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The Hydrogeological and Biological Characteristics of Psoriasis Treatment Center, Turkey

Mustafa Değirmenci[1,a], Bülent Ünver[2,b,*]

[1]*Engineering Faculty, Sivas Cumhuriyet University, 58140 Sivas, Turkey*
[2]*Science Faculty, Sivas Cumhuriyet University, 58140 Sivas, Turkey*
[*]*Corresponding author*

A R T I C L E I N F O

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A B S T R A C T

More than 1000 thermal and mineral water springs with temperatures from 20°C to102°C occur in Turkey. Kangal Balikli Hot Spring is known as psoriasis treatment center is one of the most important among these springs. The main scope of this research was to determine geological, hydrogeological and biological properties and water chemistry of the psoriasis treatment center and the stream running alongside the thermal pools. The spring water is an isothermal-hypotonic and oligometalic mineral water, having average of electrical conductivity: 530 µS cm^{-1}, temperature: 35°C, CO_2 8.70 mg l^{-1}, pH 7.30 and O_2 4 mg l^{-1}. Calcium, magnesium and bicarbonates are dominant. Neither the chemical figures nor the temperature (35±1°C) of the water shows seasonal change. There are two fish species, *Garra rufa* and *Cyprinion macrostomus*, that adapted living at 35°C water temperature. The mean fork length and body weight of the fish living in the psoriasis treatment center is significantly lower than those living at the stream. Some of the fish in the pools showed symptoms of illness such as exophthalmus, scale loose, skin ulceration, pale gills, and bloated appearance. Gut analysis revealed that both species have been feeding on algae, insect parts, fish scales, and debris. In most cases the guts of fish caught in the pools were either empty or had very little content in it. Zooplanktons had little species and were not recorded frequently.

[a] degir@cumhuriyet.edu.tr https://orcid.org/0000-0003-2074-1386 | [b] bunver@cumhuriyet.edu.tr https://orcid.org/0000-0002-9318-1992

Introduction

Spring waters are used for wide range of purposes such as drinking, irrigation, recreation, and medical treatment. According to the latest inventory there are more than 1000 thermal and mineral water springs locations in Turkey ranging from 20 to boiling temperature (Koçak, 2002). Kangal Balikli Hot Spring which is known as psoriasis treatment center is one of the most important among these springs. The spring has two fish species which one of them called as doctor fish. Both fish adapted living at 35°C water in the thermal pools. This temperature value is the extreme level for the cyprinids. These fish are thought to contribute to the treatment of psoriasis. Psoriasis patients from many countries of the world come to the spring for treatment (Figure 1).

Human being has always searched for help from alternative sources when modern treatment methods are exhausted or not of use any more (Sevindik et al., 2017; Sevindik, 2019). In such circumstances nature comes into attention with its wide variety of offers and psoriasis is one of those kinds of illness that either there is no ultimate treatment for it or various treatments have to be performed periodically on the patient. There has been extensive coverage and publications on the description, symptoms, and treatment options (from drug to complementary and alternative methods) of psoriasis in the medical area. There have been a small number of publications about the Kangal hot spring. Detailed studies on hydrology, fish and algae of the system should be performed (Özçelik et al., 2000; Gurkan, 2002). In this paper we report a series of geological, hydrogeological, and biological surveys for the hot spring which is known psoriasis treatment center and the stream running alongside the thermal pools.

Materials and Methods

Study Site

Balikli Hot Springs (BHS) is situated in the Central Anatolia of Turkey. The spring is located some 13 km northeast of Kangal town, which is 90 km to Sivas. The thermal springs discharge from many different points at the site at an altitude of 1425 m above sea level. However, in recent years, discharge of water has been directed to the pools in order to respond increasing demand for treatment.

Field trips revealed that there are a few other thermal springs towards the south and north in the valley with small discharges which one of them called Kalkim Spring (Figure 2).

The springs were first noticed by locals in the early 18th century. Although there is controversial information on the origin of the pools, it has been reported that the BHS was a marshland in 1917 and were opened to public in 1963 with 4 bathing pools three of which are open-air. At present, there are 5 pools with varying sizes, 16 private baths, one swimming pool, a hotel (120 bed capacity) a camping site (150 tents) and motels with other facilities giving services to those who are seeking treatment for their various health problems especially psoriasis in the pools or in the stream.

Figure 1. The Kangal Balikli Hot Spring which is known as psoriasis treatment center (photo taken by Yönal)

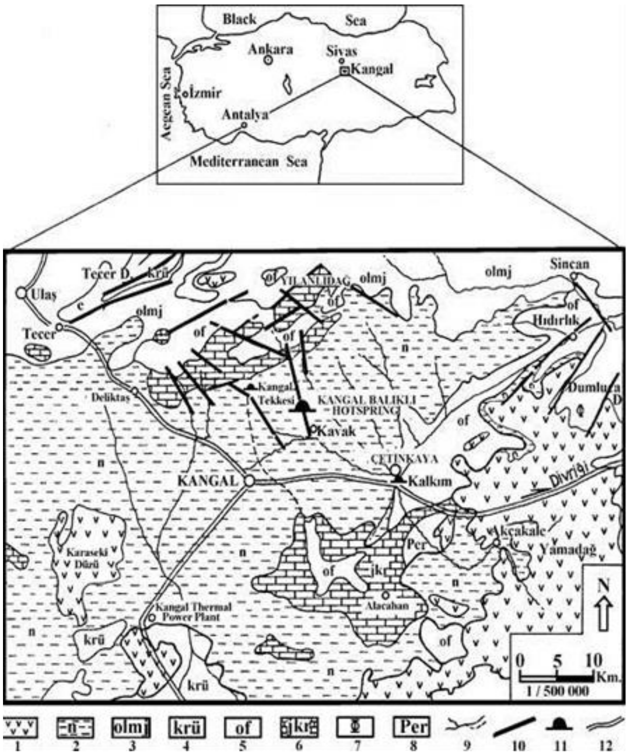

Figure 2. Location and regional geology map
(1- Yamadağ volcanics; mostly basalt, tuff and agglomerate interlayer, 2- Neogane series; sandstone, claystone, conglomerate and clayey limestone, 3- Oligomiocene aged series contain gypsum, 4- Limestone (Upper Cretaceouse), 5- Ophiolite (U. Cretaceouse), 6- Crystalized limestone (U. Jurassic-E. Cretaceouse), 7- Dumlıca batholite, cut the Cretaceouse and Paleocene rocks, 8- Permian aged basement, 9- Stream, 10- Fault, 11- Hotspring, 12- Mainroad)

Collection and Evaluation of Samples

Geological investigation was carried out to reveal the reservoir rock, cap rock, catchment area, and heat source of the hot spring. A geological map of the study area (Figure 2) has been produced from our field examinations and previous works in the area, including the 1/500.000 scale geological map of Turkey (Inan, 1993). In order to determine the origin of BHS water, water samples were taken from BHS and Çermik stream (CS) and analyzed by the International Atomic Energy Agency (IAEA) in Vienna for $\delta^{18}O$ and δD values and tritium activity. Flowrate measurements were carried out separately for each pool effluent and on the stream above and below the spring discharge points in order to determine the total amount of spring water used in the pools as well as not in use. Water samples were analyzed for major cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}), major anions (HCO_3^{-}, $SO_4^{=}$, Cl^{-}) and some traces, including heavy metals. Three sets of water samples were taken from the site. Two sets of samples were analyzed for metals by Atomic Absorption Spectrophotometry (AAS) in Sivas Cumhuriyet University and Hacettepe University. The third set of samples was analyzed for metals by Inductively Coupled Plasma Atomic Fluorescence Spectrometry (ICP-AFS) at Selcuk University. Fish species have been collected from the thermal pools and Çermik stream by using 10 mm mesh sized fishing net and electrofishing. Scales were used in determining the age of fish that are caught from stream whereas the size and frequency distribution method was used for fish caught in pools. Digestive systems of fish were removed and preserved in 4% formaldehyde solution and gut contents were studied both qualitatively and quantitatively.

Results and Discussion

A great part of the study area is covered by Neogene rocks, known as Deliktas Formation (Inan, 1993). A thin layer of lavas is present within the of 600 m-thick Deliktas formation which consists of sandstones, shale, claystones, conglomerates, pebbles, and clayey limestones overlaid by the 1000 m-thick Yamadag volcanics. The Yamadag volcanics consist mostly of basalt lavas, tuffs and agglomerates. Around the BHS thick conglomeratic limestone layers are present. They are densely cracked and fractured suggesting the presence of a fault running along the valley bottom. Tectonic breccias and the alignment of hot water discharges support this inference (Figure 2). Meteoric water infiltrates into the permeable Cretaceous limestones cropping out to the north and south of the BHS site. It slowly descends at depth and acquires heat through conductive heat transfer from the rocks with which it gets in contact. Finally, meteoric water reaches the geothermal reservoir, which is probably situated in the permeable limestones of Cretaceous age and is covered by the impermeable clastic rocks of the Neogene series, acting as cap rack. Hot waters convectively circulate into the geothermal reservoir and locally rise up relatively quickly along deep-reaching faults, discharging at the BHS and the other thermal springs of the nearby region (Figure 3).

The $\delta^{18}O$ and δD values of the hot spring (SI-4) and local stream waters (SI-5) are reported in the $\delta^{18}O$ - δD plot, where they are right on the "Global Meteoric Water Line" (Craig, 1961), and very close to each other indicating that both waters are of meteoric origin. The tritium activity of a groundwater sample can be used to infer its time of residence in the reservoir (aquifer) of provenance, referring to two theoretical limiting models known as piston-flow and well-mixed-reservoir models (Pearson and Truesdell, 1987). Both theoretical limiting models are based on the knowledge of tritium concentration in local precipitations. In Turkey, these data have been collected on a relatively regular basis since the early’60s in the three IAEA stations of Adana, Ankara, and Antalya. These data can be obtained from the ISOHIS Database. To estimate the residence time of BHS, the values of Ankara IAEA station (a time series of 310 data) were used. The analytical datum for this thermal water, 4.9±0.3 TU, indicates a residence time either >30 years or close to 200 years based on the piston-flow model and the well-mixed-reservoir model, respectively. The second value is considered more reasonable than the first one. Minimum and maximum total discharges of BHS were 161 Ls^{-1} and 256 Ls^{-1}; respectively with an average of 192 Ls^{-1}. Seasonal variations are evident for the stream flow whereas the spring has a permanent and stable flow regime and it is not directly affected by time changes in regional rainfall. The pools were created by excavating approximately 1.5-2 m down into the alluvial material. The side-walls of the pools are made of concrete whereas the bottom is left as natural alluvial material. The water in pools used for treatment seeps through the natural alluvium material at the bottom and overflows into channels discharging water to the stream. There is a natural hydrological relationship between pools because they are part of the same alluvial aquifer system. The calculated volume (m^3) of pools, the amount of circulating water (Ls^{-1}) and the retention time (hour) in Indoor, Arch roofed, Heptagonal, Rectangular Pools were 90, 10, 2.50; 105, 20, 1.46; 175, 10, 4.86; and 130, 10, 3.60, respectively. The water presently used in the pools is only one third of total hot spring water discharge (Figure 4). BHS water is clear, colourless, odourless and total dissolved ion content is very low (approximately 12 meq L^{-1} corresponding to 450 mg L^{-1}). Neither the chemical parameters nor the temperature (35±1°C) of the water shows seasonal change.

Dominant cations and anions are calcium, magnesium and bicarbonates, which is typical of waters interacting with carbonate rocks. Stream water temperature fluctuates between 5- 26°C before the spring water discharge enters the stream and 18-28°C after spring water enters stream depending on time of the year. Saturation indexes for calcite, dolomite and gypsum and Pco_2 for BHS (Table 1A, 1B) were calculated using the WATEQF computer program. BHS water is under saturated with respect to gypsum over saturated with respect to calcite and close to saturation with dolomite. In spite of this no carbonate precipitation was observed around the spring (except the heptagonal pool), downstream and especially in the pipeline. Table 1A and 1B also show that selenium concentration we have got from two different laboratories are below detection limit (<0.13 and <0.005 mg/ L^{-1}). Discharge measurements showed that the thermal water passing through the pools is only one third of total spring discharge. It is also possible to increase the amount of thermal water used in each pool by a good planning. Therefore, the retention time of the thermal water in the pools could be remarkably shortened thus having cleaner water especially in summer months when demand increases to its highest point. As a result of the investigation carried out in 1993, approximately 40 L s^{-1} of thermal water entering the stream, which was not used in pools now, supports 1 swimming pool and 16 private baths after our suggestion (Figure 4) (Degirmenci, 1995). Repeated analyses carried out in this study showed that selenium concentration in spring water is below detection limit (<0.13 and <0.005 L^{-1}). On the other hand, Gurkan (2002), using the kinetic spectrophometric method found a selenium concentration of 1.366±0.011 mgL^{-1}. There is a common belief that fish is one of the important factors along with the radiation (Ozcelik et al., 2000), there may also be other factor/s affecting treatment of disease such as free living or attached micro flora. Although it has been shown that fish living in pools feed on dead skins of psoriasis patches allowing sunlight, hot water or other factors to reach live dermis where just about any therapy needs to get to be effective, there is no direct evidence of fish being the only possible biological effect on the disease. Therefore, not only selenium but also free living and attached micro-flora in the spring water and their possible effects on psoriasis treatment deserve further investigations.

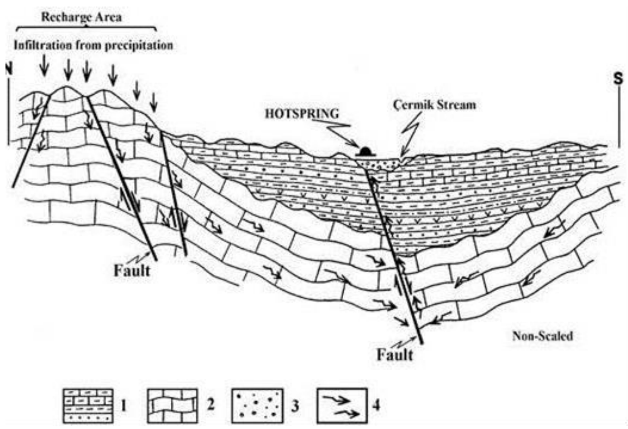

Figure 3. Discharging model of the hotspring
(1- Cap rock (sandstone, claystone conglomerate and clayey limestone; semi permeable-impermeable), 2- Reservoir rock (crystalized limestone; higly fractured-fissured and faulty), 3- Alluvium (sandy, clayey and pebbly), 4- Groundwater flow)

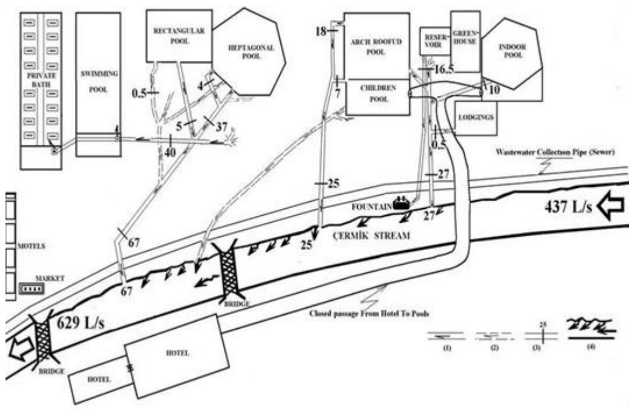

Figure 4. General sketch of Balikli Hot Spring, discharge measuring points and discharge values
(1- Effuluent/circulation water channels of the pool (rectangular concrete channels), 2- Underground drainage system (concrete pipes having holes on the surface), 3- Discharge measurement points on the channels and their discharge values, 4- Hot water discharge points (as a leakage) along artificial hole on the border of the flood control channel)

Table 1A. Chemical analysis results of the Kangal Balikli Hot Spring

P	1	2	3	4	5	6A	6B	6C	7A	7B	7C
Ca meq L^{-1}	3.74	3.44	2.71	4.0	3.55	3.79	3.33	3.36	3.10	3.20	5.016
Mg meq L^{-1}	1.78	1.48	3.75	1.00	1.32	1.39	1.87	2.16	1.70	1.42	2.896
Na meq L^{-1}	0.87	0.73	0.17	0.193		0.72	0.63	0.2280	0.72	0.80	0.056
K meq L^{-1}	0.026	0.030	0.030			0.108	0.044	0.032	0.04	0.03	0.069
HCO_3 meq L^{-1}	4.70	5.1	4.96	4.40	4.32	4.90	4.99	4.82	4.10	4.225	
Cl meq L^{-1}	0.67	0.59	0.675	0.740	0.76	0.60	0.753	0.80	0.73	0.699	
SO_4 meq L^{-1}	0.96	0.79	0.958	0.207	0.61	0.715	0.541	0.450	0.62	0.569	
Hardness, Fr	27.6	24.6	32.23	25	24.2	25.9	26	24.7	24.0	23.1	39.56
T.Any. / T.Kat.	6.41-6.33	5.68-6.48	6.66-6.59		4.87-5.69	6.09-6.15	5.87-6.28	5.78-6.07	5.40/5.56	5.49/5.45	8.04
EC µS cm^{-1}	590	420	590	481	536.4	526	526	524	544	544	544
CO_2 mg L^{-1}	8.88		8.88			8.60	8.60	7.82	4.00	4.0	4.0
PH	7.30	8.0	7.20	7.45	7.6	7.18	7.18	7.5	7.40	7.40	7.4
Temp. °C	35	36	35			35+0.5	35	34.9	35.5	35.5	
O_2 mg L^{-1}	6.5		4.41	0.72		4.05	4.05	3.74	3.90	3.9	
NO_2 mg L^{-1}							0.0022	0.00087	0.00		
NO_3 mg L^{-1}				0.006			0.72	0.945	1.02		
PO_4 mg L^{-1}						0.0175	0.033		0.180		

Table 1B. Chemical analysis results of the Kangal Balikli Hot Spring

P	1	2	3	4	5	6A	6B	6C	7A	7B	7C
Fe mg L^{-1}			0.175	0.1		0.08	0.15	<0.02	<0.024	0.011	0.00041
Zn mg L^{-1}	0.016		0.02					0.007	<0.005	0.000	0.00000
Al mg L^{-1}	0.045						<0.03				0.00561
Mn mg L^{-1}			0.1				0.008	<0.08	<0.009	0.000	0.00028
Cu mg L^{-1}			0.027				0.02	<0.015	<0.017	0.000	0.00000
Cr mg L^{-1}			0.1				<0.03	<0.1	<0.054	0.000	0.00316
Pb mg L^{-1}			0.1			0.03	<0.04	<0.04	0.049	0.000	0.00000
Se mg L^{-1}			1.30							0.000	0.00000
Br mg L^{-1}	0.675		0.27								
F mg L^{-1}	0.50		0.27								
Sr mg L^{-1}							0.40	0.42	0.260	_	0.57369
Ni mg L^{-1}									<0.054	0.0000	0.00000
Co mg L^{-1}									<0.028	0.0000	0.00072
Li mg L^{-1}									<0.005	0.017	0.01379
Rb mg L^{-1}									<0.033		
Cd mg L^{-1}										0.0000	0.00037
As mg L^{-1}											0.00000
B mg L^{-1}											0.02603
Ba mg L^{-1}											0.76833
Ga mg L^{-1}											0.00373
P mg L^{-1}											0.00000
Ti mg L^{-1}											0.30332
V mg L^{-1}											0.10931

Total Alfa Activity	3.77±0.81	Pci L^{-1}
Total Beta Activity	5.03 ± 1.5	Pci L^{-1}
Radon Rn222	180	Pci L^{-1}
Radium Ra226	0.59	Pci L^{-1}
Uranium U238	0.842	µg L^{-1}

P: Parameters, 1: I.T.U. Medicine Faculty (İstanbul), Aug. 1974; 2: Mineral Resarch and Exploration (Ankara), June 1982; 3: C.U. Science Faculty (Sivas), Ann. Ave. 1987; 4: Balıklı Hotsprig Administ-ration (Sivas), July 1991; 5: Bank of Provincs Lab. (Ankara), Nov. 1992; 6A: H.U. Karst Wat.Res.Cen.Lab. (Ankara), April 1993; 6B: C.U. Env.Eng. Dept. (Sivas), April 1993; 6C: C.U. Env.Eng. Dept. (Sivas), May 1993; 7A: C.U. Env.Eng. Dept. (Sivas), Sept. 2001; 7B: H.U. Karst Wat.Res.Cen.Lab. (Ankara), Sept. 2001; 7C: S.U. Agricult. Faculty Res.Lab. (Konya), Sept. 2001

Table 2. Mean fork length (mm) and body weight (g) values of *Cyprinion macrostomus* and *Garra rufa* caught from the Balikli Hot Spring pools and Cermik Stream (N: Number of specimens, FL: mean fork length, W: mean body weight, SE: standart error)

Species	Balikli Hot Spring				Cermik Stream				t-test
	N	%N	FL ±SE (min.-max.)	W±SE (min.-max.)	N	%N	FL ±SE (min.-max.)	W±SE (min.-max.)	FL W
C. macrostomus	42	68.8	69.1±4.5 (36-127)	20.6±2.0 (2.0-33.3)	21	61.8	100.8±6.3 (44-160)	63.2±7.6 (7.2-113.0)	P≤0.05 P≤0.05
G. rufa	19	31.2	45.3±2.8 (28-70)	6.7±0.8 (1.1-14.9)	13	38.2	63.5±5.1 (27-91)	19.7±3.2 (3.7-46.8)	P≤0.05 P≤0.05

Two fish species (*Cyprinion macrostomus* Heckel, 1843 and *Garra rufa* Heckel, 1843) have been caught in the BHS pools. A total of seven fish species all belonging to Cyprinidae have also been caught from the stream [*Squalius cephalus* L., 1753, *Alburnus chalcoides* (G., 1772), *Capoeta sieboldii* (Steindacher, 1864), *Capeota trutta* (Heckel, 1843, *Barbus* sp., *C. macrostomus*, and *G. rufa*]. Descriptive biological features of those species found in the study area are given in detail elsewhere (Geldiay and Balık, 1988; Nikolsky, 1963). *G. rufa* was found to be more confined to the bottom of the pools whereas *C. macrostomus* was found in the water column. Our observations revealed that although not many, fish can freely travel from stream to the pools via drainage canals. *C. macrostomus* and *G. rufa* living in pools varied considerably length and in weight (Table 2) compared to the same species living in the stream. Mean values of fork length and body weight of same two species living in the stream were significantly bigger than those of pool population ($P \leq 0.05$). Some of the fish in the pools showed symptoms of illness such as exophthalmus, scale loose, skin ulceration, pale gills, and bloated appearance. Also, no morphological abnormalities were observed in the stream fish population of those two species. The annuli on the scales of stream populations were clear whereas it was impossible to see them in spring population.

Gut analysis revealed that both species have been feeding on algae, insect parts, fish scales, and debris. The form of feeding of both species is omnivorous. In most cases the guts of fish caught in the pools were either empty or had very little content in it. There was no noticeable difference in diets of the species caught in pools compared to fish caught in the spring. However, fish caught in the stream had almost in all cases full stomach. Filamentous algae dominated the diets of both species. Diatoms were found to be second in abundance were detected in the guts. We also found some parts of ostracods, nematodes and rotifers which were mostly digested and could not be identified to any lower level as well as fish scales and insect parts. Zooplanktons had little species and were not recorded frequently. They were mainly consisting of ciliates and nematodes. There is clear evidence that fish growth and activity are highly dependent on the environment in which they live. Our study showed that the size of *C. macrostomus* and *G. rufa* living in the pools is considerably smaller than ($P \leq 0.05$) those live in the stream (Table 2). The reason for this was probably mostly caused by constant high temperature (35°C), which may limit optimal growth of most algae except thermophilic species. As a result of inadequate supply of food plus increased metabolism in warm water in the pools leads to starvation and stress. This was supported with our findings of almost empty stomach of pool population whereas fish caught in the stream all had full stomachs. The nutritional state of fish not only affects their size but also their reproduction ratio by directly having effect on vitellogenic and maturational enlargement of oocyte within the ovary (Nikolsky, 1963; Wallace and Selman, 1978) which is very important from culture and conservation point of those two species. Although fish travel from pools to stream or vice versa, our findings suggest that fish population in the pools do not completely mix with stream population. For instance, almost all fish caught from pools did not have annuli whereas few had annuli and mean fork length and body wet weight values had bigger than the rest suggesting those were the ones travelled from stream. It is a well-known fact that annuli are a result of environmental variables most importantly the water temperature (Nikolsky, 1963). All the fish have been caught from stream clearly had annuli whereas fish caught from pools did not have annuli (except few) during the study period which may have been as a result of no fluctuation in the water temperature. The fish populations in the stream were very healthy. However, number of fish in the pools had morphological and anatomical abnormalities such as exophthalmus, scale loose, skin ulceration, pale gills, bloated appearance, and sudden death. All above symptoms greatly increase during summer months when number of visitors increase almost by 100 times. There are clear evidences of stress caused by environmental and anthropogenic factors leading to suppressed immune system of fish consequently leaving fish to susceptible infectious disease caused by *Aeromonas hydrophila* (Chester, 1901) (Camus et al., 1998). *A. hydrophila* is a ubiquitous gram negative, motile, rod-shaped bacterium which is commonly isolated from fresh water ponds and which is a normal inhabitant of the gastrointestinal tract of fish and opportunistic pathogen (Swann and White, 1991). Environmental stress factors, particularly those associated with poor level of nutrition, high water temperature, low dissolved oxygen levels, high ammonia and nitrate levels, pH disturbances. All above stress factors except ammonia and nitrate levels are coupled with high number of visitors during the summer months give way to infection of fish by the bacteria (Beaz-Hidalgo and Figueras, 2013). Also despite strict control, there are still visitors entering pools wearing sun bloc might have direct effect on fish or deteriorating the water quality. Fish living in the pools were found to be stressed by the lack of food and oxygen as well as the visitors. In addition to stress, fish death and ill fish number increase in summer months are found to be the result of misuse of pools by visitors. This is very important with regard to conservation of those fish which are naturally found in the system. Therefore strict precautions should be taken in management as well as breeding pools to be created to protect the standing stock of fish in case of an unwanted loss of all fishes in the pools and the stream.

Conclusion

Known as “Kangal Balikli Hot Spring” is just one of the most important and most attractive of psoriasis treatment centers in the world not only in Turkey. Patients from all over the world visit this center for hydrotherapy and psoriasis treatment. The biological and hydrogeological characteristics of this special area are the basic data for other studies in the field.

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