IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Physico-Chemical Characterization And Seasonal Variations Of Geothermal Hot Springs In North Maharashtra, India.

Khairnar Kunal[1,4*], Vasait Jagdishbhai[2] and Borale Rajendra[3]

[1]Department of Zoology, M.S.G Arts, Science and Commerce College, Malegaon, (Nasik) 423 105, And Savitribai Phule Pune University, Ganeshkhind, Pune 411 007, MS India.

[2] Department of Zoology, M.G. V's, Arts, Science and Commerce College Surgana, (Nasik) 422 211,

[3]JET's Z. B. Patil College, Dhule 424 002, MS, India.

*Corresponding Author

Abstract

This study examines the physico-chemical properties of four geothermal hot water springs—Unapdev, Indava, Kundava, and Anakdev (Dara)—located in the Jalgaon, Dhule, and Nandurbar districts of North Maharashtra, India. Water temperature across all sites ranged between 39–45°C, confirming their geothermal nature and potential for balneological use. pH values varied widely (5.1–9.42), with acidic conditions observed at Kundava and alkaline extremes at Anakdev, while Unapdev and Indava remained near neutral to slightly alkaline. Total Dissolved Solids (TDS) and major ion concentrations indicated significant mineralization, most notably at Indava (TDS 977 mg/L; sulphates 943 mg/L; chlorides 440 mg/L; magnesium 943 mg/L), suggesting a sulphur-rich geothermal source. In contrast, Anakdev exhibited lower TDS (136–248 mg/L) and hardness, with elevated sodium and potassium contributing to a mildly saline character. Organic load was moderate, with BOD ranging from 10–18 mg/L and COD from 16–29 mg/L, reflecting anthropogenic influence from bathing and religious practices. Dissolved oxygen remained moderate (5–9.6 mg/L) and turbidity negligible, indicating clear water despite high mineral content. Seasonal variations strongly influenced water chemistry, with concentration effects during summer and dilution during monsoon. While the waters are unsuitable for potable use due to elevated TDS, sulphates, and hardness, they retain considerable value for therapeutic, medicinal, and cultural applications.

Key words: Physico-Chemical, Hot water spring, kundava, Indava, Unapdev, Anakdev.

Introduction

Geothermal energy is practically perennial, inexhaustible, eco-friendly, and pollution-free, making it a promising alternative to conventional energy sources. Unlike hydro-energy, it does not depend on seasonal variations, allowing for a constant level of production throughout the year. From an environmental perspective, geothermal power generation is far more benign than the burning of fossil fuels, significantly reducing greenhouse gas emissions and acid rain. The recent rise in geothermal resource utilization can be attributed to several factors such as technological improvements, economic viability, and environmental advantages. Technological progress ranges from early exploration to large-scale production of electrical power. Because of these benefits, geothermal energy is often considered economical in comparison with traditional energy resources.

In India, the multipurpose potential of geothermal energy, already recognized in various countries, has attracted attention from both the scientific and administrative communities. Research and academic institutions have initiated preliminary, and in some cases detailed, investigations of geothermal fields to evaluate the feasibility of utilizing thermal springs. A holistic approach toward conservation and management of this resource would create awareness of its importance while ensuring both quality and quantity are preserved. Exploration and exploitation of this form of energy can indeed open new pathways toward meeting the nation's future energy requirements. Studies of the physico-chemical characteristics of water and gas have been carried out to understand the nature and source of geothermal fluids and to develop conceptual models of their origin. The thermal springs of North Maharashtra, for instance, are considered to be of meteoric origin, with heat derived from geothermal gradients, radioactive element disintegration, or exothermic reactions during metamorphism.

Material and Method

Sampling was conducted seasonally between March 2023 and April 2025. At each location, a one-liter water sample was collected. These samples were later analysed for their physicochemical parameters to assess the water quality. As part of the present investigation, seasonal field trips were organized to various hot springs in collect environmental and hydrochemical data. During these surveys, several in-situ parameters were recorded, including the temperature of the spring water and the ambient air temperature of the surrounding region. To ensure accuracy in temperature measurements, digital thermometers (Model ST-9269) were employed. These devices, with a measuring range of –50°C to 200°C and an accuracy of ±1°C, were used carefully in the field. Particular attention was given to measurement procedures, such as holding the thermometers in position for sufficient time, in order to obtain stable and reliable readings. For the chemical composition analysis, water samples were collected directly from the source of the hot springs. The collected samples were immediately stored in clean sample bottles to avoid contamination and were subsequently submitted to the water testing laboratories at Shet Jamin Mimasa, Satana, where detailed analyses were carried out *(Mohammed H. S. Zangana, 2015).*

RESULT AND DISCUSSION

Table 1 Displayed standard deviation and Jarque Bera test of physico-chemical parameters of Indava hot spring.

Sr.no	parameters	Year-2023 to 2025					
		Summer		Monsoon		Winter	
		Standard Deviation	Jarque-Bera	Standard Deviation	Jarque-Bera	Standard Deviation	Jarque-Bera
1	Temperature	1.77	13.92	0.17	13.92	1.84	13.92
2	PH	0.18	29.32	0.15	29.32	0.21	29.32
3	COD	0.67	19.18	0.85	19.18	0.71	19.18
4	BOD	1.34	37.34	1.41	37.34	0.71	37.34
5	TDS	16.26	92.59	50.20	92.59	52.33	92.59
6	Total alkalinity	7.21	56.49	4.24	56.49	4.10	56.49
7	Total Hardness (CaCO3)	18.95	28.61	0.00	28.61	7.07	28.61
8	Bicarbonate	20.51	96.43	0.00	28.61	0.00	96.43
9	Calcium	36.77	36.77	0.00	909.72	0.00	909.72
10	Magnesium	19.63	18.04	0.71	18.04	0.03	18.04
11	Sulphate	36.06	506.28	311.13	506.28	7.78	506.28
12	Chloride	298.61	27.58	70.71	27.58	7.16	27.58
13	Sodium	107.48	90.54	0.00	90.54	0.00	90.54
14	Potassium	3.54	109.08	0.00	109.08	6.79	109.08
15	Iron	0.12	98.54	0.00	98.54	0.00	98.54
16	Nitrate	0.64	703.99	0.25	703.99	0.00	703.99

Table 2 Displayed standard deviation and Jarque Bera test of physico-chemical parameters of Unapdev hot spring.

Sr.no	parameters	Year-2023 to 2025					
		Summer		Monsoon		Winter	
		Standard Deviation	Jarque-Bera	Standard Deviation	Jarque-Bera	Standard Deviation	Jarque-Bera
1	Temperature	0.99	13.92	1.46	13.92	1.67	13.92
2	PH	0.62	29.32	0.35	29.32	0.93	29.32
3	COD	0.42	19.18	1.41	19.18	0.92	19.18
4	BOD	0.06	37.34	0.71	37.34	0.28	37.34
5	TDS	310.42	92.59	70.71	92.59	35.36	92.59
6	Total alkalinity	15.46	56.49	35.36	56.49	2.97	56.49
7	Total Hardness (CaCO3)	58.55	28.61	70.71	28.61	0.01	28.61
8	Bicarbonate	18.38	96.43	0.00	96.43	0.00	96.43
9	Calcium	33.94	909.72	0.00	909.72	0.00	909.72
10	Magnesium	16.12	18.04	3.54	18.04	0.00	18.04
11	Sulphate	45.25	506.28	7.07	506.28	4.24	506.28
12	Chloride	271.25	27.58	1.41	27.58	0.17	27.58
13	Sodium	111.02	90.54	0.00	90.54	0.57	90.54
14	Potassium	4.24	109.08	0.00	109.08	0.00	109.08
15	Iron	0.12	98.54	0.00	98.54	0.00	98.54
16	Nitrate	0.52	703.99	0.00	703.99	0.00	703.99

Table 3 Displayed standard deviation and Jarque Bera test of physico-chemical parameters of Anakdev (Dara) hot spring.

Sr.no	parameters	Year-2023 to 2025					
		Summer		Monsoon		Winter	
		Standard Deviation	Jarque-Bera	Standard Deviation	Jarque-Bera	Standard Deviation	Jarque-Bera
1	Temperature	0.64	13.92	0.85	13.92	1.34	13.92
2	PH	1.36	29.32	0.28	29.32	0.99	29.32
3	COD	1.95	19.18	0.12	19.18	1.98	19.18
4	BOD	0.21	37.34	1041	37.34	0.35	37.34
5	TDS	257.39	56.49	70.71	56.49	21.21	56.49
6	Total alkalinity	97.23	56.49	3.54	56.49	1.77	56.49

7	Total Hardness (CaCO3)	45.11	28.61	1.41	28.61	4.24	28.61
8	Bicarbonate	16.26	96.43	0.00	96.43	0.00	96.43
9	Calcium	38.89	909.72	0.00	909.72	0.00	909.72
10	Magnesium	31.65	18.04	0.71	18.04	0.00	18.04
11	Sulphate	43.84	506.28	179.61	506.28	5.66	506.28
12	Chloride	146.58	27.58	6.36	27.58	0.09	27.58
13	Sodium	136.47	90.54	0.00	90.54	0.57	90.54
14	Potassium	4.24	109.08	0.00	109.08	0.00	109.08
15	Iron	0.13	98.54	0.07	98.54	0.00	98.54
16	Nitrate	1.05	703.99	0.71	703.99	0.00	703.99

Table 4 Displayed standard deviation and Jarque Bera test of physico-chemical parameters of Kundava hot spring.

Sr.no	**parameters**	**Year-2023 to 2025**					
		Summer		**Monsoon**		**Winter**	
		Standard Deviation	**Jarque-Bera**	**Standard Deviation**	**Jarque-Bera**	**Standard Deviation**	**Jarque-Bera**
1	Temperature	2.47	13.92	0.64	13.92	0.35	13.92
2	PH	1.37	29.32	0.57	29.32	0.92	29.32
3	COD	0.21	19.18	0.77	19.18	1.41	19.18
4	BOD	0.18	37.34	1.41	37.34	0.57	37.34
5	TDS	207.18	56.49	70.71	56.49	134.35	56.49
6	Total alkalinity	12.30	56.49	35.36	56.49	8.13	56.49
7	Total Hardness (CaCO3)	1.34	28.61	49.50	28.61	0.71	28.61
8	Bicarbonate	14.85	96.43	0.00	96.43	0.00	96.43
9	Calcium	31.82	909.72	0.00	909.72	0.00	909.72
10	Magnesium	15.43	18.04	0.71	18.04	0.00	18.04
11	Sulphate	35.07	506.28	108.19	506.28	5.66	506.28
12	Chloride	118.03	27.58	7.07	27.58	0.57	27.58
13	Sodium	103.24	90.54	0.00	90.54	7.07	90.54
14	Potassium	3.54	109.08	0.00	109.08	0.00	109.08
15	Iron	0.11	98.54	0.00	98.54	0.00	98.54
16	Nitrate	0.52	703.99	0.71	703.99	0.00	703.99

Detailed Interpretation of Physico-Chemical Parameters of Hot Water Springs

Temperature

The recorded temperatures across all sites consistently range between 39°C and 45°C, confirming that these are geothermally heated hot water springs. Among the studied locations, Kundava spring generally registers the highest temperatures, often close to 45°C, whereas Indava occasionally records slightly lower values around 39–40°C. Seasonal variations are evident: during the monsoon and winter months, the temperatures tend to decrease marginally due to dilution by rainfall or lower atmospheric conditions, while summer months maintain higher readings. This temperature profile aligns with natural geothermal activity, making these springs attractive for therapeutic bathing and religious use.

pH

The pH values fluctuate widely, ranging from 5.1 to 9.42, which demonstrates significant chemical variability. The most extreme values were observed in Kundava (January and March 2024–25), where the water turned acidic (~5.1–5.4), and in Anakdev (March 2025), where the water was highly alkaline (~9.4). In contrast, Indava and Unapdev display more stable pH conditions, remaining in the neutral to slightly alkaline range (6.9–7.6). This suggests that while most springs maintain favourable bathing conditions, certain seasonal or geological influences at Kundava and Anakdev cause marked shifts in pH, which could have implications for water usability.

Total Dissolved Solids (TDS)

The TDS values show striking variability across the springs. The highest recorded TDS was 977 mg/L at Indava (May 2023), indicating very high mineral enrichment. By comparison, Anakdev (136–248 mg/L) consistently demonstrates lower TDS, suggesting relatively "softer" water. Elevated TDS levels are often a direct result of prolonged water–rock interaction in geothermal environments, where minerals are dissolved from the surrounding lithology. The high TDS at Indava suggests intense geochemical enrichment, whereas Anakdev reflects a comparatively less mineralized hydrochemical environment.

Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD)

The COD values range between 16–29 mg/L, while BOD varies between 10–18 mg/L. These results reflect moderate organic loading across the springs. Elevated organic contamination is likely linked to local usage, especially as many of these springs are sites of bathing, tourism, and religious activities. For instance, Indava (August 2024) exhibited the highest BOD of 18.13 mg/L, pointing to increased biological activity or organic input during this season. Overall, while the waters are not pristine, the organic loads remain at moderate levels typical of heavily used hot springs.

Alkalinity and Hardness

Alkalinity and hardness values show high variability, with notable extremes at Unapdev and Kundava. For example, Unapdev (August 2024) displayed an exceptionally high alkalinity of 299.9 mg/L and hardness of 274.17 mg/L, while Kundava (August 2024) recorded the peak hardness of 196.13 mg/L. Such elevated values indicate significant contributions from carbonate and bicarbonate minerals, a hallmark of geothermal groundwater circulation through mineral-rich strata. These fluctuations may also reflect seasonal recharge and dilution effects.

Major Ions (Calcium, Magnesium, Sulphate, Chloride, Sodium, Potassium)

The ionic composition highlights the mineral richness and geothermal origin of the springs.

Calcium and Magnesium levels fluctuate dramatically. At Indava (July 2023), magnesium spiked to nearly 943 mg/L, a highly unusual concentration compared to the much lower values elsewhere. This reflects strong water–rock interactions in sulphate- or dolomite-bearing formations.

Sulphates show extreme concentrations at Indava, reaching 943 mg/L (July 2023) and 503 mg/L (August 2024). Such levels confirm that Indava is strongly sulphur-rich, a typical marker of geothermal origin.

Chlorides are also elevated in Indava (440 mg/L in May 2023) and Unapdev (412 mg/L in May 2023), further supporting their geothermal nature.

Sodium and Potassium concentrations are generally moderate, but Anakdev shows the highest sodium (~215 mg/L) and potassium (~6 mg/L), imparting a slightly saline taste to its water.

This ionic profile indicates that Indava is the most mineralized and chemically enriched spring, whereas Anakdev shows comparatively moderate levels.

Nutrients (Nitrate and Phosphate)

Nutrient levels are generally low across all locations. Nitrate values remain below 2 mg/L in most cases, except for Indava (12 mg/L), which stands out as an anomaly, possibly due to surface contamination or localized agricultural runoff. Phosphate concentrations are negligible (<0.2 mg/L) throughout, suggesting that there is little input from agricultural fertilizers or sewage. The overall nutrient profile confirms that these springs are relatively free from significant anthropogenic pollution sources.

Dissolved Oxygen (DO)

The DO levels range between 5 and 9.6 mg/L, which is considered moderate for warm geothermal waters. As expected, DO concentrations are generally lower in the warmer samples due to decreased oxygen solubility at higher temperatures. Springs with elevated organic load (e.g., Indava, Unapdev) also tend to show slightly reduced DO levels, indicating active organic decomposition.

Turbidity

Across all measurements, turbidity remains extremely low (0–0.2 NTU). This demonstrates that the waters, despite their high mineral content, remain visually clear and free of suspended particulates. The clarity of the water enhances their aesthetic and recreational value.

Conclusions

Geothermal Nature:
All springs maintain high temperatures (39–45°C), confirming their geothermal origin. This makes them suitable for balneological and therapeutic use, aligning with their long-standing religious and cultural significance.

Indava Spring

Exhibits the highest mineralization, with extreme values of TDS, sulphates, chlorides, and magnesium.

Likely originates from sulphur-rich geothermal processes.

Chemically enriched but less suitable for drinking water due to excessive dissolved salts.

Unapdev Spring

Displays moderate mineral content, with some seasonal spikes in alkalinity and hardness.

Organic loads (BOD ~10–13 mg/L) suggest human influence from religious and bathing activities.

Kundava Spring

Characterized by high hardness and mineral variability.

Shows occasional acidic pH (~5.1–5.4), which reduces potability and may affect skin tolerance.

Anakdev (Dara) Spring

Comparatively lower TDS and hardness, making it chemically "softer."

Displays slightly higher sodium and potassium, imparting a mild saline character.

More chemically stable and consistent compared to Indava and Kundava.

Overall Water Quality

None of the springs are potable due to high TDS, sulphates, hardness, and BOD.

The waters are best suited for balneological, medicinal, and religious purposes, rather than for drinking.

Seasonal fluctuations influence water chemistry, with summer showing concentration of minerals, and monsoon leading to dilution.

Acknowledgements

The authors are thankful to the principal and authorities of the MSG Arts, Science and Commerce College Malegaon and JET's Z. B. Patil College, Dhule for providing necessary facilities to conduct the research and development. Authors also thanks to government laboratories Shet Jamin Mimasa, Satana for the water analysis. Authors also thankful to the S.P. Pune University for providing platform for the research to the research scholar.

References

1. J.D. Vasait, R.P. Borale and K.B. Khairnar (2025) Physico-chemical Characterization and Baseline Survey of Aquatic Insects in the Hot Springs of North Maharashtra, India. *Eco. Env. & Cons. 31 (February Suppl. Issue): 2025; pp. (S89-S94) EM International.*
2. R. Mathan Kumar· Kunal Jani · J. R. Parvathi· Becky M. Thomas· Suresh S. S. Raja· Anita Pandey · Avinash Sharma (2022) Bacterial diversity of geochemically distinct hot springs located in Maharashtra, India. Archives of Microbiology (2022) 204:110
3. Md. Arzoo Ansari, Suman Sharma, U. Saravana Kumar, Sitangshu Chatterjee, Diksha and Upananda Low (2014) Hydrogeological controls of radon in a few hot springs in the Western Ghats at Ratnagiri district in Maharashtra, India current science, vol. 107, no. 9, 10.
4. Arvind Prasad Dwivedi (2016) Physico-chemical Characteristics of Ground Water Samples Collected from Chitrakoot Region, Satna District. *International Journal of Advanced Research in Chemical Science (IJARCS) Volume 3, Issue 11, PP 38-44 ISSN 2349-039X (Print) & ISSN 2349-0403 (Online).*
5. Wagh R.V, Auti S. K. and Rathod B. L. (2013) geo-chemical constraints of anakdev (Dara) hot spring of shahada in middle Tapi valley, Nandurbar district of Maharashtra, India. Geoscience research issn: 0976-9846 & e-issn: 0976-9854, volume 4, issue 1, pp.-116-119.
6. Mohammed H. S. Zangana *(2015)* Physical and Chemical Characteristics of Thermal Springs: A Case Study. International Journal of Engineering Trends and Technology (IJETT) – Volume.
7. P. J. K. Rongoei, N. O. Outa. APHA (1998) Standard Methods for the Examination of Water and Wastewater. 20th Edition, American Public Health Association, American Water Works Association and Water Environmental Federation, Washington DC.
8. Xiaoben Jiang (2015) The impact of temperature, pH and environmental heterogeneity on prokaryotic diversity in Yellowstone National Park thermal springs. https://digitalrepository.unm.edu/biol_etds/57.
9. Dewashish Kumar, S. Thiagarajan and S. N. Rai (2011) Deciphering Geothermal Resources in Deccan Trap Region using Electrical Resistivity Tomography Technique. journal geological society of indiavol.78, pp.541-548.
10. Alam F (2014) Evaluation of hydrogeochemical parameters of groundwater for suitability of domestic and irrigational purposes: a case study from central Ganga Plain, India. Arab J Geosci 7:4121–4131. https://doi.org/10.1007/s12517-013-1055-6.

11. Sisay Derso, Abebe Beyene, Melaku Getachew, Argaw Ambelu (2015) Ecological Status of Hot Springs in Eastern Amhara Region: Macroinvertebrates Diversity. American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS**)** Volume 14, No 2, pp 1-22.
12. Sitangshu Chatterjeea, Suman Sharmaa, Md. Arzoo Ansaria, A.S. Deodhara, Upananda Lowb, U.K. Sinhaa, Ashutosh Dasha (2016) Characterization of subsurface processes estimation of reservoir temperature in Tural Rajwadi geothermal fields, Maharashtra, India. (vol 59, pg 77, 2016) 10.1016/j.geothermics.
13. Tripathi Indra Prasd, Kumar M.Suresh and Dwivedi Arvind Prasad, (2013) Characterization of Diffuse Chemical Pollution in Satna District of Vindhya Region, India of *International Research Journal Chemical Environmental Sciences* 2(11),46-60**.**
14. Haki, G. D. & Gezmu, T. B. (2012). Physico-chemical properties of waters from some Ethiopian hot springs and the risk to the health of the community. *Greener Journal of Physical Sciences,* pp. 138-140.
15. Haki, G. D. & Gezmu, T. B. (2012). Physico-chemical properties of waters from some Ethiopian hot springs and the risk to the health of the community. *Greener Journal of Physical Sciences,* pp. 138-140.
16. Dewashish Kumar, S. Thiagarajan and S. N. Rai. (2011) Deciphering Geothermal Resources in Deccan Trap Region using Electrical Resistivity Tomography Technique. journal geological society of india vol.78, december 2011, pp.541-548.
17. Bhusare, D. U. & Wakte, S. P. (2011). Microbiological and physiochemical attributes of hot water sulphur spring of Unkeshwar. *Life Science,* 2(4), pp. 4-6.
18. Sharma S.K. (2010) *Geothermal: a sustainable energy outlook for India*, Proceeding world geothermal congress 2010, Bali, Indonesia.
19. P.B.Sarolkar (2005) Geochemical Characters of Hot Springs of West Coast, Maharashtra State, India. Proceedings World Geothermal Congress 2005 Antalya, Turkey, 24-29 April 2005.
20. Chatterjee D., Arora, C.L., Ghatak S.K., Ghosh, D. and Ramshastri, R. (1980) Report on the geophysical investigation for geothermal resources in parts of Ratnagiri dist, Maharashtra. Geol. Surv. India, Unpubld. Rep., F.S. 1977-79.