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Hydro-Geo-Bio-Chemical Investigation of Geothermal Springs for Baleneotherapy and Thermophile Studies: Odisha, India

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Abstract: ***Hot springs had been of interest to religion, society, biology, and geology in past. The multi-faceted research on the hot spring is now expanded to extremophilic, microbial, metagenomic, water chemistry, food nutrition, agriculture and metallurgical investigations. Hot springs manifests at active places of past volcanism, tectonic activities, areas near shear zones, faults, fractures and fissures. The pressure gradient created between the crust and the atmosphere pipes out hot water.Hot springs (340numbers in India) has been identified in different fault /shear zones of India fromwestern/eastern Himalayas, SONATA zones in Peninsular India up toWestern ghats and Godavari garben. The State Odisha has 3, 3, 1 and 1 numbers of perrinial/intermitentsulphurous hot springs in it MSZ (Atri, Tarabalo&Deulajhari), NOBL(magarmunha, Banakhola&Badaberena), VSZ (Taptapani) and NSZ(Boden) respectively discharging <10cumec having temperature <70^0 C which are less scientifically explored. Three hydrothermal springs Tarabalo, Deulajhari and Badaberena are multiple outlets clustered in a patch of area. Elemental Analysis by Energy Dispersive X-ray Fluorescence (EDXRF) with EPSLON software bynon-destructive methods was employed to assess the quantity of element present in the water of the hot springs at Atri, Tarabalo lying in an iso fault zone MSZ and compared with similar results of hydrothermal units of Odisha and India. The baleneopathic and pelotherapic uses for health, wellness and ecotourism has been discussed for developing fitness and spa resorts as the water is not upto drinking standard.***

Keywords: Water chemistry, geothermal, ,shear zone , balneotherapy, Thermopile, spectrometry

1. Introduction

A geothermal spring is flow of water from underground (UG), heated at rock depth and evolved to surface by convection or pressure gradient where the water temperature is higher than the air of that place. Geo-hydrothermal springs are volcanic or tectonic origin. The hot springs originate in fracture zone or thermopiles in precamberian terrain.

Hot Springs are found all along the earth from equator to pole but more in Peninsular regions. The countries like Uganda, Columbia, Chile, United states (highest in number), India, Japan, Malaysia, Italy and Slovakia and many other countries of world has >20numbers of hotsprings (Wikipedia). Hot springs are generally volcanic or tectonic lay ongeothermal gradient origin or tectonic shear zones or lineaments.

India has a number of hot springs from Kashmir to KanyaKumari. The acknowledged hot springs are at Math, Bakreswar,(WB),Taptapaniand Atri(Odisha), Borong and Ralong (Sikkim), Manikaran (HP), Puga (J&K), Panamik (J&K), Taptakund Badrinath, GouriKundKedarnath, Sahasradhara (Uttarakhand), Vajreswari, Aravaliin (Maharashtra), Rajgiri (Bihar), Tattapani, Vashista, Khir ganga (HP), Dhunipani (MP),Chumathang (Ladakh) and many other hot springs in India (Wikipedia) and https://www. Indiatravelforum .in/threads/hot-springs-in-India.2148

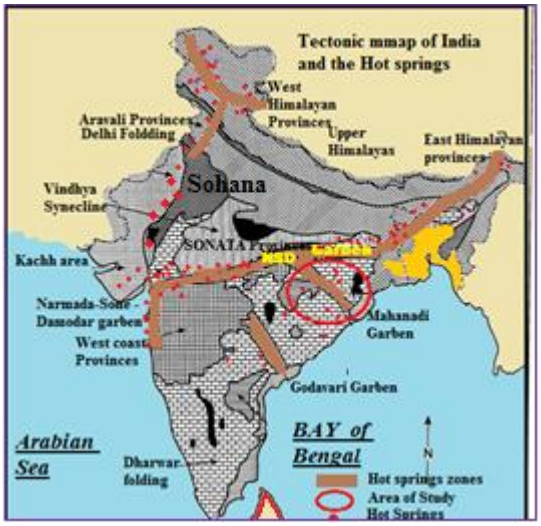

Figure 1: Study Area of hot springs and geothermal provinces, on tectonic map of India.

2. Review of Literature

Vasishta, P.C 1968[1]stated that some of the examples of the predominant forms of cyanobacteria common to all hot springs in India are Chroococcusyellowstonesis, Synchococcuselongatus. Var. amphigranulatus, Oscillatoriajasorvensis, O. tenus, O. filiforms, Phormidiumlaminosus, Lyngbyanigra and Mastigocladuslaminosus.Olive, E,.1990[2].Poddar et al., 2018[3], have reported that the water temp. and pH of hot spring ranges from 37^0 C to 99 °C and 6.8-10 respectively

which manifests conducive temperate zones for abundant growth ofthermophile bacteria's like phyla Firmicutes, Proteobacteria, Actinobacteria, Thermi, Bacteroidetes, Deinococcus-Thermus and Chloroflexi and some cyanobactrum. Water chemistry is the combination of the physical parameters like temperature (Temp.), turbidity, colour, suspended and floating matter, Where asthe Chemical parameters (elements, ions or oxides salt of Non-metals, metals, metalloids and lanthanides and actinides) dissolved oxygen (DO), nitrogen in various forms, chlorides, pH, alkalinity, pesticides, Hardness) and biological parameters (biochemical oxygen demand (BOD), chemical oxygen demand (COD), bioassay, coliform bacteria, pathogens, and species diversity), Kumar Naresh et al.,2013[4]. Springs that discharge ground water which has a temperature more than the normal local groundwater are called thermal springs Todd D. K., 1980[5]. The hot water from geothermal springs mainly contain oxides of dissolved minerals of Ca, Mg, Na, K, Si, Al, Fe, Mn and Li and evolve gasses like oxides, chlorides, bicarbonates and hydroxides of carbon , sulphur and other minerals such as fluorides, Borons and Arsenic,White et a; 1956[6], Rowe et al., 1973[7], Fourier et al 1976[8], Cowan D. A., 1992[9],Reysenbach et al., 2001[10],Erfurt p. J. 2011[11], Reddy D. V.et al ., 2013[12] and Porowski A., 2018[13].Hot springs contain even the life long before they reach the surface, and the warm water of the springs allows the abundant growth of the two organisms i.e. algae and bacteria to survive (called as thermophilic microorganisms) which were the ancient livesSen S. Ku., 2010[14].Kumar N. et al.,2013[4], reported that water of Vashista Hot spring is potable as absent of bacteria and satisfies WHO's portable water standard.Singh H. K. et al., 2014[15]reported that the reservoir of hot spring at Bakreswar and Tantloi hot springs has higher reservoir temp. 160 to 250^0 C.

KashidS.S.,et al.,2018[16]conducted water chemistry tests ofAravaligeothermal springRatnagiri district of Maharashtra and opined that the spring's water is not fit for drinking and only compatible with sanitation uses due to high temp, alkalinity, sulphur concentration and metal concentration. Telford et al. 1990[16]; Jacoby et al., 2009[17], and Singh H. K et al. 2015[18] reported change in (+)veto (-) vegravity anomalies, faults over hot spring areas indicating basement/mantle faults (deep seated), and uplift or mafic intrusion can be the heat sources of thegeothermal water. Hot springs are the base for the researchers working on global warming as the growth of both zoological and botanical species can be investigated under temperate natural water bodies.Bist S. S. et al, 2011[19],Mohanty S. et al. 2014[20]has reported the hot spring,Atri is in natural ecosystem and the spring lie on the sismic zones and tectonic fault areas. The fish fauna in the drainage water of the hot spring Atri are minor carps Puntiussophore, and Cirrhinusreba (occasionally), the murrelChannastriatus and prawns which were cultured in the drains of hot spring Yadav R. P., 2012[21] and Mohanty S., 2014[20].Verma et al, 2014[22]reported that Thermusand theThermusaquaticus can grow at pH 7.5, incubation temp. 65° C and incubation period was 96 hours.

3. Relevance of Study

Akkiraju V. V., 2018[23]reported that there is steady rise of surface air temperature (SAT) from 1860AD onwards alongwithfrustal warming particularly in peninsular region of North central India @ 1.0 ± 0.2°C for 129 ±18 years on the basis of the conduction by Fouriers Law and observed sequential variations in SAT (z=0) which diffuse gradually in the subsurface and causing temporary perturbations ΔT(z, t),$\frac{\delta^2 \Delta T(z,t)}{\Delta z^2} = \frac{1}{\alpha}\frac{\Delta T}{\Delta t}$ (one-dimensional heat diffusion equation) where z = the depth (+ downward) and α= thermal diffusivity of the earth. According to Working Group IPCC report (AR-5) in 2013-14, global SAT rise in 20th century @0.7^0C and MSL rise was 20cm. The Biennial Update Report (BUR) reported to UNFCCC MOEF, India in 2016 that the country shall suffer in four sectors i.e. agriculture, water, forests and human health due to climate change.About 50 million Indians along coast will be evacuated forMSL rise if global temperatures shall rise by 1.5°Celsius above today's level by 2100 (IPCC report AR-5)https://www.deccanherald.com/national/ipcc-report-india-be-highly-696813.html. From 2000 onwards 16 out of 17 years has gone hot in India and the temp is in an increasing trend, Mishra S. P. et al, 2018[24]. Similarly according to studies of the IUCN-2017, out of 91523 items of species 25821 numbers are threatened species of higher group such as vertebrates (152.69%),, non-vertebrates (158.75%) and plants (134.7%) respectively within the years 1997 to 2017Mishra S.P. 2018[25]. Under rising temperature and rate of defaunation, it is high time to search for the micro-organisms and thermophilicspecies that can grow under ground and in raised temp..Hot springs has gained importance for generation of geo-thermal energy, source for mineral water, aqua culture, balneotherapy,pelotherapy, agriculture, ecotourism and finally a novice source of research and economic source in 21st century.

The present study is related to geo-bio water chemistry of **Attri Hot Spring**in Khurda District. is around 10 km west of Khurda. Atri is famous for its perennial one point outlet hot spring with constant temperature ≈ 55 ^{0} to 57 °C converging within a well of 3m diameter evolving sulphurous water. **Tarabalo,**is in Bhapur block ofNayagarh District is famous for a cluster of four hot spring outlets dotted over an area of 8 acres. The main twin outlets are close where asothe two are at a distance of 30m and 50m from the main source. The HS is at a distance of 75 km from Bhubaneswar and at a distance of ≈20Km from the river Mahanadi. The four outlets have varying .temperature atTarabaloof 44 to 57°C. These two continuous discharging hot springs lie on isofault line over MSZ, so are ideal for studing the Hydro-Geo-bio-chemical investigation.The geological investigations, their classification, geo-bio-chemical notes, comparison with other hot springs of the region and therapeutic use of the hot springs in Odisha are detailed in the present study.

4. Methods and Methodology

4.1 Extremophiles

Extremophiles, are living organisms that canflourish in extreme settingsin hydrothermal pools in form of hot water with gases, or only gasses (Hot prings (geothermal units)or hot water gasses (geysers) or only gasses (fumaroles) to earth surface).Heat absorption capacity of water is high and a good moderator. Vouk'scategorisationextremophilicAtri HS as Acrothermal (50-70ºC) and Tarabalo as Euthermal (30-50ºC) Vouk V. 1950[1]. Some bacteria and a few protists can survive in the harshest and strangest of environments and so also some flora and fauna can thrive in hot spring water when it become cold. Extremophiles may be divided into two broad categories: extremophilic organisms *i.e.* bacteria, archaea, and eukarya, algae, fungi and protozoa which need extreme conditions to grow, and extremo-tolerant organisms which can withstand extreme physicochemical parameters though growing optimally at "normal" conditions. The different extremophiles are given in **Table 1.**

Table 1: The characteristic of different Hot springs classified as per Bio-chemical parameters

#	Classification	Extremophile (20^0 C to 122^{0} C)	Range of Temp.	Characteristic use	Source
A	**Temperature**				
	Mesophile (Peninsular).	Thermo Tollerant	20～ 40 ˚C	Formation of cyanobacterias,yeasts capable to formate, Algae growth,	Tong Yu, 2015[26] RothschildL2001[27]
	Low temp. Hydrothermal	Thermophile	40 ～60˚Cupto 80^0 C	PH: 6-7, Exist of Actinobacteria, thermostableenzymes (amylases, cellulases, chitinases, pectinases, xylanases, proteases, lipase, and DNA polymerases)	Tong Yu, 2015[26], Murugan Ku, 2014[28]
	Warm spring	hyperthermpophile, (Max growth $>80^0$C)	60 ˚C ～local boiling Temp.	Pyrolobusfumarii, (113^0 C) Pyrococcusfuriosus, (85°C) Anaerobic heterotroph Thermotoganeapolitana (100°C)Geo thermal marine sediments	Tong Yu, 2015[26] Schicho et al., 1993[29]
	Psychrophiles	Low Temp	max. growth $<15^0$ C	Some archaea, cyanobacteria &thegreen algae like Dunaliellasalina can withstand periods in saturated NaCl.eukaryoticpolyextremophilesBacillus in cold sea water ,Aerobic heterotroph, Polaro-monas vacuolata, Bacillus, cold sea water,Aerobic hetero trophPolaro monas vacuolata	Tong Yu, 2015[26], Rinker et al., 1999[30]
	Halophile (X-Cl, Br or I in %)	Halophile (High salinity)	<4 M NaCl ≥4–5 M NaCl	HalobacteriumhalobiumHypersaline waters, Aerobic heterotroph Halobacteriumsalinarum(4–5 M NaCl)	Tong Yu, 2015[26]
	Alkalinity (high pH v>9)	Alkaliphiles(Basic) Low, Medium High, Extreme	8-9, 10 ,11, even >12.8	eukaryotes can tolerate high pH ≈11, Natronobacterium, Bacillus firmus OF4, Spirulinaspp .(all at pH 10.5)	Rothschild L. 2001[27], Rampeloto P. H. 2013[31]
	Acidophiles (lowest pH)	Acidic(Low, Medium & High	pH values 1-5,Extremely acidic bacteria are found when pH<1	Metallosphaerasedula Hot acid pools (pH 2.0 at 75°C) Facultative chemolithotroph. Some eukaryotes, bacteria, and archaea can grow in sulphur pools. 3nos fungi, Acontiumcylatium, Cephalosporium sp. &Trichosporon Cerebriae , grow at ≈ pH 0	Tong Yu, 2015[26], https://biologydictionary.net/extremophile/
	Barophiles (101KPa=1atmos. = 1.013 bar)	Pressure(Atmospheric/High)	Weight-loving Pressure-loving	The Mariana trench ($11^0$22'N, $142^0$25'E) at deepest sea floor 10,898 m, organisms can grow at std NTP and yield piezophilic species that can grow at 70 to 80 MPa, but notbelow 50 MPa. This area to be ventured	Rothschild L., 2001[27]

Other extremophiles are Anaerobophiles (little O_2 needed for their metabolism), Hypoliths (Lives in deep rocks or deserts), Metallotolerant (lives in mines of heavy metals and metalloids),Radio resistant, Oligophiles, Osmophilesand Xerophiles (zero moisture conditions).

4.2 Hot Springs origin in India

The temperature of rocks maintains a positive geothermal gradient from earth's crust to mantle. The heat produced geo-thermally is absorbed by ground water (when in contact), rises to earth's crust if find a path like crack in sedimentary rocks, fissure or a fracture or a fault in shear zones, and lineaments. Oldham T.,1882[32] and Krishnaswamy et. al., 1982[33]reported about 340 hot springs in India out of which 113 can be explorable for geothermal power. Sarolkar P. B 2018[34], has reported that hot springs at Bakreswar in Mahanadi geothermal province has water temperature 40°C to 70°C and @ of discharge of 420 lpm with Gandwana rock genesis. Thermal springs of the Indian subcontinent hastemp. 32^0C- 99^0C or even moreOldham T.,1882[32]. They occur in groups along some major tectonic trends in some belts , plate boundaries, continental margins and rifts, mid-continental rifts, Cretaceous-Tertiary volcanism and regional fault zones. During volcanic eruption small fraction of the molten lava comes out but a lions share blocked at depths of 5 to 20 km in liquid form or as heated solid magma which release heat to neighbouring rocks. **Table 2.**

Table 2: The geo-bio chemical comparative studies of some major hot springs of India

#	Hot Spring	State/place	Geo thermal province	Study and results	Reference
1	Manikaran	Parvati valley, Kullu, HP,	Himalayan province	Elv: 1760m, Temp. 89^0C to 95^0 C (max India),thriving bacterial microphytes (Nutrient agar, Thermusagar, TPMY & King's B)	Muruganet al., 2014[28]
2	Unkeswar	Maharastra, RatnagiriAravali,	SONATA	Temp: 42°C,TS: 474, TDS:300, DO: 0.53mg/l, BOD: 0.3mg/l, pH:7.65, TH:120, SO_4: 40ppm, SPC: 7637 SPC/ml,MPN:25MPN/100ml.	Vyankateshet al. 2013[35], Bhusare et al, 2011[36]
3	Poloki Tatopani	Sikkim	Himalayan provinces	Temp:45-70°C,TS: 474, TDS:300, pH:8.0,EC:850, TDS:398, F:5.8, TH:39, PO_4:0.05ppm,	Sherpa N. T., 2013[37]
4	Borong, Tatopani	Sikkim	Himalayan provinces	Temp:45-70^0C,TS:474mg/l,pH:8.0, EC:850,TDS:398,F:3.96,TH:39, PO_4:0.05ppm,	Sherpa N. T., 2013[37]
5	Vashisht	Kullu, HP	Himalayan provinces	Temp:110^0C,TDS:400mg/l, pH:7.0, DO: 2.52mg/l BOD:4.8mg/l COD:0.048mg/l, TH: 165.2mg/l, Cl:197.4mg/l	Naresh Ku. Et al 2013[4]
6	Bara & Setpur Hot spring	Dumka, Bihar (CGC complex & Rajmahaltrap)	SONATA mega lineament	Temp:42-70^0C,SO_4:41.4-78.9 mg/l, Na:102.2-118 ppm, K:1.2-2.1mg/l, Ca:1.1-1.3 mg/l pH:7.1-9.5, Cl:47.9-97.5mg/l	(CGC)&Rajmahaltrap.SinghH. K. et. al.2014[14]
7	Soldhar and Ringigad Hot springs	Garhwal / Uttaranchal	Himalayan provinces	Temp:90^0C, pH:8.2 , P:0.003ppm, S:0.001mg/l higher amount of Zn:(2.4 and 2.7ppm), Fe (169 & 12ppm), Cu: 1.78ppm & Mn:10.3ppm (Soladhar)	Bhavesh Ku.et al. 2004[38]
8	Bakreswar	Birbhum, WB	SONATA	Temp: 40°C - 70°C Discharge: 6 lit/sec Chottanagpur Gneissic rocks at contact with Gondwana sediments. Helium Gas,pH: 7.4 - 9.2, No CO_2 , Oscillatoria sp., Navicula sp., Cyclotella sp. &Tetraëdron sp. thrive at Temp 51^0C	Sarolkar P. B. 2018[34]
9	Tural	Ratnagiri, Maharastra	WGB Hills (central)	Temp:60.5^0C, pH:7.35 , EC: 1359 µS/ cm PO_4:0.405ppm, SO_4:56.8mg/l, Cl:381mg/l, F:1.65mg/l, higher amount of Zn:(2.4 and 2.7ppm), Fe (0.174ppm), Cu:31.8ppm, Mn:31.6ppb, Li:1134ppb, Pb: 2.97ppm, DO:4.3mg/l. BOD:5.35 mg/l and COD:271.5mg/l respectively.	high water temp,. highconc.of Na, Cl,F& SO_4, Kashid et. al. 2018[15]
10	Aravali(17° 08'N Lat. & 73° 19' E long.	Ratnagiri, Maharastra	WGB Hills (westcoast)	Euthermal, Temp: 40°C - 42°C, H_2 S odur, TDS:613.5mg/l, pH: 7.65,EC:1016µS/cm, Cl:179mg/l, PO_4 :0.49mg/l, Na: 119mg/l, K:22mg/l, SO_4 :47mg/l,F:1.33mg/l, Fe:0.075mg/l, Pb:0.0055mg/l, Cu:trace, Mn:0.0021, Do:4.15mg/l, BOD:28.25mg/l, COD:91.5mg/l	TC > WHO's std,Non potable and only can be used for domestic sanitation, Khasid et al, 2018[15]
11	Deulajhari (cluster hot springs,conjugate cold fresh & hot springs xist)	Athamallick, Angul, Odisha	MSZ, Mahanadi Province	Euthermal, Temp: 56°C - 69°C, H_2 S odur, pH:6.68-8.36, Cl:179mg/l, PO_4 :0.49mg/l, Na: 119mg/l, K:22mg/l, SO_4 :47mg/l,F:1.33mg/l, Fe:0.075mg/l, Pb:0.0055mg/l, Cu:trace, Mn:0.0021, Do:4.15mg/l, BOD:28.25mg/l, COD:91.5mg/l	Zimic V. et al., 2017[39]& Singh et al., 2016[40]

The predominant forms of cyanobacteria common to all hot water springs in India are *Chroococcusyellowstonesis, Synchococcuselongatus. Var. amphigranulatus, Oscillatoriajasorvensis, O. tenus, O. filiforms, Phormidiumlaminosus, Lyngbyanigra and Mastigocladuslaminosus.*

4.2.1 Geo thermal provinces, India

India has six geothermal provinces with clustered large numbers of hot springs are classified under the following geothermal zones under geo-tectonic and volcanic set up. They are Himalayan Province-Tertiary Orogeny belt, Areas of fault blocks ofAravalli belt, Naga-Lushi in West coastregions, Volcanic arc-Andaman and Nicobar islands, Deep sedimentary basin of Tertiary age such as Cambay basin in Gujarat, Radioactive Province- Surajkund, Hazaribagh, Jharkhand, Cratonic Province-Peninsular, India. The seven geothermal provinces in India are the Himalayas,(Sohana), West coast, Cambay, Son-Narmada-Tapi (SONATA), Godavari, and Mahanadi.The geo thermal zones can be classified as Hydrothermal, Geo-pressurized brines, Hot dry rocks and Magma http://shodhganga.inflibnet.ac.in/ bitstream /10603 /128758/11/11 chapter %201.Pdf.

4.2.2 The Mahanadi geothermal province

Through rock fractures, water penetrate into these hot rock zones, high temperature geothermal zones are formed. When find a path the hot water, water with steam, or steam released from a depth of 600 m to >3000 m forms a hot spring. There are eight major hot springs identified in Odisha.TheMahanadi geothermal province (MGP) has three of them i.e. Atri, Tarabalo and Deulajhari. The other three in north Odisha border line (NOBL) i.e. Magarmuha, Badabareni (Angul), Bankhol (Angul), has not been studied in detail till now. The old and known hot spring lies in Bansadhara basin, Taptapani (Ganjam), is studied by Athamallick (Angul) and Boden (Nuapada) in Odisha **Fig 4.** But more than 28 individual units of small/ large perineal/intermittent geo thermal units are in Odisha. A list of studies done by different geologists, biologists, physicist, chemist, environmentalists on the Hot springs of Odisha (Zimik et. al 2017[39], Singh Archana et al 2016[41], Pradhan B et al, 2016[42], Mohanty S et al, 2014[20], Das et al.,

2012[43], Palita S. K, 2012[44]) and their results of studies are given in **Table 3.**

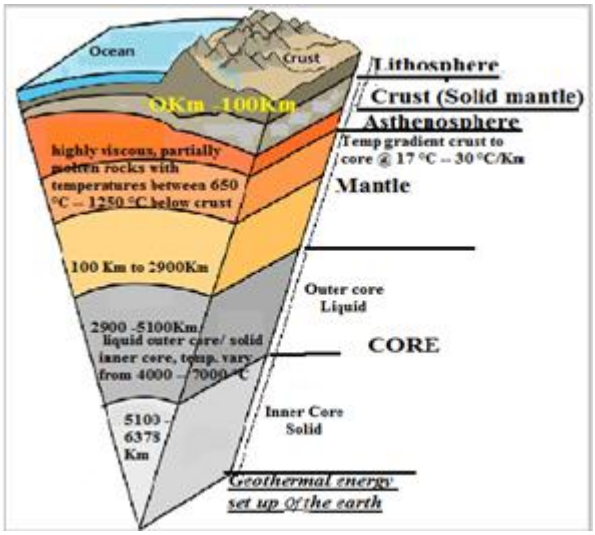

Figure 2: Geological Energy Setup of the earth http:// www.indiaenergyportal.org/subthemes_link.php?text=geothermal&themeid=13

4.3 Geologicalstatus of Hot Springs, Odisha

The hot springs, look as the identical but differ in physiognomies such as temp., flow rate, water chemistry and microorganism. The mineral water that percolate to deep UG become free from bacteria and microbes. But Iodine, mineral salts (mainly Sulpher) and CO2 can adapt thermal spring water from neutral to alkaline. The UG water attains a temp.≈28°C to 70°C in hot springs in Odisha zone.

All the hot springs in Odisha lies over north EGB Hills range. The Mahanadi Graben lies in Odisha, Chatishgarh Jharkhand and, Madhya Pradesh with a NW-SE orientation and emerge out from the Narmada-son river valley(SONATA) and finally joins sea between Devi river mouth and Paradip. Mahandigarben is surrounded by four shear zones i.e The Mahanadi shear zone (MSZ), The Nagabali shear zone (NSZ), The Koraput-Sonepur shear zone (KSZ), and The vansadhara shear zone (VSZ). The major hot springs Attri, Tarabalo and Deulajhari lies on the MSZ, Taptapani is adjacent to NSZ and Boden is near VSZ. The other small and minor hot spring i.e Magarmunha, Banakhola and Badaberena emerges adjacent to the left bank of river Brahmani and it lies near the North Odisha boundary fault (NOBF). These three hot springs have water of less temperature, ephimeral and of less outflow and lies within Bauxite/iron mines. In Mahanadi garben the hot springs present are Atri, Tarabol and Deulajhariin Mahanadi shear zone**Fig 3**whereas the HS Magarmunha, Banakhol and Badaberena lies in Brahmani shear zone.

Figure 3: The hot springs Deulajhari, Tarabola and Atri in MSZ, middle Mahanadi Basin(Goole)

4.3.1 The hot spring reservoirs

The source of hot springs in the peninsular India is meteore water which infiltrates deep UG reservoirs steadily to the earth crust or deep percolation of garben water through cracks or faults. On contact with the neighbouring rocks the water get heated up and become enriched with disolvedchemicals from different rocks. Finally it form a hot aquifer, as a UG reservoir of a constatnt temperature deep underground for a long period achieve and chemical equilibrium between the water and the rock chemicals. The reservoirs traverses due to action of pressure gradient and availability of path from one place to other in UG. When the aquifer encounter a fault zone, fracture/crack in a shear fracture/fault zone, it emerges out to the surface. During return the temperature of the adjacent roks cools down the hot water and additional chemical exchanges also occur

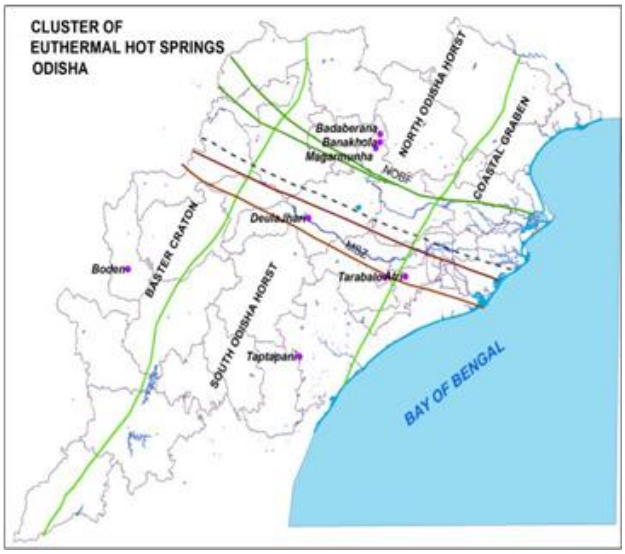

Figure 4: The hot springs in geological map of Odisha

A rapid change in discharge and hotness may occure and even a hot spring may become dry for a long period or short period (example: Narrow Gauge Springs and Cheops Mound USA). The body of water housing or the reservoirs of the hot springs can vary in size and temperature. They can be perennial or ephemeral or intermittent. The surface manifestations of geothermal resources are fumaroles, geysers, streaming grounds, hot springs, warm springsetc.A hot spring can geomorphologicallymanifest to a shape and changes the topography either to a caledra, fisher ridges, Terracettes, terraces, hot spring cones etc. The rift and grabens of Gondwana basins of the Damodar, the Godavari and the Mahanadi rivers are boosting areas for creation of hydrothermal sources but they are nonorogenic regions Razdan et al 2008[45].

4.3.2 Cause of sulpurours water in Hotsprings Odisha:

Sulphur, a natural mineral, is found primarily near hot springs and volcanic craters. Sulfur with water has rotten egg smell, caused due to formation of sulfur dioxide gas. Sulphur is plentiful element (≈0.25%) of our body. The most common gases produced at hot springs are H_2S, SO_2 or CO_2 in the hot springs of India. Rotten egg smell is produced around outlets where the water is evaporated and causes acid rain at times. Geologically Odisha has Renagali tectonic province and adjacent to ITCZ, The different cartoons lies in Odisha are Singhbhom carton, Bhandracarton,,the north Orissa craton (NOC), the west Orissa craton (WOC) and the Eastern Ghats mobile belt (EGMB). A numbers of shear zone lies in Odisha are MSZ, VSZ, NSZ, Ranipathar Shear zone, and KSZ.

Volcanic eruptions release large quantities of sulfur dioxide into the air which returnback to earth surface and accumulate in volcanic areas and infiltrate UG by meteore water. The hot springs release these sulfur in form of dioxide into the atmosphere. Hydrogen sulfide is released from marshes fossils and living organisms where biological decay is taking place in tectonically active areas. The H_2S coming in contact with UG water forms SO_2. The common impact of high conc. Of SO_2 cause acid rain.

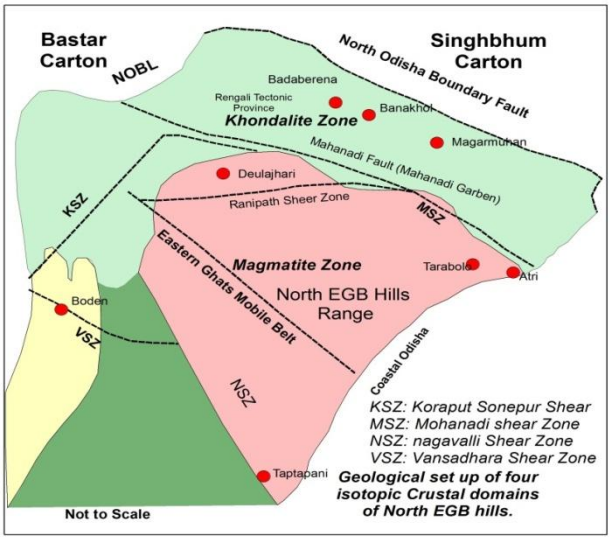

Figure 5: The geological set up of shear zones, faults, fractures and hot springs in central Odisha

The different faults that the geology map of Odisha exhibits are .The faults exists are Mahanadi fault, the Brahmani fault, Easternghats boundary faults, and Akul fault and the boundaries are separate as the north Orissa boundary fault, (NOBF) and the west Orissa boundary fault (WOBF).The NOBF fault rurunsalong Mahanadi rift. The north Odisha cartoon (NOC)comprises extensive occurrences of manylowprofile folds of banded iron formations (BIFs).With so geological anomalies it is evident that the tectonic activities were frequent in different shearzone and probably may be the cause of the Hotsprings. Particularly theMahanadi grabenhas two majorfaults i.e. NOBF and MSZ extending up to coast. These cutting of NW-SE trending faults all along the litho diverse the Mahanadi middle basin may be the cause of the formation of Atri**Fig 6**, Tarabol **Fig 7**and Deulajharihotsprings to the right of the course of the river.

4.4 The chemical composition of Hot spring water, Odisha

Attri in Odisha is well known for its hot sulfurous water located at a distance of 42 kms from Bhubaneswar, the capital of Odisha. The hot sulfur spring maintains a steady temperature of 55-57^0 C throughout the year. There is bathing complex adjoining the hot sulfur springs in Atri that affords a chance to take advantage of the curative powers attributed to the spring. It is situated amidsts EGB hills and in between the rivulet Rana and the river Malaguni and a vast extended clayey area at Daltotola. Discrete odour of sulphur is spread around the entire surrounding area**Table 3.**

Table 3: The thermotollerant Hot springs of Odisha and their physic chemical characteristics (Common to all hot springs Cl, SO_4 & Na ions in Odisha)

Hot spring	Temp.	pH	DO	Outlets	EC	Chemical characteristics	Extremophile
	In ^{0}C	No	Mg/l	No	µS/cm		Category
Attri (Natural Ecosystem)(20◦ 12′ 30″N, 85◦ 30′E; 40 m altitude)	55-57	7.42-8.93	499-534	Single but unique that continuity of hot water even in rainy season	689-1075	TDS 271mg/L, EC 380µs/cm, F: 4. 04mg/L, Cl:10.6mg/L,TH:48mg/L, K:1.4mg/L, Mg:1.2mg/L, Na:36.9 mg/L, Ca:18mg/L, SO4:29.4mg/L, P:2.3mg/l, Fe:0.11mg/l, As:0.0069 mg/l, Pb:0.0082mg/l	ThermophileSulphorous Discharge: 2.1ltr/s, Thussu J. L.2002[46]&2015[47]
Tarabalo,	55-58	7.96-	214-381	4outlets,encom	978	TDS 510mg/L, EC:744µs/cm, F: 11	Thermophile,Sulp

20◦12′20″ N,85◦17′50″E ;At 50 m alt.	Measured 45^0 C	8.89		passed by swamps/marshes (Daldal)		.48mg/L,Cl:143.5mg/L,TH: 18mg/L, K:2.8mg/L, Mg:1.2mg/L, Na: 90.1 mg/L, Ca:6mg/L, SO4:44.4mg/L, P:3.1mg/l, Fe:0.21mg/l, As:0.0012 mg/l, Zn:0.0015mg/l, Cd: 0.0115mg/l Pb:0.0158mg/l	hurous(Ca, F, K), Discharge: 2.7 lit/sBadhei et al, 2015[48],
Deulajhari, Lat. 20.7420 N, Long. 84.492, At ≈550m altitude,	43-69	6.68-8.36	563-595	24 springs Agni, Tapta, Hima,Ambruta,&labakushKunda (1.5sqkm)	2500	In pandanusforest(kiabana).TDS:780.4mg/l, EC 1130(µs/cm) AS:0.0012ppb,Zn:0.0014ppb, Pb: 0.00037ppb, Fe:0.17mg/l,SO4 (85.2 mg/L),Phosphorous:3.9mg/l, F:3.8 mg/l,Cl(173mg/L)TH:145.5mg/L, K:4.7mg/L,Mg:3.7mg/L,Na:109mg/L, Ca:54.5mg/L,Cd:0.00023mg/l	Sulphurous, No of outlets reduced from 84 to 24 Nos, Discharge 2.1 ltrs/s. Area Badhei et al, 2015[48]
Banakhol	42-45	5.05-6.74	16.9-17.6	Singlevent, Bauxite mines areas	29.1	NOBL Shear Zone, right of Brahamani basin, Buxite, Iron quartzite ore areas, TDS(mg/L)EC(ls/cm)F(mg/L)Cl(mg/L)Alkalinity(mg/L)K(mg/L)Mg(mg/L)Na(mg/L)Ca(mg/L)SO4(mg/L)	Zimik et al 2017[39]
Taptapani (19◦29′N, 84◦23′45″E; 450 m altitude	41	6.84-7.71	188-194	Single vent, Hill top, volcanic quarter nary /recent origin ≈f 75	274	In Bansadhara Shear zone, and EGB hills, TDS(mg/L)EC(ls/cm)F(mg/L)Cl(mg/L)Alkalinity(mg/L)K(mg/L)Mg(mg/L)Na(mg/L)Ca(mg/L)SO4(mg/L)	Discharge : 2-7 ltr/s (varies seasonally) Das et al., 2013[43]
Magarmuha	36-37	6.37-6.67	18.8-20.9	Singlevent, Bauxite mines areas	NA	Yet to be explored but a very small source. Water comes out from mouth of a stone crocodile. No tanks are made to pool discharge	In Pallahara block near village Inchidi.
Badaberena	36-40	8.64-8.80	165-186	3spots (1000sqm)	849.5	TDS(mg/L)EC(ls/cm)F(mg/L)Cl(mg/L)Alkalinity(mg/L)K(mg/L)Mg(mg/L)Na(mg/L)Ca(mg/L)SO4(mg/L)	In Angul district but less discharge
Boden	(av 32)	7.9	201-246	Single vent	1239	TDS:607mg/l, F: 0.79 (mg/L) Cl: 41.5(mg/L)Alkalinity :434mg/l, K: 1.66mg/l), SO_4 :36.9(mg/L)	Badhei et al, 2015[48]

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4.4.1 The Ecological Significance

The water emerging from a thermal spring is heated by geothermal energy and possesses its own hydrothermal ecosystem. The distinctive features of its specialized habitats have their life at elevated temperature, depressed DO level and high pH. Recently the hot spring zones are considered as geothermal hot spots where the geothermal nonrenewable energy sources can be generate electric power.

Figure 6: The Hot spring with bubbles at Attri, and different tanks Khordha

Baleneotherapy, Pelopathy include treating skin conditions as well as many prolonged chronic diseases like arthritis, joint pains and burns. The thermal spring water continues to be used today to treat inflammatory skin conditions, itchiness, eczema, rosacea and blemishes. Some of the more modern uses of Thermal Spring Water include toning, refreshing, and soothing irritation.

4.4.2 Isotopic studies of Geothermal Water

$^{16}O_8$ has three isotops i.e. ^{16}O (99.6%), ^{17}O (0.04%) and ^{18}O (0.2%). Craig 1996 has found a constant relationship

between the $\delta^{18}O$ and $\delta^{2}H$ (δD) values rain beyond evaporation are linearly correlated by: $\delta D = 8\ \delta^{18}O + 10$. The relation of $^{18}O/\ ^{16}O$ in waters, rocks, and most solutes are reported in ‰ (permil) relative to Vienna Standard Mean Ocean Water (VSMOW). These Stable isotope analyses of δD and $\delta^{18}O$ for the thermal and cold surface and the 14C ages specify that the cold surface water is relatively modern, while the hot water from hot springs are older, ≈ 5000 years old which .

Figure: Trarabalo Hot Spring TANK1)

Figure: Trarabalo Hot Spring TANK 2

Figure: Trarabalo Hot Spring TANK 3

Figure 7: The four hot springs in TaraboluaNayagarh District

The studies of borehole made by Akkiraju V. V. et al., 2018[23]resulted that the geothermal temperature up to 600m has depleted by 2^0 C in peninsular India which implies that the the reservoir of the hot springs must be lying more than 600m below the ground. This specifies that both hot and surface water are meteoric, but their source reservoir is different. This explicates the origin of hot springs are tectonic or volcanic origin in inactive terrane.

5. Present Study

5.1 The Hot Spring Attri and Tarabalo

The Eastern Ghats Belt (EGB) of India is of granulite facies and its northern fringe is dissected by WNW-ESE trending shear zones and fractures on the southern Mahanadi Basin and wastern catchment of Chilika lagoon.The hydrothermal springs at Atri is near Khordha and Tarbalo is near Nayagarh are within EGB Hills range and structurally NE-SW striking, SE dipping in E-W trending squashy Mahanadi Shear Zone. The water at outlet of the hot springs is ≈ 60°C where as immediate neighbouring tubewell at 100m distance was measured to be only 28.8°C.The existence of twin opositcharactered hot and cold sources also found at Deulajhari adjacent wells indicating the source of hot spring is closed conduit flowbut not influenced by local water.Majumdar et al. 2005[49]reported that the origin of hot springs in the eastern India were from meteoric precipitation, and the δ2H and δ18O values of GW in Eastern Indian region increase in the winter. Radioactive isotopes are mainly used for estimating the residence time (age) of groundwater. Chemical studies reveal that water from hot springs ot have discrete structures than cold waters. The hot water is rich in Na+, K+ , S and Cl-.

5.1.1 Geo-chemical Investigations

Common tests like titrimetric method of determining DO, BOD and other digital meters for calculation of pH, TDS, TSS, Cletc are determined in the laboratory of CUTM, Odisha. Various methods are employed insitu and in the laboratory to find nonmetals, metals , metalloids, oxides of metals, rare-earth metals by using instruments X-ray fluorescence spectrometr (XRF), Polarography, AAS (atomic absorption spectroscopy, ASV (Anodicstripping voltammetry), Neutron activation analysis and Gas chromatography Analysis to evaluatequantity of heavy metals in water. XRF spectroscopy method is one of the modern and easy laboratory method where X-ray fluorescence technology is used toStudy chemicals, minerals, sediments, non-destructive rock materials present in water sample.

5.1.2 The biological entity of Atri and Tarabola hot water:

The extremophiles that can exist in the hot water of Atri are physically, bio-chemically, meta-bolomics retorts are adapted to pressure, acclimation & the remote tolerant specis in adjacent water are Channastriatus .Puntiussophore in Sulphurous&Ca, F, K water. The Zooplanktons are Copepod spp., di-atoms, Rotifers, Cladospora are can exist.

The Phytoplanktons can be found Chlorophycea, Cyanophycea, Bacil-arophycea, Euglenophyceve relation of phytoplankton-ton with water temp. &pH can grow in hot water having high pH, DO, NO3 & PO4. The hot spring water of tarabola is Fluoride contaminated, ground water near hot spring and all other are above CPCB standard Kundu et al., 2002. The water of both the hot springs are not eligible for drinking purposes and amount of water discharge is not adequate for geothermal units.

5.1.3 The geo-bio-chemical parameter of surface water:
MOEFCC GOI has classified the inland fresh water according to use in India. Similarly WHO, EPA has fixed norms for water physic-bio-chemistry of water for drinking, bathing, irrigation, fish and animal use. The norms specified by different agencies are in **Table 4**

Table 4: Indian standard: Water Quality Standards for Classifying Surface Water Sources (IS 10500)http://www. punenvis. nic.in/water/riverbasin.htm

#	Parameter		Class A	Class B	Class C	Class D	Class E
		Unit	**Permissible Limits**				
	Physical		Drinking without treatment & disinfection	Outdoor bathing (organized)	Drinking with treatment & disinfection	Wild life and fisheries growth	Irrigation and Industry only
1	Temperature	DegsCelsiu					
2	pH value		6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
3	Colour,	Hazen units,	10	300	300	--	--
4	Odour		10	300	300	--	--
5	Taste		Tasteless	--	--	--	--
6	Total dissolved solids,	mg/l, max.	500	--	1500	--	2100
7	Tot. hardness(as $CaCo_3$),	mg/l, max.	300	--	--	--	--
8	Cal hardness ($CaCO_3$),	mg/l, max.	200	--	--	--	--
	Metals / nonmetals / Ions						
1	Free ammonia (as N),	mg/l, max.	--	--	--	1.2	--
2	EC at at 25° C	µʊ/cm.	--	--	--	1000×10^{-6}	2250×10^{-6}
3	Carbon dioxide (CO2),	mg/l, max.	--	--	--	61	--
4	Sodium absorption ratio	Number	--	--	--	--	26
5	Magnesium hardness	mg/l, max.	100	--	--	--	--
6	Copper (as Cu),	mg/l, max.	1.5	--	1.5	--	--
7	Iron (as Fe),	mg/l, max.	0.3	--	0.5	--	--
8	Manganese (as Mn).	mg/l, max.	0.5	--	--	--	--
9	Chlorides (as Cl)	mg/l, max.	250	--	600	--	600
10	Sulphates (as SO_4)	mg/l, max.	400	--	400	--	1000
11	Nitrates (as NO_3)	mg/l, max.	20	--	50	--	--
12	Fluorides (as F)	mg/l, max.	1.5	1.5	1.5	--	--
	Heavy metals affecting health						
1	Mercury (as Hg)	mg/l, max.	0.001	--	--	--	--
2	Cadmium (as Cd)	mg/l, max.	0.01	--	0.01	--	--
3	Salenium (as Se)	mg/l, max.	0.01	--	0.05	--	--
4	Arsenic (as As)	mg/l, max.	0.05	0.2	0.2	--	--
5	Cyanide (as CN)	mg/l, max.	0.05	0.05	0.05	--	--
6	Lead (as Pb)	mg/l, max.	0.1	--	0.1	--	--
7	Zinc (as Zn), mg/l, max.	mg/l, max.	15	--	15	--	--
8	Chromium (as Cr^{6+})	mg/l, max.	0.05	--	0.05	--	--
9	Barium (as Ba)	mg/l, max.	1	--	--	--	--
	Radioactive elements						
1	Alpha emitters,	uC/ml, max.	9-Oct	9-Oct	9-Oct		
2	Beta emitters,	uC/ml, max.	8-Oct	8-Oct	8-Oct	8-Oct	8-Oct
	Biochemical Parameters						
1	Dissolved Oxygen	(mg/l), min.	6	5	4	4	--
2	BOD (5-days at 20° C)	(mg/l), min.	2	3	3	--	--
3	Total Coliform	MPN/100ml,	50	500	5000	--	--

6. Results of Observation

The X-ray fluorescentSpectrometer (Model: Epsilon 1 PANalytical B. V., the Netherlands) is used to find the quantity the metals, oxides of metals, nonmetals, metaloids and rare earth elements Mishra S. P. et al 2017[50]. In this method 5 mL of filtered and unfiltered samples were pipetted into special cups which has a 1.5 µm thin mylar film below. The X-ray beam is filtered by an Al-thin filter to determine K and Ca, kapton filter for S and default for Na. Samples were analyzed for 1-2mnts and the spectrums of elements were analyzed by using EPSILON 3 software to determine the elemental concentration and the results are in **Table 5.**

Table 5 : The comparative physic-bio-chemical parameters of water of atri and Tarabol and its portability standard.

Parameters	Unit	Method	Atri	Assessment	Tarabalo	Assessment	Permissible limits
Color	Hazen	Visual	Clear	A	clear	A	clear
pH	-	pH meter	8.53	NR	8.23	NR	6.5-8.5
EC	µS/cm	EC Meter	1163	permissible	978	permissible	2250 Ind.(CPCB-2016)
Alkalinity	(mg/l)	Titrimetric	20	permissible	28	permissible	150mg/l
DO	(ppm)	Titrimetric	6.1	Agreeable	5.9	Agreeable	4.6 , WHO 1993

BOD (5days)	mg/l	Titrimetric	9.35	Agreeable	10.4	Agreeable	30mg/l (at 25^0 C)
Turbidity	NTU	Turb. Meter	0.37	Agreeable	0.4	Agreeable	1-5 max permissible 10
TH (CaCO3)	mg/l	EDTA	131.9	permissible	175.8	permissible	13-300 mg/l
TDS (mg/l)	mg/l	Digital Meter	309	Agreeable	402	Agreeable	500-2000
Si (ppm)	ppm	XRF	727.4	Agreeable	993.7	Agreeable	No standard limit
Potassium (K+)	ppm	XRF	558.1	Agreeable	572.1	Agreeable	5 Bajgai et al., 2017)[51]
Sulphate (SO_4^{2-})	ppm	XRF	188.2	permissible	186	permissible	IS:3025(Part-24)-1986
Cl (ppm)	ppm	XRF	468.9	permissible	352.2	permissible	250-1000
Ca (ppm)	ppm	XRF	544.6	objected	583.2	objected	75-200, 5-500
Fe (ppm)	ppm	XRF	61.7	objected	77	objected	0.3mg/l
Co (ppm)	ppm	XRF	-		-		8 picoCuries/L(US EPA
Cu (ppm)	ppm	XRF	4.5	objected	4.9	objected	0.05 - 1.5 (0.003 -0.03
Sn (ppm)	ppm	XRF	40.1		39.5		
Te (ppm)	ppm	XRF	49.5		-		
Eu (ppm)	ppm	XRF	4.9		-		
Er (ppm)	ppm	XRF	61.4		-		

N:B- All the permissible limits are taken from the WHO and IS 10500 : 2012 Indian Standard and CPCB 2016 norms. The water sample was taken in sterile Thermal steel containers from the source bathing ponds when the water was completely settled for 5 hours and had no human intervention or activities. Abbreviations with their original meaning: U=Unobjectionable; A=Agreeable; NR=No Relaxation; DL= Desirable Level; MPL=Maximum Permissible Limit; mg/l=milligram per litre. All the permissible limits are taken from the WHO-2018 and IS 10500 : 2012 Indian

7. Discussion

Natural springs are emerging out to be a source of nonrenewable geothermal source. Modern townships/ hotels/Resorts are using the spring hot water as water supply to bath rooms and swimming pools as a mark of aristocracy and health care. The age old record envisages, countries like Rome, Turk, New Zealand, China, India and Ottoman were using the mineralized hot spring water for baleneotherapy by baleneogical treatment for some diseases like pelotherapy (healing by clay) https://www.ncbi. nlm. nih.gov/pmc/articles/PMC2334056/. Dr. W Ring Rose Gore, 1911 has reported that the hot spring water is useful for treatment of chronic bacteriological diseases related to skin and digestive system. The water is electron rich and the mud in hot springs behaves as an antioxidant for pelotheraptic uses. However all agrees that a bath in hot springs relaxes our body and mind and relieves fatigue.

7.1 The benefits/adversities of water of HS on human health

Thermal springs are non-volcanic (heat and water are aftermyth of volcanism); (2) intermediate (excess heat due to unusual high geothermal gradients caused from volcanism, and the water is meteoric); (3) volcanic (excess heat, high mineral content, and water are from volcanic source). The presence deficient or high concentration of chemicals in water of Hot spring, and their contact by bathing, drinking and presence atmosphere can have both positive and negative effects. The human benefits / adversities that may occur due to drinking of hot spring water is given in **Table 6**

Table 6: The benefits on human health due to presence of minerals with or without sulphur in water of HS:

A – Alkali and alkaline earth metals

Elements	Effect on human	Remark (present/absent)
Aluminium	Alzheimer's disease (AD), osteomalaci, normal renal dysfunction, infants bone mineralization and delay in neurological development (neither genotoxic or carcinogenic)	Aluminium a common earth constituent ,Sudjaroen Y., et al, 2017[52]
Silicon	Bone tendons aorta, liver and kidney deposits alzheimer's chronic bronchitis	Present present study
Phosphorus	Respiratory tract infection ,coughing in humans severe burns, benefits weakness, bone health, brain function, sexual weakness, dental care, body metabolism *when sulphur free*	High concentration of phosphorus present
Sulphur	Neurological effects, disturbances in blood circulation, heart damage, reproductive failure, suffocation and lungs problem ,dermatological disorders	Present
Chlorine	Airway irritation, wheezing, sore throat, cough, eye irritation, skin irritation	High concentration
Potassium	Hyperkalemia ,hormonal disorders, lupus ,kidney failure, uncontrolled diabetes	Present
Calcium	Kidney stonesabnormal, blood pressure, depression, nausea, vomiting, diarrhoea	When in High concentration
Sodium	Reduces arthritic symptoms, stimulate the body's lymphatic system and maintain body fluid balance.	present
Magnesium	sustains normal heart rhythms, reduces high blood pressure and eliminate body toxins and converts blood sugar to energy and promote healthy skin.	present

B- Transition Metals

Manganese	Ataxia, fatness, blood clotting, skin disorders, changes in hair colour, birth defects	Trace amount of manganese present
Iron	builds blood quality, reduces stress and fatigue , improves skin tone, resistance to disease , aids in muscle function, Joint pain , abdominal pain, heart failure,	Present

	liver failure, hemochromatosis skin damage	
Stannic	Irritation to eye skin and respiratory system, chromosomal aberrations, neurological problems, cancer	
Lead	Children:Behavior and learning problems,LowerIQ,Slowedgrowth,Hearingproblems,Anemia, Women: Reduced growth of the fetus,Prematurebirth,Adults: Cardiovascular effects, increased blood pressure and incidence of hypertension,Decreased kidney function,Reproductive problems (in both men and women)	https://www.epa.gov/ground-water-and-drinking-water/basic
Zinc	Skin healthy, healing of wounds, colds, weight loss, aids in digestion *without sulphur*.	https://www.ouraycolorado.com/hot-springs/sulfur-free-water

C – Rare Earth Metals

Europium	Regarded as toxic but less affect human metabolism	Absent
Erbium	Difficult to detect because erbium is present in human body in bones smaller amount in liver	Trace amount of erbium

Necessities of water for bathing purposes are mineral content <30 g/l and the temperature range should be from 24 to 30 °C where as hot water used for therapeutic drives (Baleneopathy) should contain < 50 g/l and the required temp should be 28 to 42 °CSudjaroen Y. 2017[52]. The water of hot springs contain different ions and elements and mostly sulpher as element or oxides of sulphur (SO_4^{-2}) as gasses in middle earth thermal springs as Sulfur is a naturally mineral that is found primarily near volcanic craters. Presence of sulphurous compounds impart water of hot springs is medicated as0.25 percent of human body is sulfur by weight. It is available in keratin, which imparts strong hair, nails, and skin (nature's beauty mineral) as body needs it to creat collagen. The collagen keeps your skin elastic, beautiful, and young looking. Sulfur also react with vitamins B1 (thiamine), B5 (pantothenic acid), and H (biotin) to stimulate metabolism and communication between nerve cells http://middleearthcr.com/why-sulfur.html. However Chieh-Chi Lee et al, 2014[53]reported that thermal sulfur baths can adverse of adverse effect of sulfur spring dermatitis.

The geothermal waters differ in chemical composition based on the geology, limnology and geography of the area and the diversity is well marked by the geomorphology of the area. The geothermal waters are categorized by the physic-chemical and biological dynamism which is based on the study done by Javedet. al.,2009[54] , The hot water from hot springs at Attri and Tarabol is rarely used for domestic purposes. However it is used for bathing purposes and the tail runoff water is disposed to the nearby paddy fields for irrigation purposes. So it is pertinent that it should satisfy bathing standard and meet the norms for irrigation water. The permissible norms is provided by Central Pollution Control Board Ministry of Enviornment Govt. of India is given in the table below.

Hot-spring waters are characterized by dominance of sulphur, and carry solutes that stay in solution during boiling, such as chloride, silica, and major cations (Ca, Mg, Na, and K). Initially Sulphurated water holds free or combined ion. These Physico-chemical analyses were performed to measure pH, total dissolved solids (TDS), and conductivity using calibrated instruments. Temperature was measured insitu at the time of sample collection. Total hardness was measured in the laboratory by titration method..Metals (Al, Si, Fe, Mn, Pb, Cd, Ni, Cu) were measured by using XRF spectro photometer and major ions quantized are Si, P, S, Cl, Ca, Mn, Fe, Co, Cu, Sn, Te, Eu, Er etc. The physical quantities in water samples were evaluated for temperature, pH, $CaCO_3$ hardness, total hardness, alkalinity, DO, BOD and COD. The parameters obtained are compared with the pond water permissible limits and the deviations obtained are given below.

The uses of EDXRF are analysis of petroleum products, oils, polyester; metals and alloys, glass and plastic, PV cells, waste, effluent, liquids etc by X-ray Transmission (XRT) process gauges. It has the visoninspecton of spectra/scans so that a comprehensive picture of the sample is obtained within a wide range for qualitative or quantitative analysis of all detected elements in full quantity referring the modern periodic table. It is a graph ploted a portion of the XRF spectra of several different elements between Energy in KeV and intensity in cps referring to periodicity and applying Moseley's law i.e. energy is proportional to Z^2 . Organic elements (i.e., H, C, N, O) has no XRF peaks as fluorescence photons have low energy. Elements having low atomic number like Cl, Ar, K, Ca give only K peaks where asLpeaks are absent. High atomic number elements like Ba, Hg, Pb, U give only L- lines as K peaks of these elements are too high in energy of electrons and high binding energies so that they cannot be segregated within the limited voltage available in field of the XRF spectrometer. The combined EDXRF analysis graph of water sample obtained of Atri and Tarabalo Hot springs are given **fig 8.**

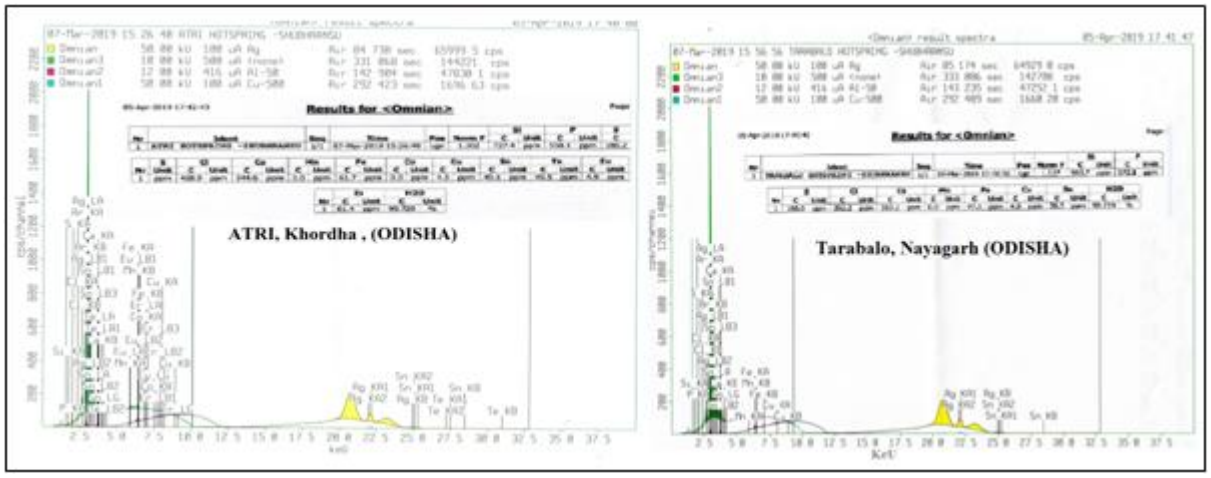

Figure 8: Generalization of XRF Energies for Various Elements of Atri and Tarabalo

The middle At. No. elements like iodineand and Rh etc.give both K and L lines. K lines give K_α (10.53KeV range) and K_β (11.73KeV range) lines for low to medium At. No.elementslike Cl, Fe, As and not observed for 75.0 and 94.9 keV which is too high in energy to be excited. L lines not observed for energy range 1.28 and 1.32 keV which is too low in energy to be excited.L-lines for high At. No. elements (Hg, Pb, Th) consist of L_α (10.61KeV range) and L_β (12.55KeV range) and peak energies attimes remain apart as (2.1 keV apart for Pb).

From the graph it is found that the concentration of fluorine, Si, P, S, FE, Cu, Sn is higher than drinking water standard and portable water norm specified by CPCB. The Omnian analysis of hot spring water indicates raised concentration of F, Si, P, S, Cl, Ca, Cu and Sn higher than that of Tarabola water. The hot water of Tarabola does not contain any dissolved lanthanides and actinides whereas the hot water of Atricontain tellurium metals and REE's like Eu, Er. Presence of Eu indicate the atri areas had tectonic activities in past and has least contribution to human metabolism..The absence of Europium (Eu) in Tarabola hot water sample indicate that the springs are not formed due to tectonic activities Mishra S P., 2017[55]. .

Seasonality, diurnal variability and climate plays important role on quantity, quality, turbidity of the water of Attri and Tarabol. It is observed that bubbles of water coming in the main pond at Atri where as it is in larger bubbles during extreme summer climate only. In plain areas the quantity of hot water discharge is higher than the hilly mines areas of Odisha.

The Temperature of Water plays pivotal role for the metabolic effects of balneotherapy and is classified classified as Cold (< 20°C),hypothermal (20-30°C), thermal" (30-40°C), or hyperthermal (>40°C). Nasermoaddeli A., 2005[56]. The temperature of the hot mineral water of hot springs should lie between 40 to80^0 C but can go upto130^0 C (hot springs at Italy (SoffioniBoriferi-Tuscany) is 130 °C and Japan (BEPU) of 100 °C, or Argentina, Rosary of La Frontera of 97 °C,de Carvalho AM et al., 2015[57]. The average observed temperature of in the month of March 1st to 7th in 2019 was 570at Atri where as that of Tarabol was 45^0C. The water temperature remains almost constant during day time. Variations in temperature of geothermal water have individual effect on the spring user. The body enzyme activity decreases after bathing in hot springs for 10 minutes at 39°C and 25°C. but longer bath increases the value of enzyme activity and have negative effect to the diabetic patientsZaini et al, [201[58]3]. Pospisil et al., 2007[59]related heart rate and diastolic blood pressure in patients with Parkinson's disease with bathing in hot spring water (32.5°C) up to heart level.

The negative logarithm of Hydrogen ion concentration (pH) is vital in many life processes and living organisms are reliant on and sensitive to pH. .The pH values of the pond water as per CPCB norms is 6.5-8.5 and for irrigation can go up to 9.0. The pH value of water at Attri and Tarabol was 8.53 and 8.23 respectively. These high pH values indicates higher alkalinity which may be due to higher concentrations of Ca2+, Na+ and K+ . The study area is having latsols and bentolite soil, and it is observed that the concentration of Ca^{+2} in both the areas are high.

Electrical Conductivity (EC) is the ability of a solution to conduct electricity or medium for transfer for electric current. The electrical conductivity (EC) of the water of Hot spring was found to be Atri was 1163 µS/cm and that of Tarabol is 978 µS/cm measured.The electrical conductivity standards for pond water fixed by SON drinking water standard is 1000 µS/cm and CPCB irrigation water standard the permissible limit is 1180 -2250µS/cm. The higher values of EC are due to presence of high chemicals in the solution in the two Hot Springs.

The dominating dissolved elements present in hot springs are HCO_3 (common), OH and CO_3 ions of Ca, Na, Mg and K and the permissible value as per WHO standard is 200mg/l and ISI is 150mg/l. Amanial H R 2015[60]. The observed alkalinity of Hot springs (HS) Attri and Tarabol is 20 and 28 respectively which much below permissible limit.

Dissolved Oxygen (DO)is a measure of the amount oxygen is dissolved in the water and the common measure tells about the health of water, as it is used by the aqua habitats. The DO of hot springs are generally low but the value es vary with temperature. The National water standard quality of Malaysia has fixed for Class I as 7 and Class II as 5-7.

Presently Atriand Tarabol have DO values 6.1 and 5.9 respectively which is within WQ permissible limits.

Biological Oxygen demand (BOD) is used to surrogate the degree of organic pollution in sample water. KashidS..S. et al, 2018[15] measured of oxygen consumed by microorganisms in water to decay or oxidization of organic matter where as COD a higher value than BOD is the requirement of DO for both oxidation of organic and inorganic constituents. The present study of Attri and Tarabol water from hot springs have BOD values were 9.35 and 10.4 mg/l which is within safe limits prescribed by WHO.

Turbidity (unit- NTU:Nephelo-metric turbidity units)is a measure of scattering of light in the spring water. It depends on depends on the quantity, size and composition of the suspended particles like silt, clay, colloidal particles, plankton, algae and other microscopic organisms present in water with Maximum permissible limit 10 as per IS 10500-2012. Present study reavels Attri has TDS value 0.37 and Tarabol has 0.4 which is within safe limits .

Turbidity, TDS and SPM are inter related and depends upon the temperature gradient, the depth of water circulation, exothermic reactions, water - mineral interaction, un-dissolved/ dissolved gases. The TDS of the water of Atri and Tarabalo. were 309 and 402 mg/lit. Generally the turbidity and TDS (500-2000mg/l) are within permissible limit and the water is clear gastrointestinal people use water directly from main pond after the temperature subsides to atmospheric temp.

Concentration of Ca2+, K+, S, SO_4^{2-} and Cl^- obtained from the analysis by using XRF Spectrometer. It is observed that the calcium concentration of Ca2+ is high in the water samples. This prove that major element composition of the hot water is dominated by Ca2+ .

The iron present in the water of Attri and Tarabol is highly excess(61.7 ppm and 77ppm) where the recommended permissible limit is 0.3mg/l. Iron overdose in drinking water may cause hemochromatosis that affects the liver, heart, pancreas, and diabetes. The early diagnosis and symptom causes fatigue, weight loss, and joint pain. The hot spring water of Tarabol is not acceptable main reason being rich in iron. The other affects are effects the skin, foods and drinks,Staining cloths and dishes and clog the water supply lines.

The copper concentration in the hot springs of Attri and Tarabol 4.5 and 4.9 mg/l whereas the permissible limit 0.003 to 0.03 mg/l. The excess copper may pose toxicity which may cause Liver toxicity, Reproductive and Developmental Toxicity, Geno-toxicity, Mutagenicity, and Carcinogenicity of Copper in human and children are the worst affected. Hepatic and occasionally renal changes may occure due to copper toxicity in animals National Research Council (US) Committee on Copper in Drinking Water ,Washington (DC): National Academies Press (US); 2000.. https://www.ncbi.nlm.nih.gov/books/NBK225400/

It is also found that amount of Stannic (Sn) present in the hot spring water (Attri 40.1ppm and 39.5 ppm) are higher than the limits specified by WHO and EPA. This may lead to Irritation in eye skin and respiratory system, chromosomal aberrations, neurological problems, cancer. Also it affect bones and tissues of fishes.

The rare earth metals like Er is difficult to detect because erbium is present in human body in bones smaller amount in liver and its effects are less known.

7.2 Therapeutic uses

Therapautic use of hot springs water and mud likebalneolotherapy and pelotherapywas used for treating skin, respiratory, relaxing stress and musculoskeletal disorders as an age old practice. This practice is in vogue since the bronze age in India, Greece, Japan, Chinia,Turks, middle east, Rome,and Egypt. Now the therapeutic use of water from hot springs are utilized to cure pulmonary or arterial hypertension, atherosclerosis, ischemia-reperfusion injuries, heart diseases, peptic ulcer, and chronic inflammatory diseases. Further hot springs have curative power for pulmonary hypertension, arterial hypertension, atherosclerosis, ischemia-reperfusion injury, heart failure, peptic ulcer, acute and chronic inflammatory diseases, Parkinson's disease, Alzheimer's disease, erectile dysfunction, and skin diseases.Carbajo J. M., 2017[61].The main therapeutic use of minerallyloaded hot geothermal water is to heal Psoriasis, Acne, Atopic or Contact orSeborrheic dermatitis, Collagen vascular disorders alsoGianfaldoni S., 2017[62].In addition it improves promote relaxation, blood Circulation & cells oxygenation, reduces obesity, skin infections, reduce stress and promote sleep, natural relief of chronic pain,causedetoxicity,partly heals nasal congestion and digestion problems, kill viruses, germs, fight against obesity and boost immune system of the human body. Similarly the hot mud within the hot spring areas are used for chronic arthritis, fibrositis, neuritis, sciatic syndrome, after treatment of fractures and sport and industrial injuries by pelotherapticuses.The hot water/mud bath can tout many ailments as recommended by local natureopathyLund S. W., 1996[63]. The beneficial peleothraptic uses of sulphurous mineral waters/ low conc. Sulphurous mud, or peloids is used to heal the above diseases.The inhalation of sulphurous waters can improve the patients with chronic obstructive pulmonary disease (COPD).How ever the hot spring bath in Odisha has the belief of increasing fertility in childless women.

7.3 Balneotherapy benefits of Atri and Tarabalo

The baleneotherapy units (Spa's) not yet developed either at Atri or at Tarabalo. There is utmost need for commercialization of uses of the sulphurous hot waters of bothe geo thermal units. So Balneotherapy ought to be discussed with a physician before starting treatment, since variety of conditions, like cardiac diseases and immature loss of pregnancy, may result in an exceedingly serious adverse reaction. Construction of heat tubs are essential like other countries of the world. The doses must be pre determined with the hot water.It is commonly implemented that a healthy person baths from half an hour to 3 hours to

avail the bath under medical procedure. In unhealthy or obese people, this method may take up to 10 hours. That's why adding essential oils to a bath is such an effective aromatherapy treatment. It is the presence of those minerals, from the depths of the earth that creates certain spring waters highly valued for their curative properties. Eight ways Balneotherapy heals are advised by the doctors:

- Bathing in hot springs step by step will increase the temperature of the body, so killing harmful germs and viruses.
- Thermal bathing will increase hydrostatic pressure on the body, so increasing blood circulation and cell oxygenation. the increase in blood flow conjointly helps dissolve and eliminate toxins from the body.
- Hot springs bathing will increase the flow of oxygen-rich blood throughout the body, bringing improved nourishment to vital organs and tissues.
- Bathing in thermal water will increase body metabolism, as well as stimulating the secretions fluid of the intestinal tract and the liver, aiding digestion.
- continual hot springs bathing (especially over 3- to 4-week period) will facilitate normalize the functions of the endocrine glands as well because the functioning of the body's autonomic nervous system.
- Trace amounts of minerals like carbon dioxide, sulfur, calcium, magnesium, and lithium are absorbed by the body and provide healing effects to various body organs and system. These healing effects will include stimulation of the immune system, resulting in increased immunity; physical and mental relaxation; the production of endorphins; and normalized gland function.
- Mineral springs contain high amounts of negative ions, which may facilitate promote feelings of physical and psychological well-being.
- The direct application of mineralized thermal waters (especially those containing sulfur) can have a therapeutic impact on diseases of the skin, as well as psoriasis, dermatitis, and fungal infections. Some mineral waters are used to help the healing of wounds and different skin injuries.

7.4 Chronic Diseases

The recommended therauptic benefits considered by local people by taking bath in the attached tanks are healing rheumatic diseases, functional recovery of central and peripheral neuroparalysismetabolic diseases (like diabetes, obesity and gout), chronic gastrointestinal diseases, chronic mild respiratory diseases (asthma),circulatory diseases (like moderate or mild hypertension, peripheral circulatory diseases (affected hands and feet), cskin diseases ,psychosomatic and stress-related diseases ,autonomic nervous system disfunction ,Vibration disorder (a middle ear disorder affecting balance) ,Sequela of (conditions resulting from) trauma ,Chronic gynecological diseases**Fig 9.**

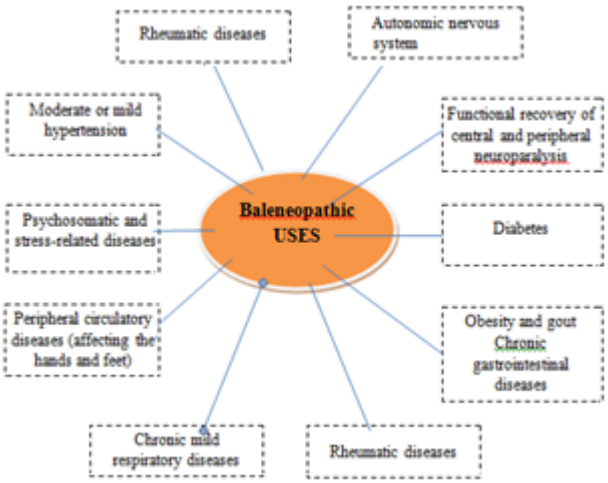

Figure 9: Major baleneopathic uses of water from hot springs odisha

7.4.1 Economic uses

Economic development of hydrothermal spring is add to development of local area by utilizing the unit for bathing, relaxation and health by giving priority to sports, sightseeing and entertainment. Hydrothermal conditioning use of hot springs water is less economical in geoheat centers due to erosion, corrosion and plugging of vents.

It is observed that in clustered hot springs in Odisha, the numbers are reducing like Deuljhari had 84 outlets in past and has been reduced to 24 at present and similarly the cluster at Tarabola was discharging at higher rate but is reducing. This indicates either there are changes rock strata or shifting of reservoir or depletion of reservoir capacity.

7.4.2 Environmental adverse adverse effects

But the high conc. Of H2S is highly toxic and have .keratolytic or keratoplastic actions due formation of colloidal sulphur below skin. Adverse effects of sulphurous environment can cause respiratory disease or stroke when the concentrations sulphur exceed 7.00 $\mu g/m^3$ Finnbjornsdottir R. G, 2016[64]. Bathing in hot springs causeirritative dermatitis to chemical burns, dermatologic disease in skin H2S reduces clonal growth, cell proliferation, and the adhesion of mature human keratinocytes by limiting the keratinocyte stem cell subpopulation in culture. So hot spring waters in open air and exact environments as in spas is safe keeping sulphide conc.<45 mg/l maximum Carbajo J. M., 2017.. Conc. > 25 ppm in the atmosphere can cause eye damage and chronic exposure to H_2S can have severe health effects.

8. Conclusion

The geo thermal Waters from the springs Attri and Tarabol in the present study is not satisfying drinking Standard. Unacceptably high levels of iron are present in both the hot springs Attri and Tarabol. Hot Springs water all over Odisha states contains Na+, K+, , Ca2+, S, SO42- and Cl- which are used for balneotherapy. Chemical composition consist in hot springs water has its own beneficial for the human's health and has advantages of up surging metabolism, smoothening muscles, accelerating healing, developing blood circulation. It also heals skin diseases and

has immense antioxidant properties (the infertile women take bath in hope of fertility). The hot springs water located in Odisha is suitable for bathing and can be used for Spa activities but inappropriate for portability. Different hot springs vary in their salt like sulphate and chloride content with rich in Ferric Oxide.

Above all due to excess in concentration Fe and Cu poses problem to use the water of Attri and Tarabol hot springs except for occasional bathing purposes. The excesses mineral water is wasted in the nearby fallow lands. Judicious planning of proper use of the water emphasizes opening natural health care balneotherapy and pelotherapy units around the hot streams in and around the hot springs to encourage tourism instead of a blessed place taking occasional bath once or twice on special occasions. More rigorous investigation is necessary to use it commercially to generate geothermal energy and finally to the fields for a better crop.

The State and the local governments has the responsibility for provision of allocation for necessary infrastructural development, efficient management, environmental developmental measures, and protection from intruders. The federal bodies or governmental and NGO's should promote safe and efficient spa culture and encourage hot spring industry for the best possible ways for hydrothermal use. For future guidance it is essential to take regular observations andanalysethephysico-biochemical parameters for preservation of natural nonrenewable source of energy for the nation.

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