INDIAN HOT WATER SPRINGS: POTENTIAL SOURCE OF THERMOPHILIC MICROBES

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Geothermal features like hot springs (HS) started gaining attention of researchers worldwide especially among those who are working for extreme environments. Hot water springs or hydrothermal springs are found in many parts of the world and India is also bestowed with about 400 big and small HS. These natural springs have higher water temperature (45-150˚C) as compared to other common water bodies (10˚-15˚C).Generally, the temperature of rocks increases with depth (geothermal gradient). Water percolate deep into the earth crust gets heated when comes in contact with hot rocks. When water temperature reaches sufficiently high pressure generated due to heating (steam pressure) forces water to rise through cracks and fissures of the ground back to the earth's surface (Figure. 1). Generation of hot water in active volcanic zones happen due to the heat produced from the Earth's mantle (magma) whereas water gets heated due to geothermal heat in hot springs of non-volcanic zones.

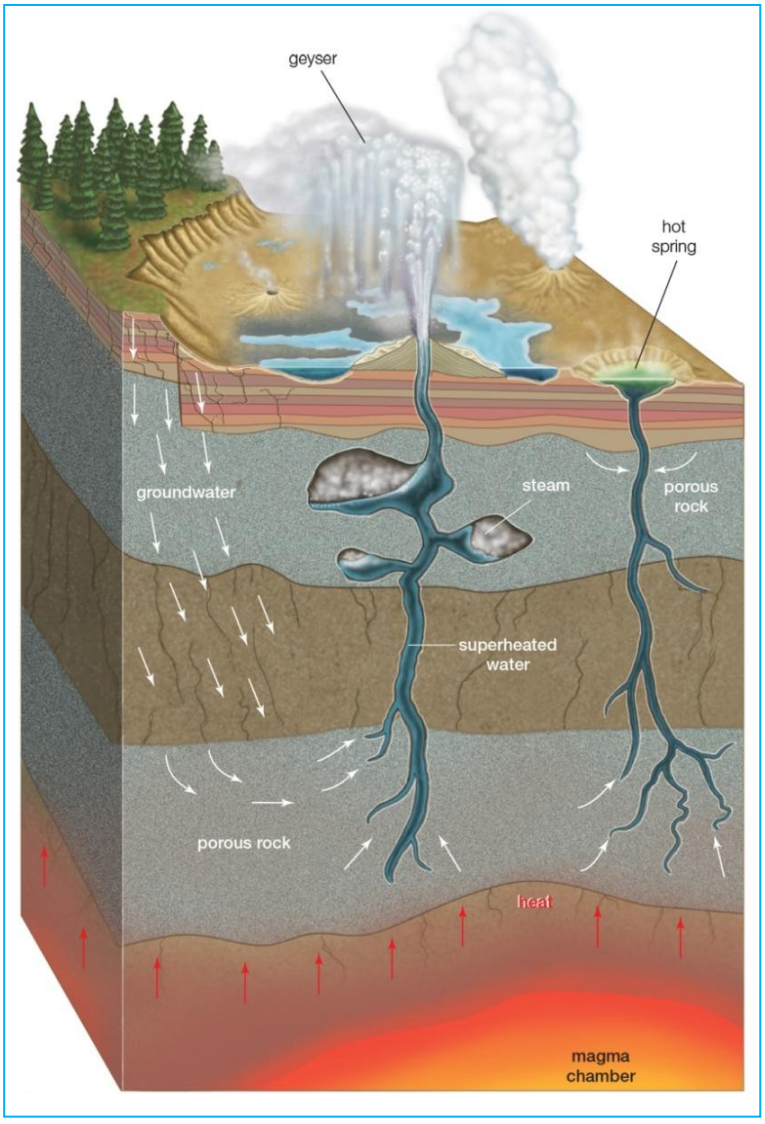

Figure 1: Hot spring formation
(Source: https://www.britannica.com/science/volcano/Hot-springs-and-geysers)

The heated water can hold more dissolved solids, high mineral content and everything that is necessary for the creation of life.

CLASSIFICATION OF HOT SPRINGS

Based on the type of elements present hot springs have been classified as

1) **Sulphur springs:** This water have white colour and characteristics sulphur smell. This water is believed to cure chronic bronchitis and dermatitis.
2) **Salt springs:** Generally found in Japan, which are colourless and don't produce lather with soap. These can absorb more heat thus also called as heat spring. The water of these springs helps in lowering the back pain and poor circulation.
3) **Aluminium springs:** Usually found in volcano zone. These helps in getting rid of skin diseases and athletes foot and lines.
4) **Mirabilite spring:** These are colourless and salty tasting springs. These contain sodium which improves blood flow and helps to cure hypertension and wounds.
5) **Melanterite springs:** These are iron cation and sulphur anion springs. These become copper coloured when exposed to air due to oxidation. Highly acidic melanterite springs contain large amounts of copper and manganese and helps in curing eczema and anaemia.
6) **Iron spring:** These springs contain more than 20mg of iron ion per 1kg of water, which on exposure to air turned dish in colour. These have more heat and have metallic taste. Anaemia and eczema can be cured by this water.
7) **Acidic iron springs:** These are skin irritating springs and having pH<3.These also cures eczema symptoms due to its powerful disinfecting action.
8) **Alkaline spring:** These are hot springs with hydrogen carbonate anions and sodium cations. These are also known as hot spring for beauty because these sanitizes wounds and improve skin conditions
9) **Radium springs:** These springs contain thoron or radon. These hot water springs have a strong sedative effect and are effective at curing menopausal disorders in women, easing neuralgia and rheumatism.

Based on the form of eruption hot springs have been further classified as **1. Geyser:** Erupts as a Jet (hot water and steam pressure), **2. Fumarole:** Erupts in the form of steam, **3.Mud pot:** Erupts in the form of water mixed with mud and clay.

In India, HS are not found on the basis of volcanic activity but are formed due to orogenic activity and convectional circulation of the heat from one layer of the earth crust to another layer which make it warm due to uneven temperature of the both layers of the earth. Geo-technologists have divided the Indian hot water springs based on tectonic trends, continental rifts and plate margins into (1) NW-SE Himalayan arc system with continuation to Andaman Nicobar Island, (2) Son-Narmada-Tapti, (3) West Coast Continental margins, (4) Parts of Gondwana-Grabens, (5) Regions of Delhi folding. In India, Hot Springs present in many states (Table 1, Figure 2).

Figure 2: Anhoni hot spring located in the Chhindwara district of Madhya Pradesh (India)

Since ancient times, hot springs have been used for medicinal purposes. There has been a long history of Japanese people bathing in hot springs for sanitation. In India, people bathe in hot springs to treat skin diseases and stomach and rheumatic disorders. It is also believed that women taking a bath in hot springs during festival periods will be cured of infertility. Many reports have shown that the water of hot springs may have therapeutic effects for treating a number of diseases (e.g., cardiovascular disease, dermatitis, spondylitis, asthma, inflammatory arthritis, rheumatic disease, and rhinosinusitis).

Table 1. List of some famous Hot Springs located in various states of India

LOCATION (STATE)	NAME OF THE HOT SPRING
Maharashtra	Ganeshpuri, Akloli, Vajreshwari
Himachal Pradesh	Manikaran, Khirganga, Tapri, Tattapani, Garam Kund
Karnataka	Bendruteertha, Irde, Bandaru
Madhya Pradesh	Chavalpani, Anhoni, Dhunipani
Chhattisgarh	Tatapani
Bihar	Suryakund, Gaya
Sikkim	Phurchachu (Reshi), Yumthang, Borang, Ralang, Taram-Chu and Yumey Samdong
West Bengal	Bakreshwar of Birbhum, Tantloi, Kendughata, Bholeghata, Tantni,
Uttarakhand	Gaurikund, Taptkund, Suryakund
Arunachal Pradesh	Hotspring of dirang area, West Kameng
Orissa	Taptapani hot spring in Ganjam district, Atri hot spring in khurda, Deulajhari hot spring in Angul, Tarabalohotspring in Nayagarh
Jharkhand	Tatta hot water spring, Jarom, BrahmaKund, Ramkund
Andhra Pradesh	Ushnagudam
Tamil Nadu	Mannargudi
Kerala	Varkala
Andaman and Nicobar	Unnamed hot springs

MICROBIAL DIVERSITY OF HOT SPRINGS

Apart from their therapeutic value, hot springs can also act as a model system for studying extraterrestrial life. Microbial diversity in hot springs is dictated by environmental physicochemical characteristics including temperature, pH, redox potential and concentration of trace elements. In terms of microbial diversity, temperature is one of the most important factors that govern species abundance and distribution. High temperature exerts pressure on microbial species, which leads to the selection of specific flora.

The microbes that grow at high temperatures have bioactive molecules that are commercially important because of their thermo stability and thermo activity. The best example is Taq DNA polymerase obtained from *Thermus aquaticus* in the thermal vents of Yellowstone National Park. Researchers started exploring similar environments in different parts of the world, such as North America, China, the Philippines, Japan, India, Russia, and other countries.

The microbes isolated from these have special qualities and have thermo stable bioactive molecules. So, there is wider scope of the study of the thermophiles for biotechnological uses and industrial manufacturing processes, because of their existence in the extreme temperatures as high as 150˚C. Also pH range of the thermophiles is wider i.e.6-11.

Although there is a large body of literature available about microbial diversity studies in hot springs, only a few studies focused on Indian hot springs and their microbial diversity analysis. Researchers of ICAR - Indian Institute of Soil Science, Bhopal are also working to explore the agriculturally important microbial population from hot springs of Madhya Pradesh (Figure 2&3).

Figure 3: Water sample collection from Anhoni hot spring locate in the Chhindwara district of Madhya Pradesh (India)

Microbes like *Synnechococcus elongates, Shewanella algae, Aeromonas algae, Thermus thermophilus and Desulfotomaculum luciae* isolates have been reported from Bakreshwar hot water spring, West Bengal. These are iron reducing in nature and can be used in acidic soils.

Manikaran hot water spring has microorganisms namely *Bacillus sp., Paenibacillus pabuli, Arthrobacter spp., Lysinibacillus spp., Rhodococcus sp., Kocuria sp., Staphylococcus sp., Microbacteriumoxydens, Pseudomonas psychrophila, Rhodococcus baikunurensis, Brevibacillus sp.* which has cellulose degrading enzymes, broad temperature and pH range and also these have tolerance to biocidal agents and abiotic stress tolerating ability which has immense use in agriculture.

Organisms from the Taptapani hot water springs of Odisha *viz. Escherichia, Aerobacter, Erwinia, Serratia, Xanthomonas, Pectobacterium, Photobacterium, Streptomyces and Aspergillus sp.,* are source of extracellular LAse which can be used to degrade lignocelluloses.

Microbispora sp.V2 obtained from Vajreshwari hot water springs, Mumbai was used to degrade chitin due to its extremely thermostable properties and acidophilic nature.

In Central India, there are reports of some microbes from hot water springs which may be useful in agriculture e.g. In Tattapani hotspring of Chhattisgarh *Anoxybacillus mongoliensis strain MB4* is capable of performing sulphur metabolism. Also, *Gulbenkianiamobilis strain MB1*isolated from Chhoti Anhoni hot water spring of M.P. helps in the mobilization of sulphur.

Bacterial species (*Bacillus cereus, Aneurinibacillus aneurivillyticus, Bacillus anthracia, Bacillus subtilis)* from Unani and Tuwahotsprings, Gujarat, possess multipotential functional properties and these can be exploited for their plant growth promotion and bio-control properties in arid and saline soils.

CONCLUSION

Till date, only few strains of thermophilic microbes has been explored and used in the biotechnological processes. Thermophiles can be well suited for the making of eco friendly materials i.e. paper and pulp industry. Unfortunately, these thermophiles have not been utilized or explored for agricultural purposes. In this regard, researchers have to put their step forward for studying these hot springs and discovering useful microbes which will be beneficial for agriculture.

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