The Hydrogeological and Biological Characteristics of Psoriasis Treatment Center, Turkey

Mustafa Değirmenci¹,a, Bülent Ünver²,b,*

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

A R T I C L E  I N F O

Research Article
Received: 03/01/2021
Accepted: 12/02/2021

Keywords:
Balıklı Hot Spring
Psoriasis Treatment Center
Hydrogeology
Hydrobiology
Kangal/Sivas

A B S T R A C T

More than 1000 thermal and mineral water springs with temperatures from 20°C to 102°C occur in Turkey. Kangal Balıklı 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, CO₂ 8.70 mg l⁻¹, pH 7.30 and O₂ 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.

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 Balıklı Hot Spring which is known as psoriasis treatment center is one of the most important among these springs. The springs have 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

Balıklı 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.

Keywords:
Balıklı Hot Spring
Psoriasis Treatment Center
Hydrogeology
Hydrobiology
Kangal/Sivas

*degir@cumhuriyet.edu.tr  **https://orcid.org/0000-0003-2074-1386  **bunver@cumhuriyet.edu.tr  **https://orcid.org/0000-0002-9318-1992

This work is licensed under Creative Commons Attribution 4.0 International License
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)

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 δ18O 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 (HCO3-, SO42-, 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 elastic rocks of the Neogene series, acting as cap rock. 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 δ18O and δD values of the hot spring (SI-4) and local stream waters (SI-5) are reported in the δ18O - 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 L s⁻¹ and 256 L s⁻¹; respectively with an average of 192 L s⁻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 alluvial 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 (m³) of pools, the amount of circulating water (L s⁻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.

Dominate 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 Pco₂ 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 has got from two different laboratories are below detection limit (<0.13 and <0.005 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 (Degirmenci, 1995). Repeated analyses carried out in this 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 spectrophotometric method found a selenium concentration of 1.366±0.011 mg L⁻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.
### Table 1A. Chemical analysis results of the Kangal Balıklı Hot Spring

| Parameter     | 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 | 0.008 | <0.08 | <0.009 | 0.000 | 0.00002 |
| Mn mg L⁻¹     | 0.1 | 0.008 | <0.02 | <0.005 | 0.000 | 0.00000 |
| Cu mg L⁻¹     | 0.027 | 0.02 | <0.05 | <0.1 | <0.005 | 0.000 | 0.00000 |
| Cr mg L⁻¹     | 0.1 | <0.03 | <0.1 | <0.054 | 0.000 | 0.00031 |
| 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 | 0.000 | 0.00000 |
| Br mg L⁻¹     | 0.675 | 0.27 | 0.000 | 0.00037 |
| F mg L⁻¹      | 0.50 | 0.27 | 0.000 | 0.00000 |
| 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 | 0.000 | 0.00000 |
| Cd mg L⁻¹     | 0.000 | 0.000 | 0.00037 |
| As mg L⁻¹     | 0.0000 | 0.00000 |
| B mg L⁻¹      | 0.02603 | 0.00000 |
| Ba mg L⁻¹     | 0.76833 | 0.00000 |
| Ga mg L⁻¹     | 0.00373 | 0.00000 |
| P mg L⁻¹      | 0.000 | 0.00000 |
| Ti mg L⁻¹     | 0.30332 | 0.00000 |
| V mg L⁻¹      | 0.10931 | 0.00000 |

**Total Alpha 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 (Istanbul), Aug. 1974; 2: Mineral Research and Exploration (Ankara), June 1982; 3: C.U. Science Faculty (Sivas), Ann. Ave. 1987; 4: Balıklı Hotspiry Administrist-ration (Sivas), July 1991; 5: Bank of Provinces 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 1B. Chemical analysis results of the Kangal Balıklı Hot Spring

| Parameter     | 1  | 2  | 3  | 4  | 5  | 6A | 6B | 6C | 7A | 7B | 7C |
|---------------|----|----|----|----|----|----|----|----|----|----|----|
| NO₃ mg L⁻¹    | 0.006 | 0.72 | 0.945 | 1.02 |
| PO₄ mg L⁻¹    | 0.0175 | 0.033 | 0.180 |

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

| Species            | Balıklı Hot Spring | Cermik Stream | t-test |
|--------------------|---------------------|---------------|--------|
|                     | N  | %N | FL ±SE | W ±SE | N  | %N | FL ±SE | W ±SE | FL  | W  | W  |
| *C. macrourus*     | 42 | 68.8 | 69.1±4.5 (36-127) | 20.6±2.0 (2.0-33.3) | 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) | 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 (Cyprinid 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), Capoeta 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 (Geldiyar 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≤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≤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.

References

Beaz-Hidalgo R, Figueras MJ. 2013. Aeromonas spp. whole genomes and virulence factors implicated in fish disease. J. Fish Diseases, 36: 371-388.

Camus AC, Durborow RM, Hemstreet WG, Thune RL, Hawke JP 1988. Aeromonas bacterial infections- motile aeromonad septicemia. SRAC Publication No. 478, U.S.A., pp. 1-4.
Craig H. 1961. Isotopic variations in meteoric waters. Science, 133: 1702-1703.
Degirmenci M. 1995. The hydrogeological characteristics of Balikli Spa (Sivas-Kangal). Bulletin of Earth Sciences Application and Research Center of Hacettepe University, 17: 69-85.
Geldiy R, Balik S. 1988. Freshwater Fishes of Turkey. Ege Univ. Sci. Fac. Book Series Num. 97, Izmir, Turkey.
Gürkan R. 2002. Kinetic spectrophotometric determination of trace amounts of selenium based on catalysed reactions (Indicator-Redox Reactions), Ph. D. thesis, Cumhuriyet University, Sivas Turkey.
İnan S. 1993. Structural evolution of South-east of Sivas Basilic. Cumhuriyet University Eng. Fac. Serie A, 10: 13-22.
Kocak A. 2002. Geothermal energy potential of Turkey. Middle East Geothermal Energy and Environment Symposium, Aksaray, Turkey.
Nikolsky GV. 1963. The Ecology of Fishes. Academic Press, London and New York.
Özçelik S, Polat HH, Akyol M, Yalçın N, Özçelik D, Marufihah M. 2000. Kangal hot spring with fish and psoriasis treatment. The Journal of Dermatology, 27: 386-390.
Pearson F, Truesdell AH. 1978. Tritium in the waters of Yellowstone National Park. U.S. Geological Survey Open-File Report, 78-701.
Sevindik M, Akgul H, Pehlivan M, Selamoglu Z. 2017. Determination of therapeutic potential of Mentha longifolia ssp. longifolia. Fresen Environ Bull, 26(7): 4757-4763.
Sevindik M. 2019. Wild edible mushroom Cantharellus cibarius as a natural antioxidant food. Turkish Journal of Agriculture-Food Science and Technology, 7(9): 1377-1381.
Swann L, White MR. 1991. Diagnosis and Treatment of "Aeromonas hydrophila" Infection of Fish Diseases, Fact sheet AS-461, Aquaculture Extension, Illinois.
Wallace RA, Selman K. 1978. Oogenesis in Fundulus heteroclitus. I. Preliminary observations on oocyte maturation in vivo and in vitro. Developmental Biology, 62: 354-369.