Asian Journal of Conservation Biology, December 2025. Vol. 14 No. 2, pp. 164-169 AJCB: FP0272/87253
ISSN 2278-7666 ©TCRP Foundation 2025 https://doi.org/10.53562/ajcb.87253

Research Article

Ecological Assessment of Limestone Caves of Meghalaya, India: Baseline Study of Microclimate and Water Quality for Faunal Conservation

Cynthia Mylliem Umlong and Madhurima Das *

Department of Zoology, Assam Don Bosco University, Sonapur 782402, India

(Received: May 14, 2025; Revised: November 13, 2025; Accepted: November 20, 2025)

ABSTRACT

This study assesses the seasonal variation in microclimate and water quality of six limestone caves across four districts of Meghalaya, India—Siju and Nakama Caves (South Garo Hills), Arwah and Maw Tynghiang Caves (East and South West Khasi Hills), and Rupasor and Shuki Caves (West Jaintia Hills)—to evaluate their ecological suitability for cave-dwelling herpetofauna. Field surveys conducted between July 2023 and November 2024 recorded consistently low light intensity (100–355 lux), negligible wind speeds (0.05–0.1 m/s), stable cave temperatures (21.9°C to 26.7°C), and high humidity levels (76% to 98%), creating ideal conditions for amphibians and reptiles sensitive to environmental fluctuations.Water quality analysis revealed high dissolved oxygen (DO) levels across sites (10.64–18.6 mg/L), low biological oxygen demand (BOD) in most caves (1.08–1.5 mg/L), with localized elevations in Nakama (6.68 mg/L) and Shuki (4.4 mg/L), indicating minor organic contamination. Sulphate concentrations were generally low during both seasons (summer: 2.2–7.4 mg/L; winter: 0.5–2.77 mg/L), except in Maw Tynghiang, which showed a pronounced increase in summer (34.2 mg/L) and remained comparatively elevated in winter (5.4 mg/L). Nitrate (NO_3^-) levels also showed seasonal variability, with summer concentrations ranging from 1.375 mg/L (Rupasor) to 3.125 mg/L (Nakama), while winter values dropped markedly across all sites (0.25–0.75 mg/L), indicating reduced surface runoff and organic leaching in the dry season. Electrical conductivity (EC) mirrored this seasonal trend, with higher values in summer (140–429 µS/cm) and lower in winter (84–375 µS/cm); Shuki recorded the highest EC (429 µS/cm in summer), while Arwah had the lowest (140 µS/cm in summer). Total dissolved solids (TDS) ranged from 56 ppm (Arwah) to 214.5 ppm (Shuki), and pH remained slightly alkaline (7.2–8.7), supporting a stable aquatic environment. These findings confirm that Meghalaya's karst caves offer largely favourable and stable microhabitats for fauna, though site-specific deviations point to early signs of anthropogenic impact. The study underscores the need for regular ecological monitoring and targeted conservation efforts to preserve the biodiversity of these sensitive subterranean ecosystems.

Key words: Siju, Nakama, Arwah, Maw Tynghiang, Rupasor, Shuki

INTRODUCTION

Limestone caves are dynamic subterranean systems formed through the dissolution of carbonate rocks, resulting in complex karst landscapes that are both geologically and hydrologically significant (Gunn, 2004). These environments are marked by unique physical features—such as speleothems (stalactites, stalagmites), variable passage morphologies, and distinct microclimates with low light, stable temperatures, and high humidity (Xiong et al., 2023). Water plays a critical role in the evolution and functioning of these cave systems, not only as an agent of rock dissolution and speleothem formation, but also as a key determinant of geochemical cycling within the karst environment (Onac & Forti, 2011; Bonacci et al., 2009).

The chemical composition of cave water reflects both the geological history and external environmental inputs, capturing a record of mineral dissolution, atmospheric interactions, and climatic fluctuations (Czuppon et al., 2018). Parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), and concentrations of nitrates and sulphatesare essential for understanding the quality and dynamics of subterranean water systems. Seasonal variability—particularly in monsoon-driven regions—can introduce shifts in these parameters, influencing the cave's structural and hydrological integrity (Sheikh et al., 2012; Fehér et al., 2016). Meghalaya, located on the northeastern margin of the Indian subcontinent, harbors one of the most extensive cave networks in South Asia. With over 1,500 recorded caves, many of which remain unexplored, the state's karst systems are shaped by its high rainfall, complex geology, and subtropical monsoonal climate (Prokop, 2014; Sohtun & Gautam, 2017). The southern slopes of the Khasi and Jaintia Hills, in particular, are rich in limestone deposits, leading to the development of vast underground drainage systems and speleological features (Tripathi et al.,1996). Previous studies have investigated the geomicrobiology and hydrochemistry of cave waters in selected locations

---

*Corresponding Author's E-mail: madhurima.das@dbuniversity.ac.in

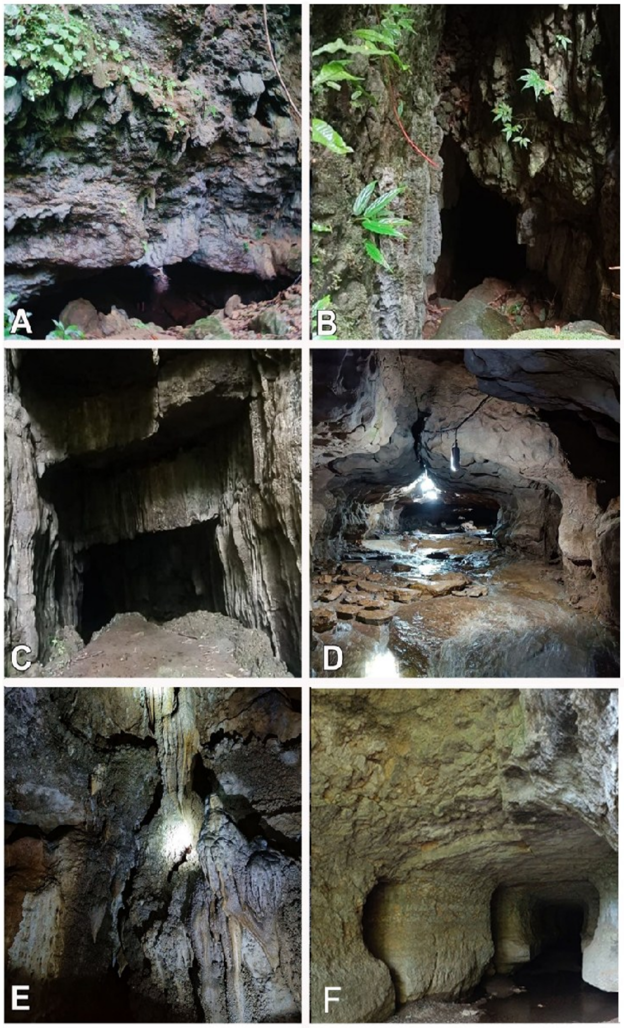

Figure 1. Photographic overview of the cave environments. A:Nakama Cave B:Shuki Cave C:Rupasor Cave D:Arwah Cave E: Maw Tynghiang Cave F: Siju Cave

(Sheikh et al., 2012; Baskar et al., 2016), but comprehensive analyses examining seasonal patterns in both physical and chemical cave parameters remain limited.

MATERIALS AND METHODS

Study Area

Meghalaya, located in the northeastern part of India, spans a geographical area of approximately 22,429 km and forms part of the Indo-Burma Biodiversity Hotspot. The region experiences a subtropical monsoon climate, with a warm, rainy season from May to October and a dry, cooler season from November to April. Due to exceptionally high annual rainfall—among the highest in the world—and widespread limestone formations in the southern plateau, Meghalaya hosts extensive and dynamic karst systems (Harries et al., 2008; Biswas, 2009; Prokop, 2014).

Approximately 1,500 caves have been documented across the state, with only 892 explored to date (Department of Tourism, (N.D). These cave systems, many of which remain untouched by mass tourism, offer valuable opportunities for speleological and hydro-environmental research. For this study, six caves (Fig. 4, Map 1) were selected to represent the geographical and geological diversity across Meghalaya. These include Siju and Nakama Caves in South Garo Hills, Arwah Cave in East Khasi Hills, Maw Tynghiang Cave in South West Khasi Hills, and Rupasor (Krem Syndai) and Shuki Caves in West Jaintia Hills. Siju Cave (25° 21'03"N, 90°41'03"E) is among the longest caves in Meghalaya, situated at 70 m asl elevation with a perennial stream and seasonal water fluctuations. Nakama Cave (25°22'42"N, 90°35'23"E), at 217 m asl elevation, is notable for its active drip water features and ecologically rich surroundings. Arwah Cave (25° 18'12"N, 91°43'37"E), located in Sohra at an elevation of 1568 m asl, features seasonal water flow and fossil-rich limestone formations. Maw Tynghiang Cave (25° 15'17"N, 91°19'24"E), situated in Nongnah village at an altitude of 1146 m asl, is characterized by canyon-like formations and is one of the longest sandstone caves in the world, measuring 3.16 km. Rupasor Cave or Krem Syndai (25°10'55"N, 92°0814E) is located at 474 m asl in Syndai village and spans approximately 450 m, with a well-defined twilight zone near the entrance. Shuki Cave (25°10'40"N, 92°08'19"E), a 1km long limestone cave at 341m asl elevation, features both drip and puddle water systems, offering a diverse microhabitat structure.

Field Survey and Data Collection

Fieldwork was carried out between July 2023 and November 2024, covering both the monsoon and winter seasons. At each site, a set of physical and microclimatic parameters was recorded *in situ* using digital portable instruments. Sampling was performed along a longitudinal gradient beginning at the cave entrance and extending into the darker interior zones, following methods suggested by Camacho et al., (2006) and Sail et al., (2021).

The following parameters and instruments were used for data collection in the selected caves: cave dimensions (width, height, and length) were measured using a standard tape meter; light intensity was recorded using an R-tek 912 digital light meter; and wind speed was measured with a handheld anemometer. Cave temperature (°C) and relative humidity (%) were assessed using a digital thermo hygrometer, while Cave wall temperature was measured with an infrared digital thermometer. Soil and water pH were measured using a Hanna Instruments portable pH meter following the method of Camacho et al., (2006), and their respective temperatures were determined using an ACETEQ digital thermometer as per APHA (1998). Electrical conductivity (EC) of water samples, indicative of ionic content, was measured using a TDS-EC digital meter.

Chemical Analysis

Chemical analysis of cave water was carried out by collecting samples from each cave and analyzing them in the laboratory following the standard protocols of the American Public Health Association (APHA, 1998). The parameters assessed included Dissolved Oxygen (DO) using Winkler's titration method; Biological Oxygen Demand (BOD) through 5-day incubation followed by titration using the same method; and Free Carbon Dioxide (CO_2) using a titrimetric method. Total Alkalinity and Total Hardness were determined using standard titrimetric techniques with EDTA. Total Dissolved Solids (TDS) were measured using a digital TDS meter, while Nitrate and Sulphate concentrations were estimated using colorimetric and turbidometric methods, respectively. All measurements were conducted in triplicates to ensure the reliability and accuracy of the data.

Statistical Analysis

Data were subjected to **one-way ANOVA** (Analysis of Variance) to identify statistically significant differences ($p < 0.05$) in physico-chemical parameters and microclimatic conditions across caves and between the two seasons (summer and winter). The analysis helped in understanding both spatial and temporal patterns in environmental variability across the cave systems.

RESULTS

Variation in Environmental Cave Parameters (Table 1; Fig. 2). This study examined seasonal variation in key environmental parameters across six caves and their influence on the subterranean microclimate. Significant differences were observed in light intensity, cave temperature, wind speed, and cave wall temperature between summer and winter seasons, as indicated by a p-value of < 0.05.

Light intensity remained consistently low in all caves, with summer values ranging from 100 lux in Maw Tynghiang Cave to 355 lux in Shuki Cave. In winter, the range narrowed from 100 lux (Maw Tynghiang) to 214 lux (Shuki), reflecting seasonal differences in light penetration. These low-light conditions are characteristic of deep karst systems.

Wind speed was minimal across all sites in both seasons, from 0.05 m/s (Rupasor, Shuki, Arwah, Maw Tynghiang) to 0.1 m/s (Nakama, Siju).

Cave temperature remained relatively stable year-round. In summer, mean temperatures ranged from 21.97°C (Maw Tynghiang) to 26.7°C (Siju). In winter, the range was from 21.27°C (Maw Tynghiang) to 26°C (Siju), reflecting limited seasonal fluctuation. Wall temperatures also followed this trend, with summer values from 17.9°C (Maw Tynghiang) to 26.87°C (Siju), and winter values from 12.17°C (Maw Tynghiang) to 22.33°C (Shuki).

Soil temperature inside the caves showed similar patterns, with the highest recorded in Siju Cave (25.63°C in summer, 20.03°C in winter), and the lowest in Maw Tynghiang (20.7°C) and Shuki (16.5°C). Outside the caves, summer soil temperatures ranged from 23.13°C (Shuki) to 28.46°C (Siju), and winter temperatures ranged from 17.76°C (Maw Tynghiang) to 22.7°C (Siju).

Soil pH inside the caves varied between 6.54 (Arwah) and 8.10 (Nakama) in summer, and from 6.8 (Arwah) to 8.7 (Siju) in winter. External soil pH ranged from 6.66 (Arwah) to 8.34 (Siju) in summer, and from 7.6 (Arwah and Maw Tynghiang) to 8.76 (Siju) in winter.

Humidity levels remained consistently high across all caves and seasons. In summer, humidity ranged from 76.83% (Arwah) to 96.66% (Shuki), and in winter from 83% (Arwah) to 98% (Shuki), indicating optimal moisture retention within the cave systems.

Variation in Physico-Chemical Parameters of Cave Water (Table 2, Fig, 3)

Water quality analysis showed spatial and seasonal variability among the caves.

Siju Cave exhibited high DO levels (10.64 mg/L in summer, 15.35 mg/L in winter), low BOD (1.63 mg/L in summer, 1.55 mg/L in winter), and minimal nitrate and sulphate concentrations. TDS values were moderate (119.33 ppm in summer, 89.33 ppm in winter), while CO_2 levels were higher in summer (26.67 mg/L).

Nakama Cave recorded the highest DO levels (14.4–18.6 mg/L) and low concentrations of nitrate (3.13 mg/L in summer, 0.75 mg/L in winter) and sulphate (4.45–2.2 mg/L). However, BOD levels were elevated (6.68 mg/L in summer, 6.08 mg/L in winter), possibly indicating localized organic contamination. TDS levels remained low (107 ppm in summer, 68 ppm in winter).

Table 1. Mean ± SD of environmental cave parameters.

Cave	Light (lux)	Wind Speed (m/s)	Cave Temp (°C)	Humidity (%)	Wall Temp (°C)	Soil Temp (°C)
Siju	128 ± 73.9	0.1 ± 0.02	26.7 ± 0.98	91.16 ± 1.52	26.87 ± 0.91	25.63±0.75
Nakama	118 ± 68.12	0.1 ± 0.05	24.76 ± 1.06	98.16 ± 2.84	21.66 ± 0.53	24.83±0.25
Arwah	133 ± 76.78	0.05 ± 0.02	23.48 ± 2.11	76.83 ± 3.17	17.1 ± 0.59	25.03±0.72
Maw Tynghiang	100 ± 64.37	0.05 ± 0.02	21.97 ± 2.28	84.66 ± 7.85	17.9 ± 0.61	20.7±2.76
Rupasor	278.5 ± 160.8	0.05 ± 0.02	23.81 ± 0.35	92 ± 2.19	19.01 ± 2.26	23.63±0.11
Shuki	355 ± 204.95	0.05 ± 0.02	23.41 ± 0.61	96.66 ± 0.78	22.33 ± 1.48	16.5±0.59

Arwah Cave showed favorable water quality with high DO (11.2–13.55 mg/L), low BOD (1.25–1.08 mg/L), and low concentrations of nitrate, sulphate and TDS. CO_2 levels were slightly elevated in summer (15.07 mg/L).

Maw Tynghiang Cave displayed high sulphate concentrations during summer (34.2 mg/L), though winter levels dropped significantly (5.4 mg/L). DO levels were within acceptable limits (14.29 mg/L in summer, 10.73 mg/L in winter), with low BOD and moderate TDS (96.33 ppm in summer, 60.67 ppm in winter).

Rupasor Cave exhibited slightly elevated BOD (3.2 mg/L in summer, 1.45 mg/L in winter) and moderate TDS (187 ppm in summer, 157 ppm in winter), though other parameters were within safe ranges.

Shuki Cave had high DO levels (13.6–18.4 mg/L) and low nitrate and sulphate concentrations. However, BOD was relatively high in summer (4.4 mg/L), and TDS peaked at 214.5 ppm in summer, reducing to 184.5 ppm in winter.

pH levels across all caves were slightly alkaline, ranging from 7.2 to 8.7 across seasons. The highest water temperatures were recorded at Siju Cave (25°C in summer, 22°C in winter), and the lowest at Maw Tynghiang (18.6°C in summer, 16.8°C in winter). Electrical conductivity ranged from 140 µS/cm (Arwah) to 429 µS/cm (Shuki) in summer, and from 84 µS/cm (Arwah) to 375 µS/cm (Rupasor) in winter.

Total hardness ranged from 52 mg/L (Arwah) to 283 mg/L (Shuki) in summer, and from 62.9 mg/L (Arwah) to 315 mg/L (Shuki) in winter. Alkalinity levels followed a similar trend, ranging from 126–376 mg/L in summer and 64–357 mg/L in winter.

Table 2. Mean ± SD of environmental cave parameters.

Cave	DO (mg/L)	BOD (mg/L)	CO_2 (mg/L)	Nitrate (mg/L)	Sulphate(mg/L)	TDS (ppm)
Siju	15.35	1.55	26.67	1.16	5.08	119.33
Nakama	18.6	6.68	3.3	3.125	2.2	68
Arwah	13.55	1.08	15.07	1.20	3.15	56
Maw Tynghiang	14.29	1.51	7.73	1.25	34.2	96.33
Rupasor	15.15	3.2	3.5	1.375	2.77	187
Shuki	18.4	4.4	3.62	1.18	2.2	214.5

DISCUSSION

The findings of this study reveal that the physical environment and water quality within the limestone caves of Meghalaya remain relatively stable across seasons, with minor site-specific and seasonal variations. Such environmental stability is characteristic of well-preserved karst systems and underlines the importance of these caves as sensitive hydrogeological entities. Previous studies by Baskar et al., (2016) examined the Syndai cave, where they measured basic water parameters such as pH, conductivity, temperature, humidity, alkalinity, and bicarbonate content. Similarly, Sheikh et al., (2012) studied cave spring waters from the Jaintia and East Khasi Hills, analyzing pH, dissolved oxygen, conductivity, temperature, total dissolved solids, hardness, alkalinity, and nitrate levels. In the present study, we explored a wider range of caves across Meghalaya, including Syndai, to observe how water quality parameters vary seasonally between different cave systems. This broader approach helps reveal how environmental and geological factors influence the chemistry of cave waters throughout the region.

High dissolved oxygen (DO) levels across all six caves—ranging from 10.64 mg/L to 18.6 mg/L—indicate good water aeration, essential for maintaining chemical balance and supporting subsurface microbial activity (Rowe et al., 2020). In contrast, biological oxygen demand (BOD) values were generally low, except in Nakama and Shuki Caves, where elevated BOD during summer (6.68 mg/L and 4.4 mg/L respectively) suggests localized organic loading (Silva et al., 2012). This could be attributed to natural detritus accumulation or limited surface runoff carrying organic matter during the wet season.

Seasonal fluctuations in CO_2 concentrations, particularly the elevated levels observed during summer in Siju (26.67 mg/L) and Arwah (15.07 mg/L), align with previous studies indicating increased cave CO_2 levels during warmer months due to enhanced microbial respiration and reduced air circulation (Czuppon et al., 2018). This pattern further reinforces the sensitivity of cave atmospheres to external climatic inputs, particularly in monsoon-dominated regions.

Sulphate concentrations remained low in most caves, generally under 5 mg/L, with a notable exception in Maw Tynghiang Cave during summer (34.2 mg/L). This spike could be related to geological or surface inputs and warrants further investigation. Nitrate levels remained consistently low across all sites, which is a positive indicator of minimal agricultural runoff or anthropogenic nutrient input in the sampled caves.

Total Dissolved Solids (TDS) and Electrical Conductivity (EC) values varied moderately across sites and seasons. Shuki and Rupasor Caves exhibited the highest TDS levels (199.5 ppm and 172 ppm, respectively), while Arwah had the lowest (56 ppm). These values fall within acceptable limits for karst groundwater, but their relative elevation in some sites may indicate mineral leaching from the surrounding lithology or minor anthropogenic influence (Sheikh et al., 2012; Fehér et al., 2016). The seasonal drop in EC during winter—especially noticeable in Arwah and Maw Tynghiang Caves—suggests dilution from increased percolation or reduced ion mobilization in cooler conditions (Raut et al., 2025).

pH values across all caves remained slightly alkaline (7.2–8.7), consistent with the presence of carbonate rock and groundwater buffering capacity. Similarly, total hardness and alkalinity levels were generally high, particularly in Shuki Cave (hardness up to 315 mg/L; alkalinity up to 376 mg/L), reflecting the natural dissolution of calcium and magnesium-rich minerals in the host rock (Chimenti et al.,2023).

Microclimatic data further support the notion of a stable internal environment. Temperature variations were minimal across seasons, with internal cave temperatures remaining between 21°C and 26°C. These conditions are buffered from external fluctuations and indicative of deep cave zones with limited surface influence. Relative humidity remained high year-round, particularly in Shuki and Nakama Caves (up to 98%), which reflects limited ventilation and high moisture retention—a common trait in mature karst systems (Onac & Forti, 2011).

The elevated wind speeds observed at a few entrances during summer were negligible overall (0.05–0.1 m/s), reaffirming the relatively static air mass in these systems. Low wind movement, in turn, aids in preserving humidity and maintaining thermal equilibrium. Light penetration remained low in all caves, decreasing deeper into the systems, which is consistent with the natural structure of limestone and sandstone caves with narrow or sinuous openings.

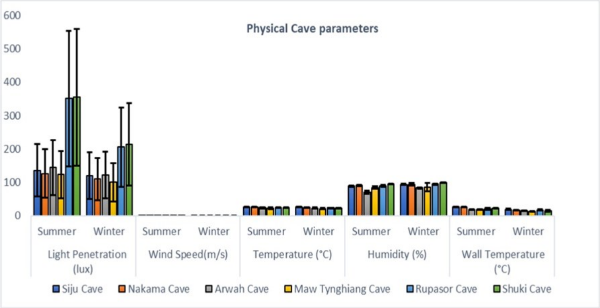

Figure 2. Graphical representation of physical parameters across the six study sites

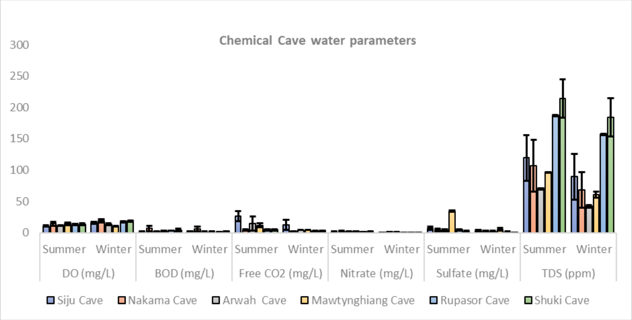

Figure 3. Graphical representation of chemical water parameters across the six study sites

Although most parameters remained within acceptable limits (Sheikh et al., 2012), the observed anomalies—such as elevated sulphate in Maw Tynghiang, higher BOD in Nakama and Shuki, and increased TDS in Shuki—point to site-specific processes or possible anthropogenic inputs. These deviations, though minor, emphasize the importance of localized cave-level monitoring.

Given the region's increasing exposure to tourism and potential land-use changes, continuous monitoring of these sensitive environmental indicators is essential. The interplay between surface hydrology, land practices, and subterranean ecosystems in karst landscapes makes them particularly vulnerable to even small-scale disturbances (LeGrand et al., 1973; Zhang et al., 2023).

In conclusion, the caves of Meghalaya, despite some seasonal and site-specific variations, exhibit overall environmental and water quality stability. This study provides valuable baseline data on the physicochemical and microclimatic characteristics of these karst systems. Future research should aim to model long-term changes in cave hydrology under shifting climate regimes and increased anthropogenic pressures, with an emphasis on identifying early-warning indicators of ecological stress. Both Sheikh et al., (2012) and Baskar et al., (2016) studied cave waters from Meghalaya but focused on different aspects. Baskar et al., (2016) worked on the Syndai cave, recording pH, conductivity, temperature, humidity, and alkalinity, reporting slightly alkaline conditions (pH ~7.4–8.0) and moderate conductivity values, typical of limestone systems. Sheikh et al., (2012) analyzed cave springs from the Jaintia and East Khasi Hills while also examining the microbial involvement in mineral precipitation, finds similar alkaline pH, moderate hardness, and low nitrate levels, indicating minimal surface contamination. In comparison, the present study covers a broader set of caves across Meghalaya, including Syndai, and observes seasonal fluctuations in pH, conductivity, alkalinity, and temperature of cave water. The overall trends are consistent with both Sheik et al., (2012) and Baskar et al., (2016) confirming that most cave waters remain slightly alkaline and mineral-rich, but our results highlight greater seasonal variation, suggesting that local hydrological and climatic factors strongly influence cave water chemistry in Meghalaya.

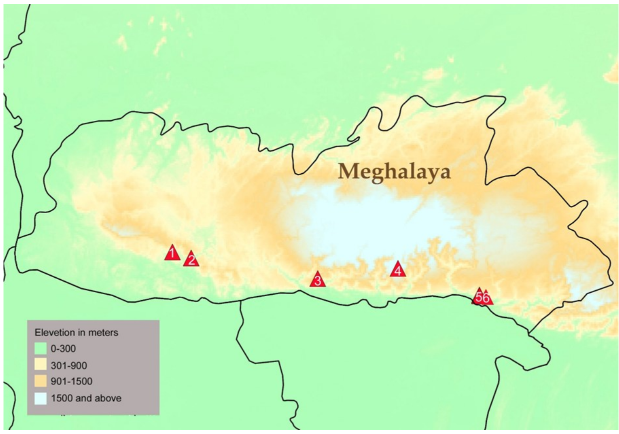

Figure 4. An elevation map of Meghalaya showing all the six study caves. 1: Nakama Cave; 2: Siju Cave; 3: Maw Tynghiang Cave; 4: Arwah Cave; 5: Rupasor Cave; 6: Shuki Cave.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Ministry of Tribal Affairs for financial support under the National Fellowship and Scholarship for Higher Education of ST Students [Award No- 202223-NFST-MEG-02142] to Cynthia Mylliem Umlong (CM). We are also grateful to the Assam Don Bosco University, Department of Zoology for their support during the study. Additionally, CM wants to express her gratitude to her parents and friends for their assistance throughout the field survey.

REFERENCES

APHA 1998. Standard Methods for the Examination of Water and Waste Water. 20th Edition. Washington: American Public Health Association.

Baskar, S., Routh, J., Baskar, R., Kumar, A., Miettinen, H. and Itävaara, M. 2016. Evidence for microbial precipitation of calcite in speleothems from Krem Syndai in Jaintia Hills, Meghalaya, India. Geomicrobiology Journal 33(10): 906–933.

Biswas, J. 2009. The biodiversity of Krem Mawkhyrdop of Meghalaya, India, on the verge of extinction. Current Science 96(6): 904–910.

Bonacci, O., Pipan, T. and Culver, D.C. 2009. A framework for karst ecohydrology. Environmental Geology 56: 891–900.

Camacho, A.I., Valdecasas, A.G., Rodriguez, J., Cuezva, S., Lario, J. and Sanchez-Moral, S. 2006. Habitat constraints in epikarstic waters of an Iberian Peninsula cave system. Annales de Limnologie-International Journal of Limnology 42(2): 127–140.

Czuppon, G., Demény, A., Leél-Őssy, S., Óvari, M., Molnár, M., Stieber, J. and Haszpra, L. 2018. Cave monitoring in the Béke and Baradla caves (Northeastern Hungary): implications for the conditions for the formation cave carbonates. International Journal of Speleology 47(1): 2.

Chimenti, M., Natali, S., Giannecchini, R., Zanchetta, G., Baneschi, I., Doveri, M., Isola, I. and Piccini, L., 2023. Hydrogeochemistry and Isotopic Composition of Waters in the Renella Cave (Central Italy): New Insights into Groundwater Dynamics. Water, 15(9), p.1764.

Department of Tourism,. (N.D). Caves and Caverns of Meghalaya. Shillong: Department of Tourism, Meghalaya.

Fehér, K., Kovács, J., Márkus, L., Borbás, E., Tanos, P. and Hatvani, I.G. 2016. Analysis of drip water in an urban karst cave beneath the Hungarian capital (Budapest). Acta Carsologica 45(3): 201–213.

Gunn, J. 2004. Encyclopedia of Karst and Caves. Fitzroy Dearborn, Chicago and London.

Harries, D.B., Ware, F.J., Fischer, C.W., Biswas, J. and Kharpran-Daly, B.D. 2008. A review of the biospeleology of Meghalaya, India. Journal of Cave and Karst Studies 70(3): 163–176.

LeGrand, H.E., 1973. Hydrological and Ecological Problems of Karst Regions: Hydrological actions on limestone regions cause distinctive ecological problems. Science, 179(4076), pp.859-864.

Onac, B.P. and Forti, P. 2011. Minerogenetic mechanisms occurring in the cave environment: an overview. International Journal of Speleology 40(2): 79–98.

Prokop, P. 2014. The Meghalaya Plateau: Landscapes in the Abode of the Clouds. Pp. 173–180. In Landscapes and Landforms of India. (ed Kale, V.S.), Springer, Dordrecht.

Rowe, M., Veerus, L., Trosvik, P., Buckling, A., & Pizzari, T. 2020. The reproductive microbiome: an emerging driver of sexual selection, sexual conflict, mating systems, and reproductive isolation. Trends in ecology & evolution, 35(3), 220-234.

Raut, V., Wagh, V., Tadse, K. and Karuppannan, S., 2025. Study of seasonal variation in groundwater geochemistry for beneficial use of drinking and irrigation in Aundha Nagnath tehsil of Maharashtra, India. Discover Sustainability, 6(1), p.330.

Sail, P., Borkar, M.R., Shaikh, I. and Pal, A. 2021. Faunal diversity of an insular crepuscular cave of Goa, India. Journal of Threatened Taxa 13(2): 17630–17638.

Sheikh, G.A., Dar, I.Y., Bhaskar, R., Pandit, A.K. and Theophilus. 2012. Geomicrobiology and Geochemistry of Cave Spring Water from Jaintia and East Khasi Hills of Meghalaya, India. Global Journal of Science Frontier Research: Environment & Earth Sciences 12(2): 1–15.

Sohtun, L.M., Gautam, P. and Kabia, S.K. 2017. Potential of speleo-tourism and its role in tourism promotion in Meghalaya. Innovative Research Thoughts 3 (1): 169–180.

Silva, M.S., de Oliveira Bernardi, L.F., Martins, R.P. and Ferreira, R.L., 2012. Transport and consumption of organic detritus in a neotropical limestone cave. Acta Carsologica, 41(1).

Tripathi, R.S., Pandey, H.N., & Tiwari, B.K (1996). State of Environment of Meghalaya. North Eastern -Hill University.

Xiong, Y., Zhou, Z., Ding, S., Zhang, H., Huang, J., Gong, X. and Su, D. 2023. Spatiotemporal variation characteristics and influencing factors of karst cave microclimate environments: A case study in Shuanghe Cave, Guizhou Province, China. Atmosphere 14(5): 813.

Zhang, J., Liesch, T., Chen, Z. and Goldscheider, N., 2023. Global analysis of land-use changes in karst areas and the implications for water resources. Hydrogeology Journal, 31(5), pp.1197-1208.