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ORIGINAL ARTICLE

DAILY AND MONTHLY FLUCTUATION OF CARBON DIOXIDE IN ALI-SADR CAVE OF HAMEDAN AND TOURISTS' HEALTH

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ABSTRACT: Great number of visitors of caves causes changes in regional elements in the caves. Ali-Sadr Cave which is located in Hamedan (Iran), as the most visited touristic water cave, attracts hundreds of visitors every year. Hence, in this paper, the change in density of Carbon Dioxide in this cave has been measured. This experiment has been done in 30 days and by taking in three times each day. To this end, by considering the dimensions, inside the cave was divided to three parts: Small, medium and large halls. The data has been measured by the utilizing of AZ (77535) model. The results show that the most daily and monthly changes occur in large halls and the least of changes are related to small ones. Furthermore, the percentage of Carbon Dioxide and the quality of the weather in the cave do not cause any trouble for visitors, but with the increase in number of the visitors, vast studies must be done.

***Keywords**:* Carbon Dioxide, visitors' health, Ali-Sadr Cave, healthy air, small halls, large halls

INTRODUCTION

Daily and Monthly Fluctuation of Carbon Dioxide in the Ali-Sadr Cave of Hamedan and Tourists' Health

Geotourism as a part of tourism industry, has influenced most of the tourism markets. This branch of tourism introduces the phenomena that are caused by geology and geomorphology to visitors according to international standards and by maintaining their spatial identity. This branch also manages the observation of this treasury and prevents it from being destroyed by people. Geotourism can also provide the essentials for development of the zone.(Yamani and Coworkers, 2012: 85)

Unfortunately in our country and in spite of the large number of its caves, studies related to the climate of the caves and the changes in climatic elements (because of the presence of the visitors in the caves) such as: Carbon Dioxide, relative humidity, temperature has been ignored, whilst in some countries, the studies of this research dates back to 1950s and even earlier on.

Schmekal et al., (2001);Linan et al., (2008)،Cowan et al., (2011); Baker(2014); Lobo(2012), have tried to examine the cases related to the inner climate of the caves and the consequences and the climatic changes of elements of caves such as temperature, co2, relative humidity, saturation point, vaporization etc. They have also examined the role of the visitors. Ek et al.,(1985) have examined the source of Carbon Dioxide in the caves of Belgium and have also compared them to other countries. He has found the role of visitors so significant in the increase of Carbon Dioxide in the caves.

Moroni(2013) in a paper entitled, "Adjustment and control of carbon dioxide and radon with an attitude of utilization of caves", has proceeded to the role of visitors in the changes of some of the climatic elements in the caves and has also asked for studying and exact measuring in the caves with the presence of many visitors. He has also offered some creative suggestions.

Tavasoli (2012) has proceeded to the polluted air of the caves and its effects on the visitors, and has written a paper about types of polluted air and the influence of co2 on the human body. Polluted air in the caves threatens the speleologists, cave visitors. This is an important issue in most of the caves in the whole world. High concentration of unhealthy weather can be a death trap for people who know nothing about its signs (Tavasoli. 2012:1)
The entrance of Carbon Dioxide in the atmosphere of caves is generally like this:

1 Carbon Dioxide produced by spoiled plants is absorbed by the water in the layers of the soil. This water which includes a considerable amount of Carbon Dioxide, enters the lower layers of soil and then penetrates to the cave through layers of stones. Some of this Carbon Dioxide is consumed in Calcite precipitation cycle and the rest enters the atmosphere of the cave. In addition

to Carbon Dioxide, in this process, Oxygen and nitrogen enter the atmosphere as well.

2 Because of the metabolism of microorganisms or exhale of animals such as bats and also humans, CO2 is produced and enters the cave. In result, the density of o2 decrease comparing to Carbon Dioxide, but the density of N2 remains fixed (Smith,1993:21). Measuring the amount of o2 in the caves is important for two reasons:

- Unhealthy weather and the concentration of co2 above 5000(ppm) in the inner air of the cave may endanger the health of the visitors.
- Concentration of O2 in Karst caves influences the condition for development of different processes in the caves by the direct influence on the process of density and breakup, affects the natural change of carbonates (Linon et al., 2008:99).

More than 800,000 people visit Ali-Sadr cave every year. And according to substructures and plans, this number will increase to 1,200,000. Daily presence of 5000 to 7000 people in the cave and the duration of their visit cause some changes in climatic elements of the cave such as: the percentage of O2, percentage of relative humidity, temperature and etc. Hence, measuring the changes of inner climatic elements is essential because of their effects on visitors' health and also evolution of geomorphology and geology phenomena in the caves. In the present paper, the author has attempted to analyze the daily and monthly changes of Carbon Dioxide by measuring its amount in the inner air of Ali-Sadr cave, and also the role of visitors in change of the amount of Carbon Dioxide in the cave. Finally, the effects of these changes on the visitors will be examined.

MATERIAL AND METHODOLOGY

The objective of this research is to examine the daily and monthly changes in the amount of Carbon Dioxide in Ali-Sadr cave. For this purpose, a tool for measuring the amount of Carbon Dioxide has been used which is made in Taiwan and its model is AZ(77535). This tool can measure CO2, percentage of relative humidity and temperature at the same time. Measuring have been done three times a day. The first time was between 8 and 8:30 in the morning (before the arrival of the visitors), the second time was at noon between 13 and 13:30 and the last time was after the exit of the visitors and between 20 and 20:30(in business days) or between 22 and 22:30(in holidays). Because of the presence of the visitors all over the cave, takings were not done from certain locations. Each taking was done in an corridor of 200 meters from the entrance the end of the cave(large halls) and every measure was done in the medium corridor of 40 to 50 meters. Because of the concentration of Co2 in tight places, the inner corridor of the cave was divided to three parts. Small or low altitude part(halls with 3 meters height), medium(up to 7 meters), and high parts(more than 7 meters). The measuring were done regularly from August 13th, 2014 to September11th, 2014 in a complete duration of 30 days. In this research, the measured amount of CO2 is not separated according to the sources, both human and natural sources are combined together.

CONCLUSIONS

Daily and Monthly Changes and Fluctuation of Carbon Dioxide in Ali-Sadr Cave

Table 1 shows the amount of CO2 which has been taken three times a day and in three places with low, medium and high altitude. The average of takings in three locations in the morning and before the arrival of the visitors is: 3094, 3156 and 3129(ppm). When the visitors arrive and despite the doors open and close for several times, until noon, the average reaches 3449, 3384 and 3332. In other words, the average increase in the amount of CO2 from morning until noon(about 5 hours) is 345, 228 and 203.

Table1. *The Average of Taking CO2 in 30 Days Based on Dimensions of Halls in Ali-Sadr Cave*

row	Taking times	Dimensions of taking halls→	Small	Medium	Large
1	The average takings in the morning		3096	3156	3129
2	The average takings at noon		3449	3384	3332
3	The average takings at night		3743	3671	3632
4	Total average		3429	3404	3365

Another important point is the difference between the average of takings in the morning and before the arrival of the visitors, and the average of takings at night and after the exit

which is: 647,515,503(ppm). These differences show the effect of presence of visitors in the cave. According to the differences, the most amount of CO2 is concentrated in the places with the altitude of 0 to 3 meters which is 647ppm which is because of the less corridor and cracks and also the limited connection with outside. Then, there are places with medium height (515ppm) and places with more corridor and higher altitude (503ppm). the highest amount is 4100 ppm which occurs at night and after the exit of visitors which has been taken from the places with low altitude and the lowest amount has been reported 2583 ppm from places with high altitude and in the morning, before the arrival of visitors. Therefore, the extent of monthly changes is 1517 ppm for all the places inside the cave.

Changes and fluctuation of Carbon Dioxide inside the cave (results from takings in the morning).

Figure1 shows the fluctuation and changes of CO2 in 30 days in places with small, medium and large corridorsفضا in the morning and before the arrival of the visitors. It is important to notice that the extent of fluctuation is higher in large corridors. In each corridor, we see 4 peaks which coincide with the holidays and the increasing number of visitors on that days. For instance, on one of these holidays, the number of visitors was 6177 plus the cave personnel. The highest recorded amount of CO2 in 30 days in the morning and before the arrival of visitors is 3655ppm, and the lowest amount is 2583ppm. Accordingly, the extent of takings in the morning is 1072ppm which is high.

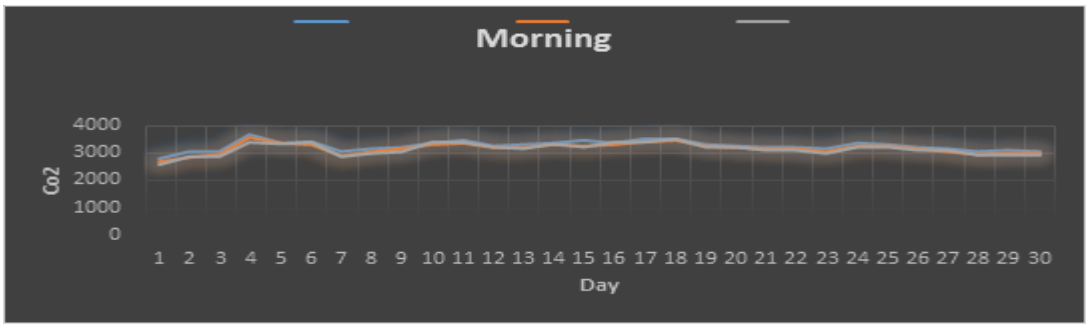

Figure 1. Diagram of changes and fluctuation of the amount of CO2 inside the cave based on the altitude (8-8:30)

Changes and the fluctuation of Carbon Dioxide in the cave at noon.

Figure 2 shows the changes and fluctuations of CO2 in 30 days in small, medium and large corridors at noon (13-13:30). In this diagram, too, the recorded amount of CO2 is higher in large corridors. The highest amount is 3720ppm at noon, and the lowest is 2925. Therefore, the extent of changes at noon for all the corridors is 768ppm.

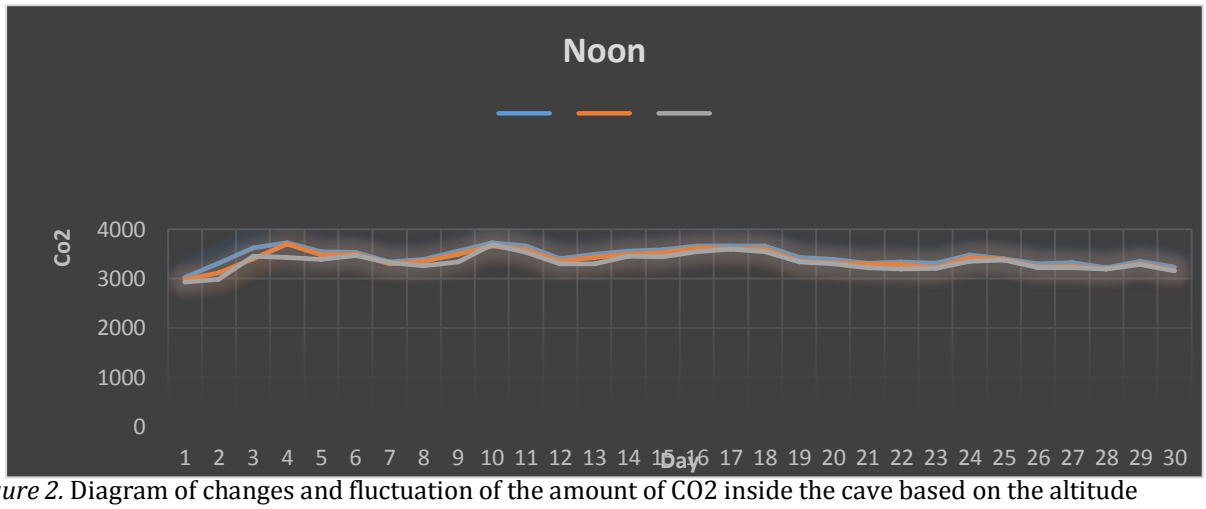

Figure 2. Diagram of changes and fluctuation of the amount of CO2 inside the cave based on the altitude (13-13:30)

Changes and fluctuation of CO2 in the cave at night (after the visitors' exit).

Figure 3 shows the changes and fluctuations of CO2 in 30 days in small, medium and large corridors at night and after visitors' exit. Like Figure 1 and 2, in this diagram the highest degree of changes and fluctuations is recorded to be of corridors with more than 7 meters height. The reason could be the larger room, more cracks and more connection to outside. The highest amount is 4100ppm at night, and the lowest is 3380. Therefore, the extent of changes at night for all the corridors is 720ppm.

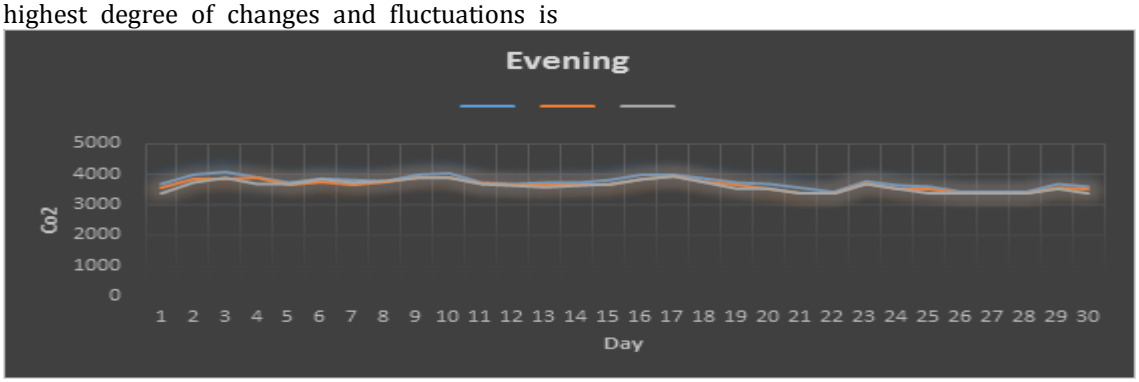

Figure 3. Diagram of changes and fluctuation of the amount of CO2 inside the cave based on the altitude (20-20:30)

Daily and Monthly Fluctuation of Carbon Dioxide in the Ali-Sadr Cave of Hamedan and Tourists' Health

Carbon Dioxide is a colorless gas that breathing it in high density causes sour taste in the mouth and combustion in the nose and throat. The reason is the solution of CO2 and saliva and the production of a weak acid which is called carbonic acid. An increase in density of CO2 could be threatening to life. This gas exists in calcareous caves in different percentages. This gas is colorless, it has no smell and incombustible?? and is the result of breathing operation of the body. In industry, the advised amount of this gas is %5 (5000ppm based on the size) a day. If the density reaches %10 or more, the result would be respiratory paralysis and death in a short time.

Effects of CO2 on Human

Although the reaction of bodies is different in stressful situations, some signs are common in people against the density of CO2 and nobody is safe in this case. The air that human breathe consists of %21 Oxygen, % 0.03 Carbon Dioxide, and the exhaling air consists of %15 Oxygen and %5/6 Carbon Dioxide. Every person breathes almost 6 liters of air in a minute. But during hard activities, this number increases to 100 liters in a minute.

Table 2. *Physiological Effects of Co2 in Different Densities in Controlled Condition (Smith,1996,10)*

Density	Signs
% .03	No effect. This is the normal density of CO2 in the air.
% 5	Increases the operation of lung up to % 5. This is the maximum advised amount according to the standards of Australia.
%1	These signs may start to appear gradually. Feeling of heat and sweating, decreased attention and concentration, tiredness, anxiety, decreasing energy and myasthenia in knees and legs.
% 2	The operation of lung increases to % 50 and in case of connection, there would be a feeling of headache for some hours. Because of deep breathes, in this density, CO2 tends to accumulate in the tissues of the body. This causes the tissues to get acidic and in result leads to decrease in energy and weakness, even after leaving the cave. At times it is needed for the visitor to be cared in an appropriate condition in order to recover his/her usual metabolism.
% 3	The operation of the lung increases to % 100, it makes the person feel panting. Some signs appears such as: headache, vertigo, visual disturbances and rashes.
% 5-10	An increase of the feeling of panting, being tired of breathing and severe headaches. Staying too long in a place with the density of % 5 can cause irreparable effects on health and if the density reaches % 6, the result would be anesthesia or suffocation.
% 10-15	It is difficult to breathe. Severe headaches and too much tiredness. And if the connection continues in few minutes, the result would be anesthesia or suffocation.
% 25-30	Connection with high density for a minute leads to coma, convulsions and death.

Examination of the quality of the air inside Ali-Sadr cave.

Almost all Iranian and foreign sources show that the beginning of the danger of CO2 is % 0.5 which equal 5000ppm and is the highest degree according to the standards of Australia. As shown in the Table above, the average of takings from small, medium and large corridors (in 30 days and 3 times a day) is 3127, 3388 and 3682ppm. Accordingly, the condition of the cave causes no danger to visitors. But the remarkable point is the record of 4100 (ppm) on the night of the holiday with the large number of visitors in the cave. This record proves that the number of visitors has direct influence on the production of CO2 and its density. According to plans and policies done by Ali-Sadr company, in few years, the number of visitors will increase to % 50 (800000 to 1200000). The fact is that according to the number of visitors and the time they spend inside the cave, density of CO2 must have been more than the recorded numbers. But because of cracks and windows in calcareous stones, connection with outside, size and scope of corridors and different branches, the density of CO2 is less than what was expected.

CONCLUSIONS

Unfortunately in our country, the studies related to changes of regional elements inside the caves have been ignored, neither with the purpose of their influence on visitors' health nor the influence on Carbonate forms inside the caves. The results show that the number of visitors has a great influence on the spatial and temporal changes of the amount and density of Carbon Dioxide inside the cave. Therefore, the number of visitors should be match the weather and climate of the place. Because according to plans and policies for increasing (% 50) the annual number of visitors for future, there will be both vast changes in climatic elements and carbonate forms inside the cave.

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