

Algal Distributions in a Hot Spring of Saudi Arabia

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ABSTRACT. The distribution of algae along the length of Tanoumah Hot Spring located north of Buraydah, Al-Qaseem is described. The orifice of the spring has a temperature of 60°C. The spring is neutral with high sodium, calcium and chloride content. A decreasing temperature gradient of 60-27°C extends from the orifice to the end of the spring where a shallow pool used for irrigation is formed. The total number of species of identified algae was 71 (37 Cyanophyta, 24 Chlorophyta, 10 Bacillariophyta). Some are new records for Saudi Arabia. Algal growth first appeared at a temperature of 56°C. The blue-green alga that dominated between 56-45°C was *Synechococcus lividus*. Below 45°C to the end of the spring blue-green algal mats mainly of *Oscillatoria boryana* and *Oscillatoria geminata* were dominant. Green algae and diatoms were observed, particularly at the spring periphery, where the temperature fell gradually to 25°C.

Almost nothing is known about the algae or chemistry of the hot springs of Saudi Arabia. A short communication that described 3 algal species from a hot spring in Al-Qaseem area in the central region of Saudi Arabia has been published (Aleem *et al.*, 1982); no other studies have been encountered in reviewing the available literature. Algal communities of the hot springs of North America, Japan and other parts of the world have been studied extensively, however, most of the studies have dealt only with the thermophilic algae of these communities (Bauld and Brock 1974, Brock 1969, 1978, Castenholz 1969a, 1969b, 1973, 1976, 1981, Emoto 1962, Jackson and Castenholz 1975). Few studies have described the algal distribution over the entire length of the spring effluents (e.g. Kullberg 1971, 1982, Jackson *et al.* 1978).

The objective of this study was to provide information about the algal flora and the water chemistry of the thermal springs in the Eastern (Al-Hofouf) and Central (Al-Qaseem) regions of Saudi Arabia. Only one spring, named Tanoumah

in Al-Qaseem, was found to have a temperature as high as 60°C and can therefore be considered a hot spring. The others are tepid, having a temperature of below 40°C or lack surface flow, the waters being totally pumped through pipes for irrigation, balneotherapy or other uses.

Materials and Methods

Temperatures were measured with a mercury thermometer or a thermistor-type meter (ATS/5009). pH and conductivity were determined using a Corning pocket pH meter and a conductivity bridge (WTW/FL 56). Water samples were taken at the orifice of the pipe and were chemically tested in the field. Most tests were run using a portable Hach Kit (Dr-el/2). The remaining tests were determined with atomic absorption spectroscopy (Pye-Unicam SP 9). All experimental values reported represent the mean of triplicate measurements. Samples of algae were collected at different representative sites based on visual observation. The water depth at the sites ranged from 20-30 cm. Samples were examined in the field with a McArthur field microscope and were taken live or preserved to the laboratory for further studies. To provide a comprehensive floristic list of the spring algae, field collected materials were inoculated into enrichment media (Stein 1975 and Castenholz 1981). Cultures were incubated at temperatures of 25, 35, 45, 55 and 65°C, under continuous illumination of 3500 lux from cool white fluorescent lamps.

Results

Tanoumah hot spring is located in the Al-Asiah area 80 kilometers north of Buraydah, Al-Qaseem (Fig. 1). The orifice of the spring is surrounded by a high concrete wall. The water gushes out from a pipe passing through a hole in the wall at a temperature of 60°C and flows freely, forming a small stream that ends in a shallow pool used for irrigation (Fig. 2). A temperature gradient of 60 to 27°C extends over a distance of about 54 meters from the pipe to the end of the stream.

Chemical analysis of spring water taken from the source is given in Table 1. The pH varied from 7.2 to 7.5 with a mean value close to 7.5. The water is high in sodium and calcium with a relatively high chloride concentration and low fluoride and silica, in contrast to many hot springs from other areas (White *et al.* 1963). Algal species along the length of the stream are presented in Table 2. The total number of algae identified was 71. Of this number 37 were blue-green algae, 24 green algae and 10 diatoms. Algal growth appeared about one meter from the orifice of the pipe and extended to the end of the stream. The upper edge of the algal cover occurred at 56°C. The blue-green alga that dominated this area and the next 10 m downstream, a temperature range from 56 to 45°C, was identified as

Synechococcus lividus (Fig. 3). A few unicells and short filaments of *Mastigocladus laminosus* were present with *Synechococcus lividus*. However, when these cells of *M. laminosus* were cultured in medium D and incubated at different temperatures they formed long branched filaments. Below 45°C to the end of the stream blue-green algal mats were dominant. The mats were composed mainly of *Oscillatoria geminata*, *Oscillatoria boryana*, *Phormidium laminosum* and *Lyngbya* sp. (Fig. 4). Green algae formed a luxuriant growth at the periphery of the spring where the temperature gradually fell to 25°C. *Cladophora glomerata*, *Ulothrix* sp. and *Hormidium* sp. were the abundant greens (Fig. 5). Diatoms were frequently present with the green algae and in the sediment. *Cymbella tumida* was the most common diatom species.

Discussion

The distribution of algal species in Tanoumah Hot Spring appeared to be similar to that of several hot springs from other parts of the world. Only

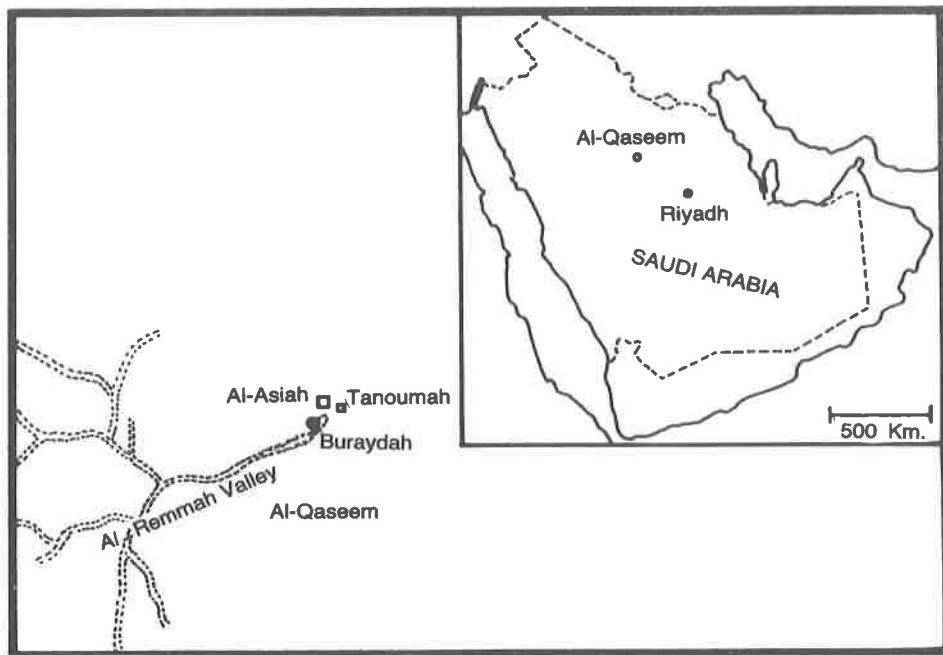


Fig. 1. General map of Saudi Arabia and enlarged portion of the Al-Qaseem area showing the study site.

Fig. 2. The 60°C spring water gushing from a pipe in the wall that surrounds the source.



Fig. 3. A portion of the spring showing *Synechococcus lividus* dominating above 45°C. (arrows indicate the outer edge of the mats).



Fig. 4. Blue-green algal mats covering the area below 45°C.



Fig. 5. Mats of green algae growing at the spring periphery at 25°C. (arrows indicate the inner edge of the mats).

Table 1. Chemical data of the spring water,
(Concentration in mg/liter).

Temperature	60°C
Conductivity	1212/ $\mu\text{S cm}^{-1}$
pH	7.5
Sodium	264
Magnesium	22.66
Calcium	113
Manganese	0.99
Iron	0.73
Copper	0.1
Zinc	0.055
Nitrate	0.44
Silicon	12.85
Fluoride	0.21
Chloride	450

Table 2. List of algae identified along a temperature gradient at Tanoumah hot spring. (All species are blue-green algae except where indicated).

Taxa	Temperature (C)							
	56	50	45	40	35	30	27	25
<i>Synechococcus lividus</i> Copeland	+	+	+	+	+	+	+	
<i>S. elongatus</i> Naeg.		+	+	+	+	+		
<i>Mastigocladus laminosus</i> Cohn		+	+	+	+	+	+	
<i>Phormidium laminosum</i> (Ag.) Gom.			+	+	+	+	+	
<i>Synechocystis pevalekii</i> Ercegović			+	+	+	+	+	
<i>Aphanothece</i> sp.			+	+	+	+		
<i>Chroococcus dispersus</i> (Keissler) Lemm.			+	+	+			
<i>Lyngbya</i> sp.		+	+	+	+	+	+	
<i>Oscillatoria geminata</i> Menegh.			+	+	+	+	+	
<i>Oscillatoria boryana</i> Bory			+	+	+	+	+	
<i>Calothrix epiphytica</i> West, W. & G.S.				+	+	+		
<i>Chorogloeopsis fritschii</i> Mitra and Pandey				+	+	+		
<i>Phormidium africanum</i> Lemm.				+	+	+		
<i>Anabaena cylindrica</i> Lemm.				+	+	+		
<i>Anabaenopsis</i> sp.				+	+	+	+	
<i>Aphanocapsa roeseana</i> De Bary				+	+	+		
<i>Calothrix</i> sp.				+	+	+		
<i>Chroococcus minutus</i> (Kütz.) Naeg.				+	+	+		
<i>C. montanus</i> Hansg.				+	+	+		
<i>C. turgidus</i> (Kütz.) Naeg.				+	+	+		
<i>Cylindrospermum muscicola</i> Kütz.				+	+	+		
<i>C. stagnale</i> (Kütz.) Born. et Flah.				+	+	+		
<i>Lyngbya major</i> Menegh.				+	+	+		
<i>Microcystis</i> Kütz.				+	+	+		
<i>M</i> sp.				+	+	+		

Table 2. (contd.)

Taxa	Temperature (C)							
	56	50	45	40	35	30	27	25
<i>Xenococcus</i> sp.				+	+	+		
<i>Spirulina laxissima</i> West, G.S.					+	+	+	
<i>Oscillatoria chlorina</i> Kütz.					+	+	+	
<i>O. terebriformis</i> Ag.					+	+	+	
<i>Phormidium ambiguum</i> Gom.					+	+	+	
<i>Schizothrix lardacea</i> (Ces.) Gom.					+	+		
<i>S.</i> sp.					+	+		
* <i>Mougeotia</i> sp.						+	+	+
<i>Spirulina meneghiniana</i> Zanard.						+	+	+
* <i>Trentepohlia</i> sp.							+	
* <i>Ankistrodesmus falcatus</i> (Corda) Ralfs							+	+
* <i>A. spiralis</i> (Turner) Lemm.							+	+
** <i>Achnanthes</i> sp.							+	+
* <i>Arthrodesmus</i> sp.							+	+
* <i>Cladophora glomerata</i> (L.) Kütz.							+	+
* <i>Cosmarium botrytis</i> Menegh.							+	+
<i>C. margaritatum</i> (Lund) Roy et Biss							+	+
* <i>C. punctulatum</i> Breb.							+	+
** <i>Cymbella tumida</i> (Breb.) Van Heurck							+	+
** <i>Epithemia turgida</i> (Ehr.) Kütz.							+	+
** <i>E.</i> sp.							+	+
** <i>Gomphonema</i> sp.							+	+
** <i>Gomphosphaeria aponina</i> Kütz.							+	+
* <i>Micractinium pusillum</i> Fres.							+	+
** <i>Navicula inflata</i> Donk.							+	+
** <i>N.</i> sp.							+	+
** <i>Nitzschia</i> sp.							+	+
<i>Oscillatoria okeni</i> Ag.							+	+
<i>O. redekei</i> Van Goor.							+	+
<i>O. sancta</i> (Kütz.) Gom.							+	+
* <i>Oedogonium</i> sp.							+	+
** <i>Pinnularia</i> sp.							+	+
* <i>Scenedesmus bijuga</i> (Turp) Lag.							+	+
* <i>S. incompressatus</i> Bohlin							+	+
* <i>S. serratus</i> (Corda) Bohlin								+
* <i>S.</i> sp.								+
* <i>Spirogyra</i> sp.								+
* <i>Staurastrum</i> sp.								+
* <i>Stichococcus bacillaris</i> Naeg.								+
** <i>Synedra</i> sp.								+
* <i>Ulothrix</i> sp.								+
* <i>Chlamydomonas</i> sp.								+
* <i>Chlorogonium elongatum</i> (Dang) Franze'								+
* <i>Hormidium</i> sp.								+
* <i>Oedogonium rufescans</i> Wittr.								+
* <i>Zygnema</i> sp.								+

* Green algae.

** Diatoms.

blue-green algae were present above 45°C. This is consistent with the observations made on most other hot springs (Castenholz 1969a, 1969b, Kullberg 1971, 1982, Jackson *et al.* 1978). The upper temperature limit for a blue-green algal cover here was 56°C. A strong water current from the orifice of the pipe may be responsible for not allowing a cover to become established at a higher temperature. The most abundant thermophilic alga was *Synechococcus lividus*. Every sample taken above 45°C exhibited the dominance of this species, possibly due to its known rapid growth rates (Peary and Castenholz 1964). Cultured cells of *S. lividus* in the laboratory using medium D failed to grow above 55°C suggesting that the strain of this species in Tanoumah represents one of the lower temperature strains.

Mastigocladus laminosus was represented in a few samples as unicells and short filaments. These cells yielded long branched filaments when cultured in medium D and incubated at various temperatures. The poorly developed morphological stages in the spring could be an indication of some unfavourable environmental factors such as competition or water chemistry (see Castenholz 1969b). Similar observations of unicells and short filaments of *M. laminosus* has been reported at higher temperature from Icelandic and other hot springs (Castenholz 1978, 1969a), but, those cells remained as short filaments after being cultured and have subsequently been identified as a high temperature form of *Chorogloeopsis* (Castenholz 1978). The maximum temperature of growth reached by *M. laminosus* in the laboratory was 60°C. This temperature is about the same growth temperature that has been previously reported for this species (Castenholz 1969b).

Neither *Synechococcus lividus* or *Mastigocladus laminosus* were reported by Aleem *et al.* (1982) from hot springs at Al-Qaseem. The species reported in their short communication were *Spirulina meneghiniana*, *Oscillatoria terebriformis* and *Oscillatoria minima*. Two of these species *S. meneghiniana* and *O. terebriformis* were found in Tanoumah spring at a temperature of about 30°C. Diversity of algal species in the spring increased as expected as the temperature decreased.

However, the blue-green algae, mostly in the form of algal mats (Fig. 3,4), continued to be abundant along the spring length. One of the most interesting blue-green algae observed is *Chlorogloeopsis fritschii*. This species is reported for the first time in Saudi Arabia although it is not restricted to thermal habitats.

Unlike the observation made by Kullberg (1971) in North American hot springs, the green algae and diatoms in Tanoumah spring never exceeded 30°C.

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توزيع الطحالب في ينبوع حار من المملكة العربية السعودية

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يصف هذا البحث لأول مرة توزيع الطحالب على إمتداد احد الينابيع الحارة بالمملكة العربية السعودية هو ينبوع تنومه الحار الواقع شمال مدينة بريدة في منطقة القصيم. درجة حرارة المصدر الرئيسي للينبوع 60°C . التحليل الكيميائي لعينة ماء من المصدر بين أن الماء متعادل في الرقم الهيدروجيني وذو محتوى عال من الصوديوم والكالسيوم والكلوريدات. امتد على طول الينبوع تدرج حراري متناقص من 60°C - 27°C وذلك من المصدر إلى نهاية الينبوع التي تشكل بركة ضحلة نسبياً تستخدم للري. مجموع الطحالب التي تم تعريفها ٧١ نوعاً (٣٧ طحالب خضراء مزرقّة و ٢٤ طحالب خضراء و ١٠ طحالب عسوية) بعضها يسجل وجودها للمرة الأولى في المملكة العربية السعودية. لوحظ أول إنتشار للطحالب عند درجة حرارة 56°C . ساد هذه المنطقة النوع *Synechococcus lividus* وامتدت سيادته إلى درجة حرارة 45°C . تحت 45°C كانت الطحالب الخضراء المزرقّة الخيطية هي الأكثر سيادة لاسيما *Oscillatoria geminata* و *Oscillatoria boryana* الطحالب الخضراء والدياتومات لوحظ إنتشارها لكن غالباً عند جوانب الينبوع حيث تنخفض درجة الحرارة تدريجياً إلى 25°C .