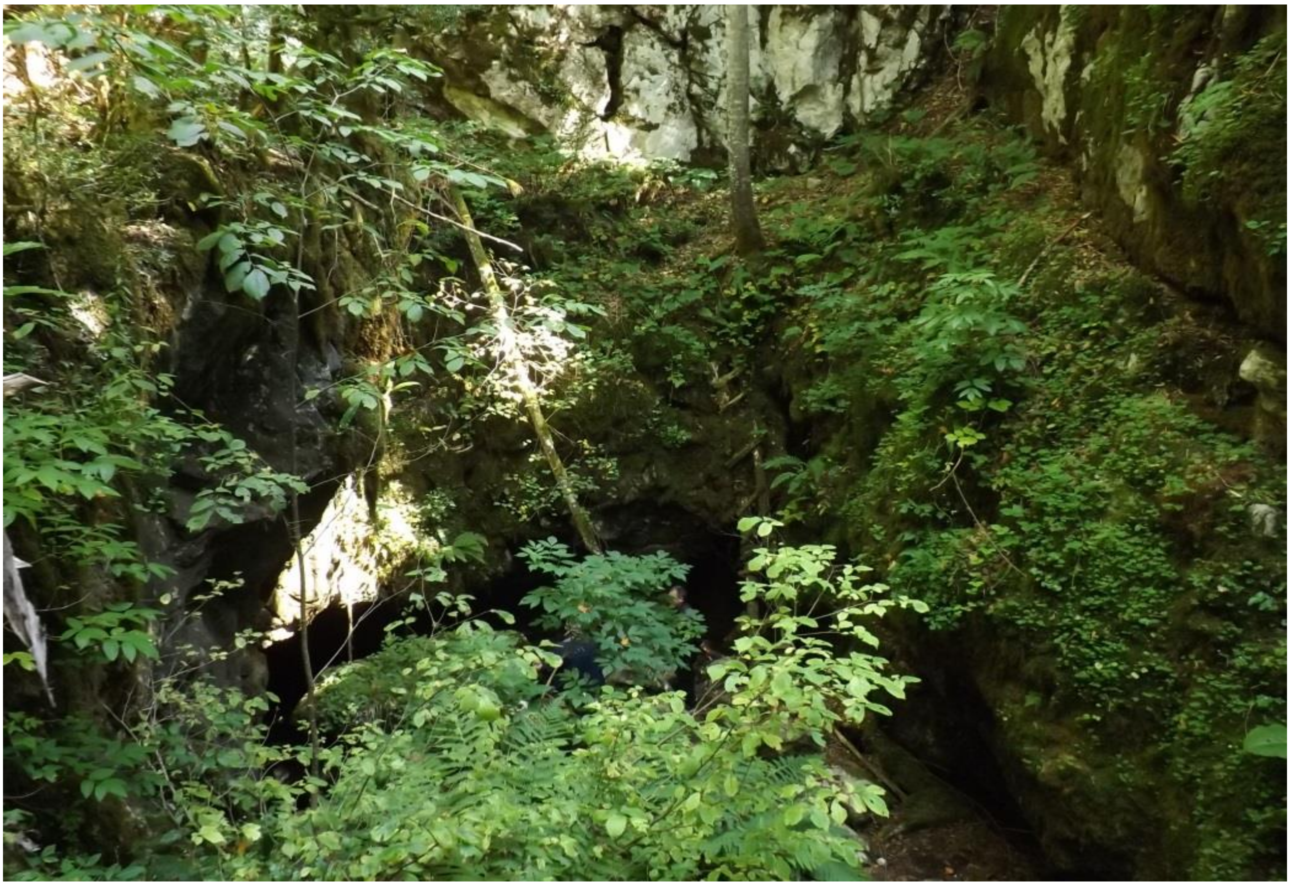


Figure 6 Entrance to the Mantar Cave

4.2. Measurements in the Mantar Cave

Entrance to the Mantar Cave is through a sinkhole under a dense plant cover. Since the presence of sinkhole limits air circulation, measurements were carried out in this section as well. Table 2 shows temperature, CO2, and humidity rates measured once in 20 meters starting from the exterior environment, sinkhole, and entrance.

Figure 7 A scene from the interior of the Mantar cave

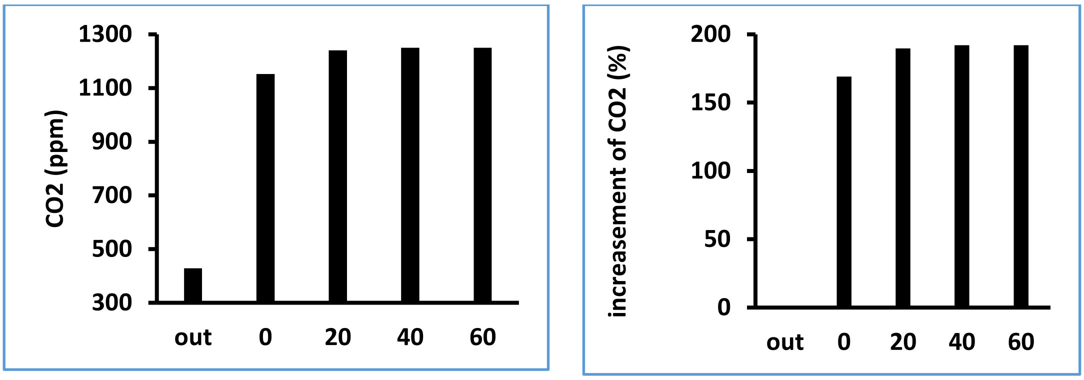
While the temperature was 23.6 °C in the exterior environment, it dropped to 17.5 °C in the sinkhole and 7.4 °C in the entrance. The temperature gradually increases as one goes further inside the cave. It reaches up to 8.5°C at the bottom. As it is possible to see from Table 2. The study revealed that in the Mantar cave, where air circulation is limited, the amount of CO_2 was 428 ppm outside the cave while it exceeded 1240 ppm inside the cave. CO_2 causes various complaints leading to performance loss, and the reason is not easily detected.

Table 2. The Indoor Air Rates of the Mantar Cave

Rates/Environment	Exterior Environment	Sinkhole	Entrance	20 m	40 m	60 m
Temperature (°C)	23.6	17.5	7.4	7.5	7.8	8.5
CO_2 (ppm)	428	1103	1152	1240	1250	1250
Humidity (%)	58.9	62.7	77.9	90.4	93.5	94.5

Humidity rate was 58.9% outside the cave while it increased up to 62.7% in the sinkhole and 77.9% in the cave's entrance with a gradual increase further through the cave reaching a final rate of 94.5%.

The rates obtained from the Mantar cave indicate that all the rates significantly differed from the ones obtained from the exterior environment. The temperature decreased to one-third of the exterior environment; the rate of humidity increased more than 50% and CO_2 level increased nearly 3 times more than the exterior environment nearly %200 shift as seen in Figure 8 a and b. These rates indicate a limited air circulation inside the cave.



Horizontal Distance from entrance (m)
(a)

Horizontal Distance from entrance (m)
(b)

Figure 8 CO2 Levels at Different Locations of the Mantar Cave

Considering the rates obtained in the study as whole, it is noteworthy that there are sudden temperature decreases and humidity increases in Mantar cave.

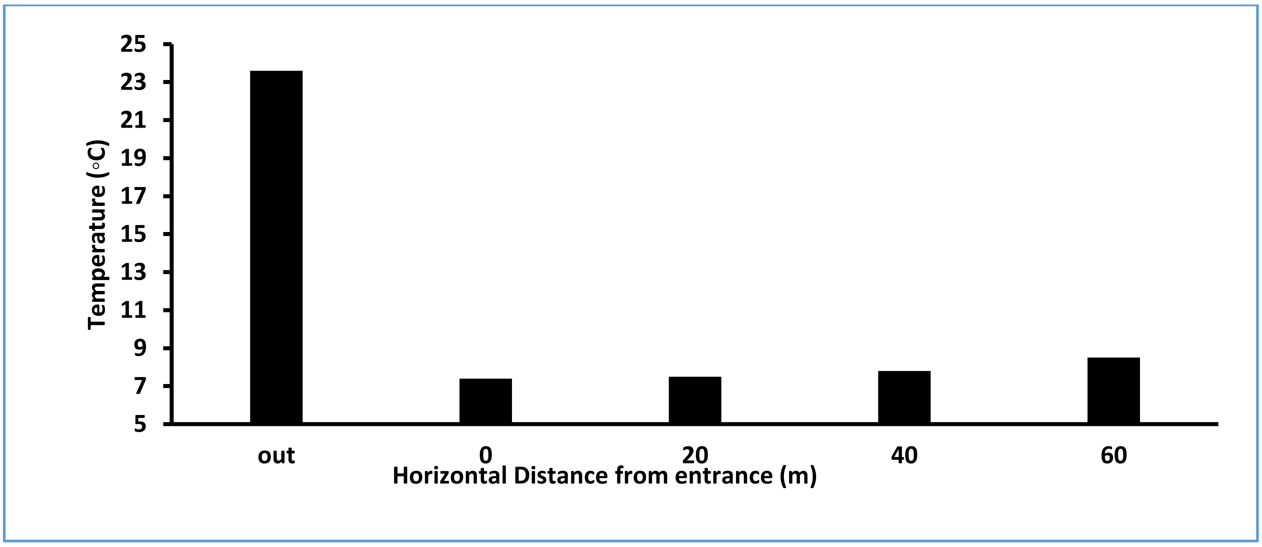


Figure 9 Temperatures at Different Locations of the Mantar Cave

It is certain that sudden changes will have various influences on human metabolism. However, such influence on human health will change from person to person.

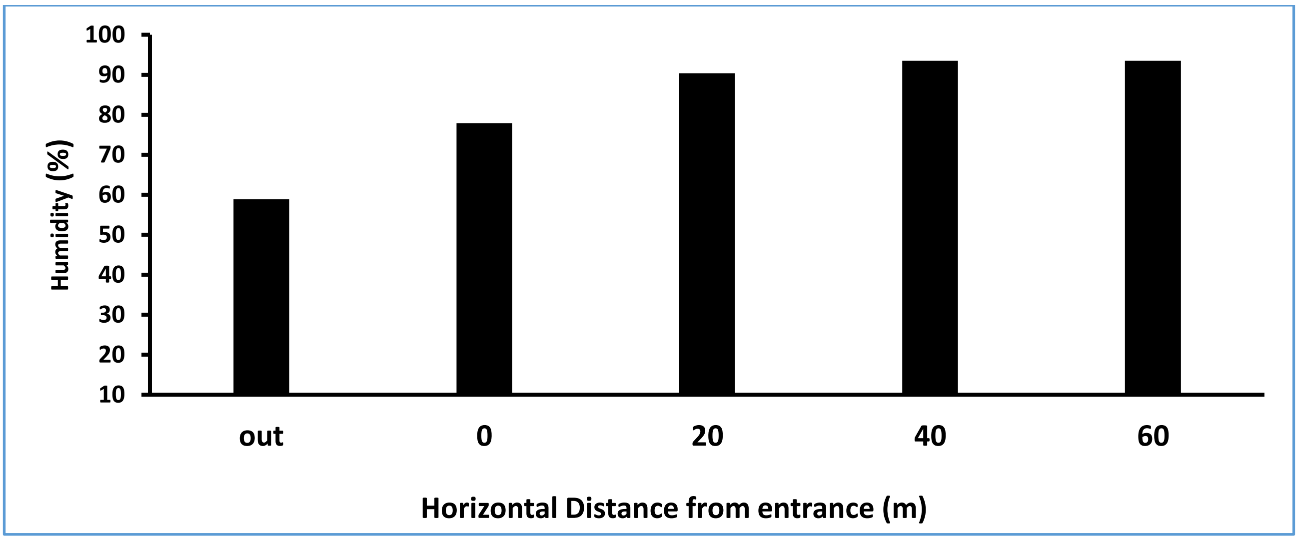


Figure 10: Humidity Level of Mantar Cave

5. CONCLUSION AND RECOMMENDATIONS

Ilgarini and Mantar caves were extensively studied in this research work. The most remarkable rate measurements were obtained for temperature and humidity. Not only in Mantar cave but also in Ilgarini cave decrease was observed in temperature while an increase was seen in humidity in both caves as expected. Therefore, comparison of the caves should be performed by individually. Though the influence of these two parameters on human health changes from body to body, it will not be more than loss of comfort for people who have no other disorder. However, it will be useful to warn elderly visitors and people with various disorders especially those with rheumatism who suffer from high levels of humidity and low levels of temperature.

Observations during the study indicate that reckless visitors especially during hot seasons enter the caves with wet clothes and experience upper respiratory tract disorders. The amount of CO_2 inside the Mantar cave is almost three times as much as outside the cave, reaching 1250 ppm which is the over than the suggested CO_2 levels of standards concerning.

This study revealed that indoor air quality in caves is rather changeable. Similar studies can be conducted in caves with long galleries and the measurements can be diversified. In addition, the gases which are important for human health can be included in the studies. Moreover, the results can be compiled and included in cave advertisement brochures or put into warning plates in the cave entrances. These practices will prevent health problems that may occur inside the caves to a great extent. As a conclusion carbon (C) isotopic fractionation must also be taken under record. Additionaly these measurements must be kept least five years and certain Turkish Standart sould be defined as soon as possible.

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