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Ecological Studies on Hot Springs of Al-Laith in Saudi Arabia

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Abstract: Knowledge about the ecosystem of hot spring areas is an important consideration as these areas will be more and more important in the future, for not only energy extraction and source of thermophilic bacteria but also for recreation and conservation. The present study aimed to determine the physicochemical character of six hot water springs, total viable count of thermophilic bacteria at different temperature degree and its surrounding flora in Al-Laith governorate, Saudi Arabia. Results showed that pH was slightly alkaline for three springs and slightly acidic for the other three springs. The highest electric conductivity, 7062 μS/cm, was exhibited by Darakah spring. Soil analysis showed that all sites have a slightly alkaline soil except that of Al Rakaa spring, which recorded slightly acidic one (pH: 6.9). Al Masal hot spring showed the maximum level of soil salinity (75.5 Ms/cm) while Wadi Markub hot spring recorded the lowest value (0.93 Ms/cm). Twenty-seven plant species were recorded, where Gramineae was the dominant family, followed by Solanaceae while the rophytes were the dominant life form followed by chaemophytes. Chorological characteristic of the recorded flora showed that Saharo-Arabian region elements recorded the highest number. Floristic study of hot water spring in Al-Laith discovered a serious invader species, *Prosopisjuliflora*, threatens native flora. We take this opportunity to shed light on this, which may represent a serious environmental problem.

Key words: Hot Springs · Thermophilic Bacteria · Al-Laith

INTRODUCTION

Thermal springs are sites where warm or hot ground water appears from the earth on a regular way for at least an expecting period and significantly above the ambient ground temperature [1]. Saudi Arabia lies within one of the driest areas in the world representing the eastern continuation of the Sahara Desert in North Africa [2]. Water resources in Saudi areas aremainly derived from groundwater, which considered a major source of fresh water that is used in different purposes [2]. Al-Dayel [3] reported that there are ten thermal springs in Saudi Arabia, six are in Gizan and four in Al-Laith area.

Hot springs in Al-Laith area are located in the vicinity of granite boundary along a cataclastic zone [4]. The physical and chemical characters of hot spring water play an important role in assessing and classifying water quality. The hydro-chemical study reveals quality of water that is suitable for agriculture and industrial purposes [5]. Geothermal hot springs and their immediate surroundings represent habitats with extreme growing conditions. These areas are generally characterized by steep gradients in soil temperature, high concentrations of minerals and highacidity, a result of these high-stress environments a highly adapted, often endemic flora occurs on geothermal hot springs. However, geothermal habitats also offer favorable conditions for thermophilic bacteria and plants from warmer regions, with increasing rates of globalization, propagule pressure of non-native plants rises also in these geothermal habitats. Hot springs, in contrast to other hydrophytic systems, have a relatively steady chemical composition, water speed and temperature [6]. Plant communities may thus be studied under approximately stable environmental conditions. Additional lineaments of hot springs make them of interest to an ecologist. These features include the establishment of thermal gradient and low species diversity within the community [7].

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Many previous studies have been conducted on the geothermal plant communities in many parts of the world, such as New Zealand [8-10], Japan [11], Hawaii [12] Canada [13] and different sites in the Antarctic area [12, 14, 15]. Most of these studies concerned moss and lichen vegetation, but some of them also included vascular plants. Geochemical studies of thermal springs from Saudi Arabia have been carried out in the past by several authors without referring to its flora [4, 16-19]. Rehman and Shash [4], recorded there are 10 hot springs with varying deep temperatures of 50 to 120°C and different flow rates in Saudi Arabia. In Al-Laith area, all the springs are located in the vicinity of granite boundary along a cataclastic zone. Three springs, Ain al Darakahh, AinMarkub and Ain al Harra, represent different fractions of a mixture of thermal water with a confined aquifer. Ain al Harra, the least mixed spring contains 48% of surface water [3].

Thermophiles and hyperthermophiles bacteria isolated and identified from hot spring water and evaluated their biological activity of thermostable enzymes [19]. Several studies indicated that thermophilic bacteria and archaea [19, 20] populate the geothermal systems.

Knowledge of the ecosystems of geothermal areas is important as it will contribute to improved decision making on their utilization and need for protection in order to gather more comprehensive information on the flora and vegetation within high-temperature geothermal areas.

The main aims of this study were to study the physicochemical parameters of the thermal spring, to determine the total bacterial count at different temperatures, to describe floristic composition within the study area and to establish relationships between hot springs and their chemical characters.

Table 1: Latitudes, longitude and elevations of the studied hot springs at Al-Laith area

Hot springs	Latitude (N) and Longitude (E)	Elevation
Darakah	N 20°40'19.6", E 40°02'19.6"	148 m
Al Masal	N 20°31'24.8", E 40°08'29.1"	133 m
WadiMarkub	N 20°31'42.5", E 40°09'21.10"	141 m
Al Rakaa	N 20°31'38.2", E 40°09'26.2"	142 m
Ghamika	N 20°27'40.73", E 40°28'16.08"	130 m
BaniHillal	N 20°18'1.82", E 40°42'3.28"	136 m

MATERIALS AND METHODS

Study Area: Six hot springs located at the confluence of the mountains of Hejaz Tihama plains on the western coast of Saudi Arabia in Al-Laith area (Table 1), 180 km south of Mecca area north of Qunfutha. Al-Laith governorate is located in the tropical area (Figure 1) and has an arid climate. The rainfall characterized by scantiness, irregular and variable, it ranges between 0 to 70 mm. In the last three years heavy but sporadic rainfall occurred on one or two days. The area distinguished by lack of vegetation cover as well as humidity increases due to its proximity to the Red Sea. In the winter the temperature moderation tendsrelatively, some rains intensely relatively few.

Water Analysis: The water samples collected from six hot springs at Al-Laith area aseptically in sterile 500 ml glass screw cap bottles. The samples were be transported in icebox to the laboratory and stored at 4°C until analysis.

The values of temperature, pH, conductivity, total dissolved solids (TDS) and dissolved oxygen (DO) of water in the different samples locations were determined using probes attached to a digital monitoring sonds (Global water, USA). Other selected measurements in the collected samples including elements (total alkalinity, total

Fig. 1: Location map of the studied hot springs at Al-Laith, Saudi Arabia

chlorine, fluoride, sulfate (SO_4^{2-}), phosphate (PO_4^{3-}), nitrate (NO_3^-), calcium,magnesium,manganese, potassium, zinc, ammoniaandtotal iron were performed in the laboratory using YSI 9500 Direct-Read Photometers [21].

Determination of Bacterial Count: The Total Bacteria Count (CFU) was recorded using plate count technique with Nutrient agar medium. Each plate received one ml of water sample. The plates were incubated at 30, 40, 50 and 60°C for 24h [22].

Vegetation Study Around Hot Springs: A survey was carried out during the period of December 2014 to the March 2015. However, it was not possible to survey quantitatively the entire project area; even then, a big effort was made to include the entire representative, topographic and physiographic condition in the study area. The collected specimens were identified with the help of various Floras, Collenette [23, 24] and Chaudhary [25].

Life form classes were constructed by following Raunkiaer [26]. When several life forms were given for a taxon, the most representative taxon was chosen; variation in the life form in the field was not considered. To avert the various conceptions of different authors for chorological units, which have resulted in different names for the two main regions in Saudi Arabia, the general approach and terminology of Zohary [27] for the Saharo-Arabian and Sudanian regions, which are well known, will be used. For each habitat, soil samples were collected from profiles of 0–25 cm depth. These samples were pooled together to form one composite s ample, a ir dried and thoroughly mixed. Textures were determined by the hydrometer method, providing quantitative data on the percentage of sand,silt and clay. Its physicochemical character analyzed according to methods of Jackson [28].

Statistical Analysis: Relationships among variables were explored using Pearson Correlation Coefficients (PC). Statistical correlations were done using the program SPSS 13.0.

RESULTS AND DISCUSSION

Physicochemical Characters of Hot Springs Water: Hydrochemical characteristics of hot springs in the studied area are summarized in Table 2.

Temperature: The temperature ranged between 37.8 to 77°C, the highest temperature was showed by Ain al Harra spring of Ghamika (77°C) followed by Wadi Markoub hot spring (55°C) and the lowest one was recorded by Ain al Darakah spring (37.8°C). It should be noted that, the water coming from those two hot springs have higher flow rate compared with other hot springs under study. The temperatures of the hot springs were determined in previous study by Khiyami *et al*., [16]. It was found that, Temperatures changed significantly and the change in temperature might be explained by the change in tectonic features of the areas and the change in crust thickness in those areas. In particular, those geothermal springs are located along the west region coast, which had an earthquake recently [16].

Table 2: Hydro-chemical analysis of water samples collected from hot springs in Al-Laith area, Saudi Arabia springs measured in the laboratory

							LSD	
	Darakah	Al Masal	WadiMarkub	Al Rakaa	Ghamika	BaniHillal	5%	1%
Total alkalinity mg/L $CaCO_3$	35±1.2*	90±2.3	175±2.4	120±13	20±1.4	75±3.7	4.5	6.35
Ammonia mg/L N	0.17±0.01	21±1.6	0.02±0.001	0.13±0.01	0.01±0.001	0.13±0.01	0.72	1.01
Calcium Hardness mg/L $CaCO_3$	430±23.4	1090±15.6	100±5.6	1210±32	4500±67	310±6.2	378.3	530.39
Flouride mg/L F	7±0.1	3±0.1	20±2.6	6.4±0.8	6.7±0.5	6.4±1.1	1.3	1.82
Iron H mg/L Fe	0.15±0.01	0.1±0.001	0.45±0.1	0.3±0.01	0.15±0.001	0.15±0.01	0.055	0.078
Mg mg/L	7±0.3	0.018±0.001	2±0.09	5±0.7	2±0.3	4±0.8	0.465	0.652
Mn mg/L	0.03±0.001	0.029±0.001	0.02±0.006	0.16±0.01	0.003±0.001	0.022±0.001	0.012	0.017
Sulphate mg/L SO_4	195±3.4	0.018±0.0001	150±6.6	185±5.6	57±1.7	195±5.4	5.73	8.03
K mg/L	27±1.5	115±12.7	2.3±1.1	12±1.6	21±1.8	25±1.4	0.0262	0.0368
Phosphate mg/L PO_4	0.35±0.1	0.69±0.1	7.8±0.9	0.68±0.01	34±1.2	0.69±0.1	0.498	0.698
Total cholorine mg/L CL	0.16±0.01	0±0	0.1±0.01	0.07±0.001	0.02±0.001	0±0	0.0156	0.0219
Zn mg/L	0.27±0.01	0.2±0.01	0.35±0.01	0.21±0.01	0.05±0.001	0.09±0.001	0.045	0.064
Nitrate mg/L N	0.189±0.01	0.2±0.01	0.08±0.001	0.41±0.01	0.185±0.01	0.325±0.1	0.069	0.097

*:±SE

Table 3: Hydro-chemical analysis of water samples obtained from different hot springs at Al-Laith area, Saudi Arabia springs measured in the field

	Darakah	Al Masal	WadiMarkub	Al Rakaa	Ghamika	BaniHillal
Temp. °C	37.8	43.6	55.2	43.7	77	42.1
Conductivity mg/L	8706	7922	9369	7924	6799	4591.8
TDS ppm	4532	3794	3863	3789	2227	2165
DO mg/L	2.67	0.18	0.39	0.35	0.35	3.8
pH	7.07	6.8	6.55	6.7	7.59	7.28
EC µS/cm	7062	6030	6019	5904	3470	4591.8

Table 4: Correlation coefficient matrix between physicochemical characteristics in different hot springs

	Total alkalinity	Ammonia	Hardness	Flouride	Iron	Mg	Mn	SO_4	K	PO_4	CL	Zn	NO3	EC	Temp.	Condu-ctivity	TDS	DO	pH
Total alkalinity	1																		
Ammonia	-0.1782	1																	
Hardness	-0.476	-0.05406	1																
Flouride	0.7717	-0.4067	-0.306	1															
Iron H	0.9493**	-0.3362	-0.2044	0.8141**	1														
Mg	-0.05127	-0.4896	-0.05587	0.02246	0.01519	1													
Mn	0.3564	-0.2083	-0.1306	-0.1447	0.3449	0.5317	1												
SO_4	0.2853	-0.7684	-0.5323	0.2716	0.2365	0.5218	0.4033	1											
K	-0.3691	0.9759	-0.01057	-0.5713	-0.5278	-0.4589	-0.2394	-0.7315	1										
PO_4	-0.2835	-0.2498	0.9077**	0.0766	0.01199	-0.104	-0.3504	-0.4232	-0.2466	1									
CL	0.1099	-0.2832	-0.4734	0.5136	0.06203	0.5344	-0.2355	0.4025	-0.3054	-0.2285	1								
Zn	0.4752	0.1563	-0.5522	0.6927*	0.3694	0.09965	-0.285	0.002495	0.02297	-0.2935	0.7721	1							
NO_3	0.03077	-0.1307	-0.05454	-0.5103	-0.01439	0.2207	0.8342*	0.3704	-0.07082	-0.356	-0.5515	-0.678	1						
EC µS/cm	0.1673	0.2388	-0.1673	0.1886	0.1416	0.5961	0.244	-0.1328	0.1514	-0.1931	0.5591	0.6359	-0.2355	1					
Temp.	-0.09151	-0.2202	0.8514**	0.2153	0.1954	-0.1939	-0.3202	-0.4499	-0.26	0.9771**	-0.2647	-0.2098	-0.3748	-0.1836	1				
Conductivity	0.2226	0.1573	0.04922	0.3275	0.2794	0.521	0.1573	-0.2488	0.04164	0.08444	0.4942	0.6203	-0.3635	0.951	0.1174	1			
TDS	0.1714	0.2211	-0.1671	0.197	0.1485	0.6078*	0.249	-0.119	0.1338	-0.1893	0.5668	0.6357*	-0.2341	0.9998**	-0.1804	0.9522**	1		
DO	-0.3146	-0.3444	-0.4241	-0.1876	-0.4358	-0.01688	-0.2195	0.6206*	-0.1954	-0.3737	0.2051	-0.2002	0.1429	-0.5496	-0.4786	-0.7147*	-0.5455	1	
pH	-0.7806*	-0.2483	0.6669*	-0.4644	-0.6149*	-0.1447	-0.4269	-0.1215	-0.08305	0.6273	-0.2879	-0.6643*	-0.04239	-0.6079	0.484	-0.5211	-0.6059	0.3809	1

** Correlation is significant at the 0.01 level (1-tailed).

* Correlation is significant at the 0.05 level (1-tailed).

pH: The pH of groundwater varies within small range (6.55–7.59) which is suitable for growing the thermophilic bacteria [16]. Three hot springs (Ain al Darakah, Ghamika and BaniHillal) elaborate a slight trend of alkaline chemical reaction, while the other three springs (Al Masal, Al Rakaa and WadiMarkub) elaborate to slight trend of acidic chemical reaction.Previous studies recorded that the pH correlated with temperature in different seasons in different hot springs [1]. According to the American Public Health Association (APHA) standards for drinking water, a pH range of 6.5 to 8.5 is recommended for drinking water [29]; all pH values recorded in the present study were in the allowable limits.

Electrical Conductivity: The electrical conductivity (EC) varies from 3470 to 7062 µS/cm. Table (3) shows that all water sample can be considered as brackish water type where, electrical conductivity (EC) was found to be a good indicator of the water quality [30, 31]. In the current study, the average of electrical conductivity varied from 3470 to 7062 µS/cm. Due to the presence of high amounts of minerals in the majority of the studied hot springs it showed high conductivity values.

TDS ranged between 2165 to 4532 ppm and recorded a high positively correlation with electric conductivity and slightly positive correlation with Zn (Table 4). It is well known that the highest desirable limit of TDS in drinking water is 500 mg/L [29] and the maximum permissible limit of TDS of drinking water is 2000 mg/l; so there is no spring is allowed for drinking based on its TDS value.

Such a wide range of EC and TDS values indicates that hydrochemistry of hot springs water is controlled by various hydrochemical processes such as anthropogenic pollution and water–rock interaction [32].

Calcium Hardness: The calcium hardness showed significantly differences between the majorities of hot springs and ranged between 100 in WadiMarkub spring to 4500 mg/L $CaCO_3$ in Ghamika Ghamika spring. Water hardness of the studied springs showed a positively correlations with phosphates, temperature and pH; at the same time hardness showed a negatively correlation with sulphates (Table 4). Generally, these high values of total hardness could be related to lithology of the aquifer matrix, which is mostly formed of weathering products of the surrounding basic and intermediate igneous rocks of the Arabian Shield [2, 4, 33].

Nitrates: The NO_3 concentrations in the studied hot springs were within the range of 0.08–0.32 mg NO_3/L. The highest nitrate level was recorded in BaniHillale (BanyHilal) and the lowest value recorded by WadiMarkub (Al-ainAlharra). Nitrate values in the present study indicate aerobic conditions of the shallow groundwater, which leads to oxidation of these nitrogen compounds into NO_3. The nitrates ions in the tested hot springs were within the permissible limit given by WHO [34].

Ammonia: Concentrations of ammonia were not significantly different, ($P< 0.05$, $P<0.01$), among all hot springs except Al Masal hot spring, which recorded high significant value of ammonia (21 mg/L). Most ammonia is produced by bacteria in water and soil as an end product of plant and animal waste decomposition. Aquatic plants quickly remove ammonium from the water. That is because aquatic plants vastly prefer ammonium over nitrates as their N source. In the present study ammonia showed a positively correlationwith Potassium and a negatively correlation with sulphates (Table 4).

Fluoride, Manganese and Zinc: Fluoride values ranged between 3 and 20 mg/L; WadiMarkub spring exhibited the highest value while, Raghaa showed the lowest one. Fluoride recorded a positively correlation with Iron and Zinc. The high value of fluoride in WadiMarkub spring above the permissible limit (1.5 mg/L) and hence possesses a serious concern [34].

Hot spring rich with Fluoride is well known in granite aquifers in other countries in the world, like India [1]. Manganese contents ranged between 0.003 to 0.16 mg/L and did not exhibited any significant correlations with other parameters. Zinc values ranged between 0.05 to 0.35 mg/L with a positive correlation with Iron and Fluoride. According to the WHO [35], no standards have been established for TDS, sodium, potassium, hardness and sulfate. The only standards that have been established are based on taste. The nitrate standard, however, is based on health effects. This also applies to the fluoride standard, but depending on local climatological conditions and the amount of water consumed, it is sometimes difficult to meet this standard. The chloride standard is primarily based on the undesirable taste effect at a concentration higher than about 250 mg/L. In the current study total chlorine ranged between 0 to 0.01mg/L under the permissible limit (5 mg/L).

Sulfate, Dissolved Oxygen, Magnesium and Potassium: Sulfate is one of the least toxicanions; however, the presence of a high concentration in the drinking water may lead to dehydration, stomach complaints and possibly diarrhea [29]. In general, the adverse effect on the taste is said to be minimal at levels of sulfate lower than 250 mg/l. The 50 mg/l standard for nitrate is based on health effects. The WHO [35] standard for fluoride of 1.5 mg/l is also based on health effects. A higher concentration increases the chance of skeletal deformations (fluorosis). The average alkalinity ranged from 20 in Ghamika to 175 mg/L in Wadi Markub. The alkalinity is the main physical parameter that can be attributed to the phytoplankton diversity [36, 37]. The alkalinity is directly related to the abundance of phytoplankton since they dissociates bicarbonate into carbonates and carbon dioxide which leads to the increase in alkalinity [37]. The average of dissolved oxygen (DO) content varied from 0.18 to 3.8 mg/L and was negatively correlated with temperature and phosphates, on the other hand DO showed a positively correlated with Mg and sulphates. This negative correlation between DO and temperature was reported in many previous studies [1]. The average of chlorine (Cl) was 0.06 mg/L, exhibited the highest value in Ain al Darakah spring and showed positively correlated with Mg and sulphates. All hot springs fall under permissible limits (5 mg/L) recommended by WHO for drinking water [35]. The average value of Magnesium varied from 0.01 to 7 mg/L; however, it showed a decreasing trend with increasing of temperature. The average of the total iron content varied from 0.1 mg/l to 0.426 mg/l. In water hardness, the cations like calcium, magnesium, iron and manganese contribute to the total water hardness. Nutrients are essential for survival, reproduction and growth of phytoplankton and in an aquatic environment phosphate ($PO4^{-3}$) is one of the limiting factors for the productivity of phytoplankton [38]. The average phosphate concentration ranged from 0.35 to 7.8 mg/l and highest was recorded in WadiMarkub spring, which may be attributed due to the anthropogenic activities. Presence of traces of phosphate provides proof for the presence of planktonic organisms [1]. Potassium element in the present study ranged between 2.3 in WadiMarkub spring to 115 mg/L inAl Masal spring Figure 2 shows classification of the studied hot springs and indicate that BaniHillal springs is distinguished from the other five springs according to its physicochemical characters and

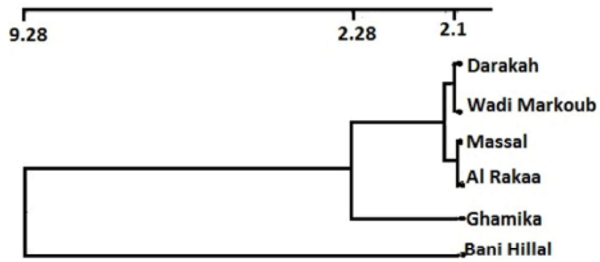

Fig. 2: Ward Classification of the studied hot springs

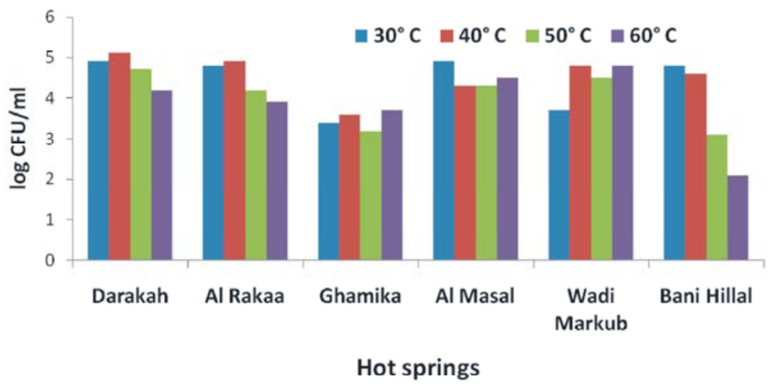

Fig. 3: The total bacterial count in the hot spring samples

it was appeared in the field by its surrounding flora which was used as fodder by chattels, while Ghamika spring separated from the rest springs by the high water temperature.

Determination of Bacterial Count: The total counts of bacteria in samples are represented in Figure 3. The total count ranged from 150 CFU/ml to 146x10^{3}CFU/ml. The higher bacterial counts observed within samples collected from hot springs of Ain al Darakahh, Al Rakaa and BaniHillal at temperature between 30 to 50°C. Low bacterial counts observed in hot springs of Ghamika and WadiMarkub. The hot springs possess low-density bacterial population at 60°C in all hot springs samples. Khiyami *et al.* [16] found that the total counts of bacteria in samples isolated from geothermal springs in Gazan and Al-Laith were from 170 to 1320 CFU/ml. Also another work [39] reported that the total counts of thermophilic bacteria isolated from four hot springs in Morocco were very low (50-5000 CFU/ml). The low number of bacteria could be attributed to the microorganisms in these geothermal springs are fastidious and exist in limited number.

Floristic Composition: The number of plant species recorded within the studied areas varied considerably not only related to the size of the areas but also to other factors, such as diverse environmental conditions, mainly moisture content.Twenty-seven species belong to fifteen families were recorded in the studied area (Table 5). Gramineae was the dominant family, represented by nine species followed by Solanaceae (three species), Leguminoseae and Cleomaceae (two species for each), while the rest families were represented by only one species for each.Therophytes were the dominant life form (37 %) followed by Chaemophytes (26%), while Phanerophytes recorded the lowest life form.Chorological characteristic of the recorded flora showed that Saharo-Arabian regionelements recorded the highest number (29.6%) followed by Sudanian elements (18.5.1%). The studied area belong to The Nubo-Sindian Province which is a part of the Sudanian Region [27] or Nubo-Sindian local center of endemism belonging to the Saharo-Sindian regional zone [40] stretches in Saudi Arabia over a narrow strip along the Red Sea coast north of Makkah as well as along Arabian Gulf coast. Life form and chorological results in the present study agree with our previous study in other locations in Saudi Arabia [41]. Saharo-Arabian elements showed the highest species number because plant species in this region show the usual ways of adaptation to aridity and very high temperature in such a harsh environment [42].

Table 5: Life form and chorology of the recorded species in Al-Laith area, Saudi Arabia

	Family	Species	Life form	Chorology	Hot Springs					
					Darakah	Al Masal	WadiMarkub	Al Rakaa	Ghamika	BaniHillal
1	Amaranthaceae	Aervajavanica (Burm. f.) Juss. ex Schul	Th	TR	-	-	-	-	-	+
2	Cleomaceae	*Cleome droserfolia*(Forssk.)Delile	Ch	SU	-	-	-	-	-	+
3		*Gynandropsisgynandra*(L.)Briq.,Ann	Ch	TR	-	-	-	-	-	+
4	Convolvolaceae	Convolvulus spinosusBurm. f.	Ch	SA	-	-	-	-	-	+
5	Cucurbitaceae	*Citrulluscolocynthis*(L.) Schrad.	Th	SA	-	-	-	-	-	+
6	Cyperaceae	FimbristylisbisumbellataForssk.	Ge	SA	-	+	+	+	-	-
7	Gramineae	*Polypogonmonospliensis*(L.)	Th	SA+ME	-	-	-	-	-	+
8		*Pennisetumsetaceum*(Forssk.) Chiov	He	SA	-	-	-	-	-	+
9		*Cenchrusciliaris*L.	He	SA+SU	-	-	-	-	-	+
10		*Cynodondactylon*(L.) Pers.	Ge	Cosm	+	+	+	+	+	+
11		*Aeluropusmassuensia*L	Ch	IT+SA	-	+	+	+	+	-
12		Chlorisvirgata Sw.	Ge	IT+SA	-	-	-	-	-	+
13		Diplachnefusca (L.)P. Beauv	Th	TR	-	-	-	-	-	+
14		Echinochloacolona (L.) Link	Th	TR	-	-	-	-	-	+
15		Leptochloafusca (L.) Kunth	He	TR	-	-	-	-	-	+
16	Juncaceae	*Juncusrigidus*Desf.	Ge	IT+SA	-	-	-	-	+	-
17	Leguminoseae	*Tephorosianubica*(Boiss.) Baker	Ch	SU	-	-	-	-	-	+
18		*ProsopisJuliflora*(Sw.) DC.	Ph	SA	-	-	-	-	+	+
19	Malvaceae	Abutilon pannosum (G.Forst.) Schltdl.	Ch	SU	-	-	-	-	-	+
20	Mullginaceae	*Glinuslotoides*L.	Th	ME+IT	-	-	-	-	-	+
21	Scrphulariaceae	Bacopamonnieri (L.) Wettst.	Ch	SA	-	-	-	-	+	+
22	Solanaceae	*Daturainnoxia*Mill	Th	Cosm	-	-	-	-	-	+
23		*Solanumincanum*L.	Th	SU	-	-	-	-	-	+
24		*Solanumnigrum*L.	Th	ME+IT	-	-	-	-	-	+
25	Tamaricaceae	*Tamarixnilotica*(Ehrenb.) Bunge	Ph	SA	-	-	+	-	+	+
26	Typhaceae	Typhadomingensis Pers.	Ge	SA	-	-	-	-	+	+
27	Zygophyllaceae	*Tribulusmacropterus*Boiss.	Th	SU	-	-	-	-	-	+
28	A	*Chara asp.*			-	+	-	-	-	-

The life forms are: Ph, phanerophytes; Ch, chamaephytes; G, geophytes; He, hemi-cryptophytes and Th, therophytes. The chorotypes are: COSM, cosmopolitan AM, American; IT, Irano-Turanian; ME, Mediterranean; SA, Saharo-Arabian; SU, Sudano-Zambezian and TR, Tropical.

Table 6: Hydro-chemical analysis of soil samples collected from hot springs in Al-Laith area, Saudi Arabia springs

Hot springs	Salinity (Ms/cm)	pH	Potassium	Ca hard	$SO^{-}4$	Mg	Soil texture % Sand	Silt	Clay
Al Rakaa	3.3±0.5	6.9±0.2	100±7.5	1500±165	775±17.5	45±0.9	58	29.7	12.3
BaniHillal	3.6±0.4	7.8±0.1	0	1550±22	875±25.3	85±0.8	51.2	33	15.8
Ghamika	5.3±0.7	7.4±0.1	43±4.5	305±55	860±32.5	110±0.5	61.6	32.2	6.2
Massal	75.5±1.8	7.3±0.1	380±25.3	48500±600	13±4.1	325±1.3	55	28.4	16.6
Darakah	14.1±0.9	7.4±0.2	185±15.5	520±55	840±47.2	125±3.2	64.1	29.6	6.3
WadiMarkub	0.93±0.05	7.7±0.3	41±4.1	710±60	925±15.3	45±2.2	78.6	16.4	5

Soil Analysis: It is well known that soil temperature is the main factor controlling vegetation pattern on geothermal fields elsewhere in the world, for example Ponponyama, Japan [11, 43], Iceland [44], Mt Melbourne, Antarctica [14] and the South Sandwich Islands, Antarctica [15]. Soil analysis (Table 6), showed that all sites has a slightly alkaline soil except that of Al Rakaaspring, which recorded slightly acidic one (pH: 6.9). Al Masal hot spring showed the maximum level of soil salinity (75.5 Ms/cm) while WadiMarkub hot spring recorded the lowest value (0.93 Ms/cm). All soils showed sandy textures particles. Al Masal soil recorded the highest values of K, Mg and total hardness, while WadiMarkub soil exhibited the highest value of sulphate.

The most obvious results that the presence of the invader species *Prosopisjuliflora* in large area (about 5 Km X 2.5 Km). In arid regions *P. juliflora* compete with many plant species for soil moisture and depend mainly on lateral roots, which grows deeper during drought and competes successfully with grasses by using soil moisture in subsoil layers [45]. *P. juliflora*, an offensive, fast spreading and highly adaptable species for all soil types, including saline alkaline soils.However, Singh [46] stated that *P. juliflora*is seen almost everywhere except cold deserts and stagnant water areas (in our project we detect *Prosopis* in stagnant water). *P. juliflora* can tolerate high soil salinity [47], has high nutrient uptake capacity and tolerate temperatures up to 46°C. Mesquite has been defined as a phreatophyte (a phreatophyte: is a deep-rooted plant that obtains a significant portion of the water that it needs from the phreatic zone (zone of saturation, or the capillary fringe above the phreatic zone and often have their roots constantly in touch with moisture) which resists drought [48]. *Bacopamonnieri* is a perennial or sometimes annual, it grows gregariously and often forms dense mats in marshy places, the banks of pools and along streams and ditches. It can tolerate brackish water [49].

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