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Environmental monitoring in the Kaklik Cave (Denizli, Turkey)

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ABSTRACT

The formation of caves is the special environment of our earth. Caves with dim natural light and lighted hypogean environments, have been found various organism. The Kaklik Cave located tectonic lines and has a very different way of formation when compare with many other same karstic formation caves. The Kaklik Cave is located in the area of Kaklik town in Honaz area and in Denizli province. The cave is one of the 54 cave opened to tourism in Turkey and endanger. In this study the cave climate, hydrology and biology were studied. The cave has specific species due to this formation, the entrance is wide and open to the sky, that makes the sunlight could go through a very wide area and cause of it is very rich about hydrology, these effects; provide a very high biodiversity to the cave. The cave has very important touristic potential because of the continuously growing travertine, geographical position, availability of access and natural beauties. The wrong artificial lightning badly changes the natural structure of the cave. This artificial lightning causes the biofilm layer and changing on the color of the travertine.

Keywords: Kaklik Cave; Environmental Monitoring; Climate; Hydrology; Geology; Biology; Turkey

1. INTRODUCTION

As known, Turkey has approximately 40,000 different caves and the geology of most of them has not been studied yet. The information about most of them discovered on touristic restores. As we know, basic geological, geomorphological, hydrological-hydrogeological, meteorological and biological characteristics has been studied and on the base of their importance 1/100 - 1/2500 sized maps (plans and cross sections) has been drawn and economical values must be studied for identify a cave truly. The researchers has been studied, investigated and marked around 2510 caves in Turkey till today [1-4].

When compare the numbers of the caves with the studies about them, it's become obvious the studies are very less for this amount of caves in Turkey. In all these studies, the basic ones has been studied and completed by the General Directorate of Mineral Research and Exploration Institute (GDMRE). The GDMRE has been explored 913th of the all identified caves in Turkey from 1979 till main date. The 15th of these caves restored by the same institute and open for public use and touristic actions and there are 80 scientific papers have been published about these caves. Also, the geomorphological and biological features of these caves are studied in those papers [2,3,5-9].

In this study, geomorphological features and physicochemical parameters determined and the biodiversity has been studied of the Kaklik Cave which was restored and opens for touristic actions in the early periods of the year 2000 by the GDMRE. The rapprochements for conservation to system represented and suggestions explained for this aim.

1.1. Study Area

The Kaklik Cave is located in the area of Kaklik town in Honaz area and in Denizli province and the coordinates of the cave as follow; 37˚51'20.86"N; 29˚23'08.50" E. (**Figure 1**). The cave is in borders of Kaklik town and at the 3 km away through north direction of Kaklik town which is located at the 30th km of the Denizli-Afyon-Ankara highway, it is also at the south hillside of the Mali Mountain (1277 m) on the edge of alluvium prairie (517 m) [1,10-13].

All the area is under the Mediterranean climate. The annual temperature during the year is 16.2˚C at the Kaklik and the area around it, annual fall is 46.7 kg/m^2 during the year. (Turkish State Meteorological Service, 11. 01. 2012).

The cave has a 50 - 60 people capacity cafeteria, an

Figure 1. The Kaklik Cave location on Turkey map (Coordinates: 37˚51'20.86"N; 29˚23'08.50"E).

amphitheater, artificial ponds full with thermal water on the other hand there are canals and a swimming pool next to the cave and gives an opportunity to visitors who wants to use the thermal water. Although the Kaklik Cave was under usage of tourism company till April 2005, today the Kaklik civil hall enterprises the cave [10, 12,13].

Some parts of the thermal water which is coming out from the Kokarhamam fountain near to the cave, has used for fill the swimming pools. The much part of the thermal water flows in the cave and creates waterfalls and builds travertine. After that the water goes natural galleries and tunnels in underground and finally pumped to the Kaklik plain for sprinkling water by the General Directorate of State Hydraulic Works Department [10-13].

After the caves detailed plan and cross sections prepared by the GDMRE in 2000, they prepared a secure and utility schedule project. The high concentrations of Carbon dioxide gas, Hydrogen sulfide gas and the low concentration of Oxygen gas is because of the thermal water which is coming up in to the cave and this situation causes (**Table 1**). Because of this situation became higher than levels for human health, only a small part of the cave open for public visits. As known, the Kaklik Cave started to formation around 2 - 2.5 million years ago by sulfurous thermal waters melted the chalk stones and the cave is a natural protected area and opened to touristic visits at 2002 [1,10-12].

1.2. Geology

The area around the cave consists; Mesozoic chalk stone, Eosin marl, clay, sandstone and conglomerates, Miocene-Pliocene old clay, sand, marl and limestone with travertine and alluviums. The Mali Mountain consist old chalk stone and dolomite chalk stone which is located at the North of the Kaklik Cave [10,11,14].

On this area, generally tectonic lines located on east-west direction and these lines causes cracks and these cracks make different heights on land, although provide the conditions to forming thermal fountains through these lines. The lithogenic and geographic structure and fault line provide the conditions to thermal water to build underground thermal water rivers. The underground rivers made galleries at the same direction with east-west fault line in the Kaklik Cave chalk stones and these galleries' ceiling collapsed and built the cave itself with this way. The cave has a collapsing doline or concave shape [10,11].

Table 1. The atmospheric results of the Kaklik Cave, measured by the GDMRE [10,11].

Measurement Point	Oxygen (O_2) (%)	Carbon dioxide (CO_2) (%)	Hydrogen Sulfide (H_2S) (%)	Methane (CH_4) (%)
Outside the cave	20.8	0.7	0	0
1	20.7	0.9	2	0
2	20.7	2.1	2	0
3	20.7	2.1	2	0
4	20.7	0.9	2	0
5	20.7	0.9	2	0
6	20.8	1	2	0
7	20.6	1.2	1	0
8	20.4	1.9	4	0
9	20.4	1.9	4	0
10	20.2	3.6	5	0
11	20.6	2.1	2	0
12	20.6	2.1	2	0
13	20.7	2.1	2	0

The Kaklik Cave is a fountain centered and still progressing cave, it progresses and grows to south-east direction [10,11,14].

The Kaklik Cave is not only had its formation by karstificatin and new fault lines because of the tectonized but also thermal water fountains has efficiency. In this respect, the Kaklik Cave has a very different way of formation when compare with many other same karstic formation caves. When the formatting processes of the cave considered, we can say that the processes are very similar with the Pamukkale area which is located 25 km northwest of the area [10,15,16].

1.3. Cave Physiography

According to accept the entrance of the cave as 0 m, caves deepest point is 14 m. The cave is 65 m lengths at northwest-southeast direction, 40 m length at north-east-southwest direction. The total length of the cave is 190 m but the second part at the southwest direction has new fall material, because of that this part is not open for public visits [1,11].

The caves height changes between 2 - 5 m and the round formation entrance has 13 × 11 m height (**Figure 2**) [14].

The second part of the cave at the west direction galleries build by underground rivers and this is not open for public visits. The part for visitors has a round shape and in the middle of the cave there are travertine on the dross came from the dropped ceiling. This travertine composed by the waters coming out from the Kokarhamam fountain contains sulfur, carbonate, bicarbonate and falling on them for a very long time. All the travertine in the Kaklik Cave has been built as wall shape canal type travertine [10,15,16].

2. METHODS

During this study, light, humidity and temperature measurements collected from different locations in the cave (**Figure 2**). Also, physico-chemical parameters measured in water analogous laboratory as the methods seen at table, from the Kokarhamam fountain water which builds travertine and feeds the much more part of the cave water. Some physico-chemical parameters measured in water of the Kokarhamam fountain by Water Quality Meter "DKK-TOA WQC 24" (**Table 3**).

The different stations parameters measured using a high sensitivity "Arzum AR 860 Humidity and Temperature Device" in the cave. The direct sun light can come through the wide entrance, this light and the other artificial lights measured with "Gossen Sixtolux" light

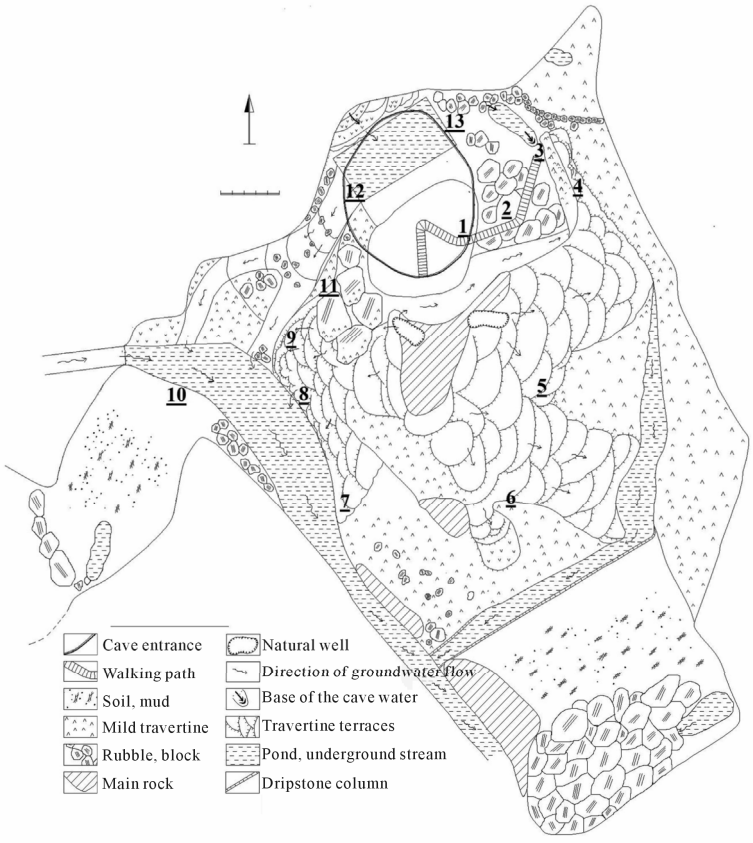

Figure 2. The schematic view of the Kaklik Cave (changed from Dereci [14]).

measurement device.

3. RESULTS

The big part of the water in the Kaklik Cave feed by Kokarhamam fountain. Although, there are different thermal water coming out spots located in the cave. Also, the sun light which comes directly through the wide entrance and the thermal water river, puts the cave into the "hot caves" class [1,10,11,14].

3.1. Climate

The temperature measurements collected from different locations of the cave is between 22˚C - 25.7˚C, humidity measurements between 72% - 84% and average temperature is 23.7˚C, average humidity is around 77.4% (**Table 2**). Temperature and humidity results are higher than many of other caves.

3.2. Hydrology

The Kaklik Cave is a very active cave for hydrological because of the waters coming out from underground and Kokarhamam fountain and this water travels in the cave. A part of the water coming out from Kokarhamam fountain which is located next to the cave, makes waterfalls and attends the inside water. The other water going through the cave is coming out to surface 78 meter west of the cave. These two underground water systems' hydrologic characteristics are same but flow is different them each other. The Public Waterworks Administration takes these waters in canals and gives the water through Kaklik plain for irrigation usage [11,14].

The cave still in development hydrological and has other water outs spots. The most evident one comes out from the artificial pond at the edge of west side Also, there are small other water outs located [11,14].

The Kokarhamam fountain's sulfurous thermal water builds the travertine; it is 23.5˚C and the physicochemical parameters of this water shown at **Table 3**.

3.3. Biology

The Kaklik Cave is naturally not a very deep and wide cave although; a very important part of it has light. For this reason, it relatively provides habitats for siafil organism also cavernous ones. Even the wet and dry places at the entrance of the cave provide habitats for regular species. The thing that affects the species variety in this hydrological rich cave is the physicochemical parameters of the water and atmospheric conditions. Different type of algae, moss, fern and higher plant species located from the entrance (**Table 4**). Algae groups are Cyanobacteria, Bacillariophyceae, Chlorophyceae, Conjugatophyceae and Charophyceae. Many of insect larvae, gastropods and gastropod's larvae, spider species, some of Crustacean species exist. Even though, *Aphanius* sp. invested in the cave. Some kind of salamander, frog and turtle species exists in the artificial ponds. There are different kinds of bird species nest in cavities in the cave. Bats make big companies on the cave ceiling and their economically valuable droppings collect and use regu-

Table 2. Selected point depth, light, temperature, absolute humidity results of the Kaklik Cave.

Measurement Point	Depth (m)	Light (lux)	Temperature (˚C)	Absolute Humidity (%)
Outside the cave	0	Daylight	19	65
1	−2.5	350 - 400	22	74
2	−3	380	22.3	72
3	−6.7	100	23	72
4	−10.8	120	23	75
5	−12	200	23.4	78
6	−12.8	200	23.6	78
7	−10.5	700	24	78
8	−11.15	500	24.6	81
9	−11.5	1250	24.8	83
10	−12	150	24.1	84
11	−11.5	1500	25.7	78
12	−8	1700-Daylight	24	76
13	−7.3	Daylight	23.6	74

Table 3. The physico-chemical parameters of the Kokarhamam fountain water.

Analyze	Method	Volume	Result
pH	Potentiometric		7.07
DO	DKK-TOA WQC 24	mg/lt	2.23
Conductivity	DKK-TOA WQC 24	ms/m	0.17
Turbidity	DKK-TOA WQC 24	NTU-mg/lt	0.0
Temperature	DKK-TOA WQC 24	˚C	23.5
Salt	DKK-TOA WQC 24	‰	0.8
TDS	DKK-TOA WQC 24	g/lt	1.4
Carbonate	Titrimetric	mg/lt	0
Bicarbonate	Titrimetric	mg/lt	106.75
Chloride	Titrimetric	mg/lt	1775
Sodium (Na)	ASS	mg/lt	218.5
Potassium (K)	ASS	mg/lt	43.01
Calcium (Ca)	ASS	mg/lt	2406
Magnesium (Mg)	ASS	mg/lt	535.5
Sulfate	Theoric	mg/lt	1608
Manganese (Mn)	ASS	mg/lt	0
Iron (Fe)	ASS	mg/lt	0
Copper (Cu)	ASS	mg/lt	0
Zinc (Zn)	ASS	mg/lt	0
Nitrate (NO_3)	TS EN ISO 10304-1	mg/lt	0
Nitrite (NO_2)	TS EN ISO 10304-1	mg/lt	0
Silisium (Si)	EPA 6020 A	mg/lt	8.1

larly. These rich feces contain azote, phosphorus and supplies optimum conditions for many species named Guanobi.

4. CONCLUSIONS

However, there are so many caves in Turkey; the studies about the caves quite a few. The Kaklik Cave has economical, geological and biological issues as very importantly effects the area tourism. There are papers about the lithogeny and geology of this area, because of the marble ores around the area. In these studies, the most conspicuous ones had been published by Nazik [11] and Dereci [14]. Also, the cave's tourism potential studied by Cetin [10]. Denizli and around area's travertine studied by Ozkul *et al*. [16] and Demirkiran & Calapkulu [15]. The potential tourism areas around Denizli; Pamukkale, Karahayit and Kaklik's thermal waters physico-chemical parameters investigated by Elci *et al*. [17].

The formation of caves by the matters of naturel process; always has different formations and environments not exist on any other places on earth. If the required restores not done and not taken cover of after discover the caves formation by long term geological processes; this negligence causes deformation, loss of biological diversity and touristic prosperity in this way. The Kaklik Cave is one of the 54 cave opened to tourism in Turkey and endanger.

There are 8 factories around the Kaklik Cave because of the chalk stone of the Mali Mountain and one of them is concrete factory and the other 7 are marble factories. These factories cause comparatively intense dust clusters around them. They use very big amounts of water and this corrupts the underground water arrangement. On the other hand, the heavy truck traffic affects negatively the caves nature.

The wrong artificial lightning badly changes the natural structure of the cave. This artificial lightning causes

the biofilm layer and changing on the color of the travertine. A new artificial lightning spot added on October 2011. While natural light in the cave varies between 100 - 380 lumen, 1250 lumen measured at this point. The travertine effected under that light had been spoiled and had a very thick biofilm on them (**Figure 3**).

Also, the artificial lights that used in the cave, makes a very bad view and presentation in the cave. Furthermore the artificial lights cause the heat on atmosphere that's why it is necessary to use non-heat lights. Especially, the

Table 4. Some identified species living in the cave.

Kingdom	Divisio/Phylum	Classis	Species
Eubacteria	Cyanobacteria	Cyanophyceae	*Pseudanabaena minima* (G.S.An) Anagnostidis *Spirulina subsalsa* Oersted *Phormidium autumnale* (C.Agardh) Trevisan ex Gomont *Oscillatoria proboscidea* Gomont
Protista	Euglenophyta	Euglenophyceae	*Euglena* sp.
Chromista	Heterokontophyta	Bacillariophyceae	*Navicula* sp. *Synedra* sp. *Epitemya* sp.
		Xantophyceae	*Vaucheria sessilis* (Vaucher) De Candolle
Plantae	Chlorophyta	Chlorophyceae	*Strauastrum hirsutum* Ehrenberg ex Ralf *Cladophora glomerata* (Linnaeus) Kützing *Cladophora fracta* (O.F.Müller ex Vahl) Kützing
		Conjugatophyceae	*Cosmarium* sp. *Scenedesmus* sp. *Spirogyra* sp. *Zygnema* sp.
		Charophyceae	*Chara contraria* A. Braun ex Kützing
	Bryophyta	Marchantiopsida	*Marchantia polymorpha* Linnaeus
		Bryopsida	*Bryum* sp.
	Pteridophyta	Polypodiopsida	*Adiantum capillus-veneris* Linnaeus
Animalia	Arthropoda	Insecta	*Larinioides suspicax* O.P.-Cambridge
		Crustacea	*Potamon potamios* Olivier
	Chordata	Pisces	*Aphanius* sp.
		Amphibia	*Pelophylax ridibundus* Pallas
		Reptilia	*Mauremys caspica* Gmelin
		Mammalia	*Myotis myotis* Borkhausen

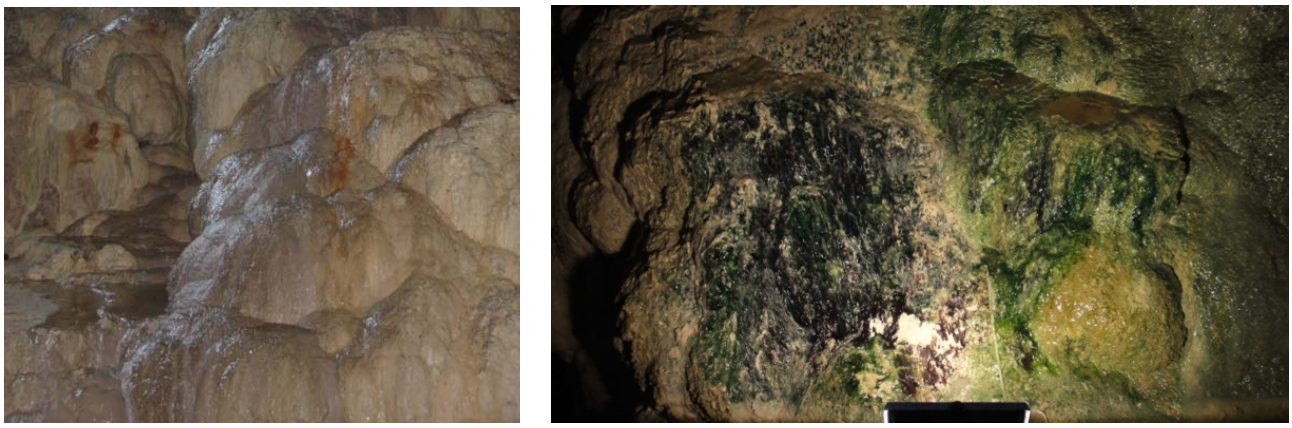

Figure 3. Appearance is in the same point in 2008 and 2011.

bat gallery wouldn't be lightening because of it offers the habitats for bats and bat density in that gallery. The artificial lightning had been chosen from the special lightning that not affects the natural flora and fauna of the cave and hidden lightning must be used in that matter.

The incoming water flow taken down on summer days, for fill the artificial ponds and this makes color changes, devolution and affects the grown and formation of travertine (**Figures 4** and **5**).

Consequently; the Kaklik Cave has many differences than the other caves have a same pit shape and open for public visits in our country. Because of the formation of the cave, the entrance is wide and open to the sky, that makes the sunlight could go through a very wide area and cause of it is very rich about hydrology, these effects; provide a very high biodiversity to the cave. The cave has very important touristic potential because of the continuously growing travertine, geographical position, availability of access and natural beauties. However, it never has enough interest cause it is very near to biggest touristic and historical places as Pamukkale and Karahayit which has famous around the world. For this reason, it had to be restored and become attractive to big tour companies to make travel programmers to bring tourists here.

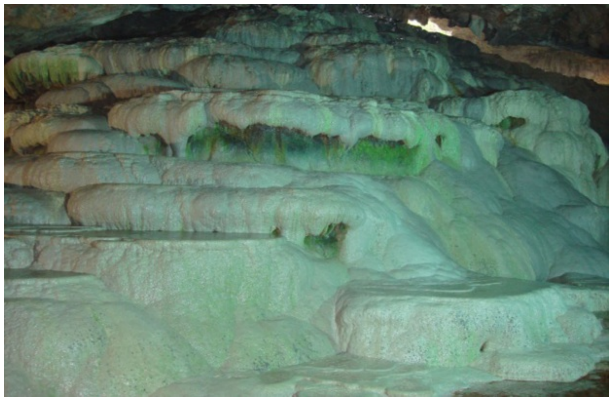

Figure 4. Color changes on travertine.

Figure 5. Deformation and devolution on travertine.

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