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# Spatio-temporal variations in surface water quality parameters of Kameng drainage, Eastern Himalaya, Arunachal Pradesh, India

**Kishor Kunal, Parvaiz A Ganie, Deepjyoti Baruah, Garima, AK Jaiswar, SP Shukla, D Sarma and P Khandu Thungon**

**Abstract**
The present study was conducted to determine the spatio-temporal variations in surface water quality at selected locations of Kameng drainage. Water samples were analysed in four different seasons (Premonsoon, Monsoon, Postmonsoon and Winter) at six stations located at various altitudes (Shergaon, Dirang, Sangti, Rupa, Munna Camp and Tenga) during 2018-2019. All the water quality parameters (water temperature (7.7-17 ºC), dissolved oxygen (7.1-9.8 mg/l), pH (6.1-7.8), total dissolved solids (14-80 ppm), hardness (19-64 mg/l), alkalinity (23-83 mg/l), phosphorus (0.07-0.78 mg/l), ammonium (0.01-0.55 mg/l), nitrite (0.03-0.83 mg/l), nitrate (0.16-2.85 mg/l) were found within the permissible limit, suitable for development of riverine flora and fauna including fishes.

**Keywords:** Water quality, Kameng drainage, Arunachal Pradesh, seasons

## 1. Introduction
The ecosystem conditions have been experiencing continuous changes worldwide, which are primarily influenced by anthropogenic activities. Biodiversity hotspots worldwide, especially in developing or less developed countries, seem to be more vulnerable to these changes, which may be primarily due to rapid developmental requirements and lack of environmental management tools. The use of modern technology has expanded agriculture and has doubled production in many areas since 1960 but has come to the environment's cost [1]. These global threats are not only confined to planes but have greatly affected hilly areas too. Land-use change, fragmentation, deforestation, and non-sustainable (or traditional) forest management are significant threats to the hilly environment. Changes in land-use practices have affected water resources' integrity and quality worldwide [2, 3]. Recent studies [4] showed that land-use changes have resulted in extensive deforestation of rural landscapes, thus influencing water and materials' transport along the watersheds in other parts of the globe. Many countries have introduced a plan to monitor and assess the pollution effects in order to evaluate the water quality of aquatic systems [5-7]. However, monitoring water quality and making qualitative and quantitative decisions based on real data have become a challenge for environmental management [8]. The condition is even worse in developing countries where the baseline information is lacking.
The state of Arunachal Pradesh, located in the extreme east of India with an area of 83,743 km$^2$, is inhabited by 13,83,727 people (2011 Census). Its mainland extends between 91º30" to 92º40" E longitudes and 26º54" to 28º01" N latitudes. Arunachal Pradesh forms a part of Eastern, Himalayan Global Biodiversity Hotspot [9] part of India. The state is bestowed with major five drainages, namely river Kameng, Subansiri, Siang, Lohit and Tirap and their tributaries. All these rivers have innumerable rivulets and streams having their own characteristic flora and fauna. Rivers flowing through various altitudes play a major role in the distribution of fish species, including mighty mahseer, rainbow trout, brown trout and indigenous snow trout in the cold water sector. Thus, it becomes essential to maintain the ecological parameters favorable for these economically important fishes.
The river Kameng in the Eastern Himalaya, originates in Tawang district from the glacial lake below snow-capped Gori Chen mountain 27°48′36″N and 92°26′38″E, at an elevation of 6,300 meters on the India-Tibet border in South Tibet and flows 264 kilometers through West Kameng District, Arunachal Pradesh and is one of the major tributaries of river Brahmaputra.

The tributaries of river Kameng, such as Dirang-chu, Tenga-chu, Sangti-chu etc. are the least explored rivers of Eastern Himalaya and are an important source of snow trout in the region. Fishery resource also plays a critical role in the regional economy and food security of the local people. Proposed hydroelectric power projects in the area also pose threat to the river ecosystem and especially fishery resources. Altogether, the tributaries of river Kameng are the least explored rivers of Eastern Himalaya and are an important source of fishes in the region.

Reports on the water quality of Himalayan rivers available but these studies are limited for the rivers of Arunachal Pradesh. Major ion chemistry of river Tenga has been studied by Sharma and Sarma [10], water quality of river Siang by Das and Kar [11] and river Dikrong by Das, Gupta [12]. Studies on the ichthyodiversiy and water quality in Kameng drainage has not been reported till date. Thus, it was quite necessary to generate a baseline data for ecosystem monitoring, conservation and management purposes.

## 2. Materials and Methods

### 2.1. Study area

The study of water quality parameters and ichthyofaunal diversity was conducted on Kameng drainage by sampling at 6 selected locations covering altitude from 1217 m to 1969 m. Water and fish samples were collected seasonally during 2018 to 2019 (fig 1). The seasons were classified as 1. Premonsoon (March to May), 2. Monsoon (June-September), 3. Post-monsoon (October- early November), 4. Winter (Late November- February).

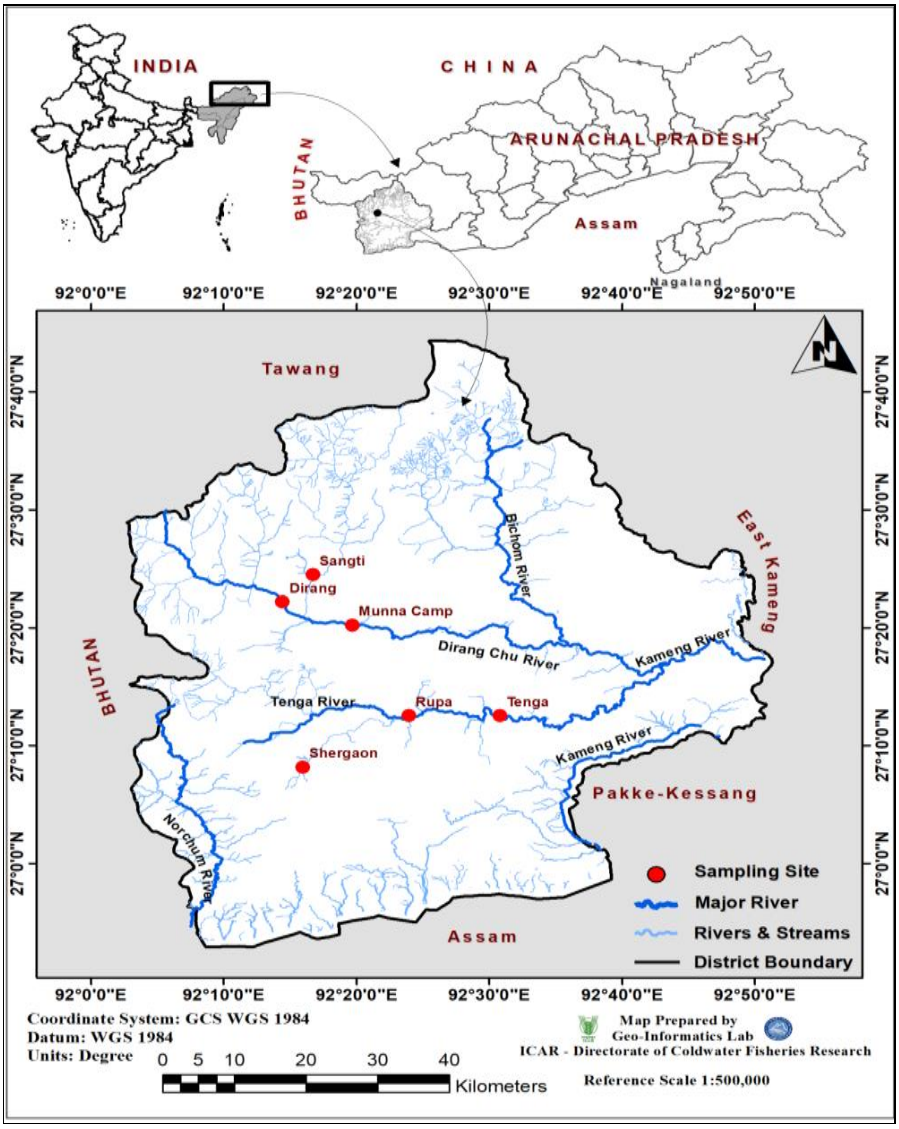


**Fig 1:** Map showing the different selected sampling sites in Kameng Drainage

### 2.2. Sampling and analysis

The parameters like water temperature, pH, DO and total dissolved solids (TDS) were measured at the time of sampling usin probe (Hanna multiprobe HI98194), while alkalinity, hardness and other nutrients were estimated in the laboratory using standard methods [13].

## 3. Result and Discussion

Spatio-temporal variation in water quality parameters in Kameng drainage is represented in Table 1 to Table 4 anf Figure 2 and Figure 3.

### 3.1 Physical-chemical parameters

The temperature is regarded as one of the most important factor in the aquatic ecology and no other single factor has such profound influence [14]. It is of enormous significance as it regulates various abiotic characteristics and biotic activities of an aquatic ecosystem [15]. It is one of the critical environmental factors which determine the profile of organisms dwelling in a particular river system. Kameng is a snow fed river [16]. Round the year lower temperature of the river is attributed due to feeding by snow melted water. Among all stations the temperature was comparatively lower at Shergaon followed by Sangti, due to larger canopy and higher altitude, while smaller canopy and lower altitude at Tenga were responsible for higher water temperature as temperature has indirect relation with altitude and canopy cover [17]. When comparing all the seasons maximum temperature was observed during premonsoon and minimum in winter which was directly correlated to air temperature and higher solar insolation or summer season in premonsoon.

issolved Oxygen (DO) is an important water quality parameter in assessing water pollution [18]. The DO concentration varies according to time of day, season and location [19]. The concentration of DO in water depends on turbulence, elevation and temperature. The location-wise analysis revealed higher value of DO at Rupa while lower at Dirang. Maximum DO concentration was recorded in premonsoon and minimum in postmonsoon. The high oxygen concentration (8.2-9.8 mg/l) recorded during the premonsoon was due to enhanced photosynthetic activities as a result of better solar insolation and reduced turbidity during the dry season. Minimum DO was observed in monsoon season which might be due to higher turbity due to rain and runoff from the catchment area. The drop in DO concentration in winter might have resulted from the vertical mixing due to low surface water temperatures. The vertical mixing might have brought hypolimnetic deposits to the water surface resulting in turbidity and reduced oxygen concentration. Similar findings have been reported in Asa lake Ilorin, Nigeria by researchers [20].

Water pH has significant effects on the toxicity of various compounds like ammonia, hydrogen sulphide, cyanides and heavy metals, especially on fish [21]. Higher pH values cause bitter taste to water, affect mucous membrane cause corrosion, and affect aquatic life [22]. pH was minimum at Dirang and maximum at Munna camp. Low pH at Dirang can be due to pollution caused by human settlement on its bank and low flow rate due to the plain regime of river while contrast occurs at Munna camp. Slightly alkaline pH distribution of the surface waters was observed at sampling stations. High pH values of 7.8 were recorded during the premonsoon while pH drop was recorded during the monsoon and postmonsoon seasons. This drop in pH was probably due to the stirring effect of the in-coming flood or water from the catchment area and streams resulting in the mixing of runoff water and surface waters to reduce pH. Also the decrease in pH of the surface waters may be due to decomposition of the inundated terrestrial vegetation of the littoral zone following increased water levels during monsoon and post monsoon. Decomposition reduces the amount of oxygen, while increasing the amount of carbon dioxide in the affected environment [20].

Alkalinity is a chemical measurement's ability to neutralize acids. Alkalinity at the higher altitude is mainly caused by weathering of rocks above which water flows. The availability of carbon dioxide for phytoplankton growth is related to alkalinity [23]. No proper paatern in alkalinity variation could be observed at the sampling stations. However, alkalinity present at all the stations and in all the seasons were found to be in the range favourable for growth of phytoplankton and, which indicate good primary productivity.

Hardness is defined as total sum of calcium, magnesium and predominant cations present in water. Calcium and magnesium ion are essential to fish for metabolic reactions such as bone and scale formation [24]. Total hardness was higher in premonsoon and lower in winter months. The lower hardness in winter may be attributed to low temperature and low water flow in winters which may have caused lesser dissolution of cations from rocks into the water.

Total dissolved solids (TDS) comprises of inorganic salts and small amount of organic matter which are dissolved in water. In case of mountain water, the effect of siltation gets drastically reduced due to fast flowing water. Highest value of TDS was observed in monsoon months on all the location due to surface run off from nearby catchment area during rain. The water quality also gets affected by livestock rearing on the bank of river. Dirang was having the maximum TDS values mainly due to presence of various construction works on its bank followed by Shergaon where also some construction works could be observed. Value of TDS was higher in monsoon months due to entry of allochthonous components from surrounding during surface runoff by rain water. High TDS influence the other parameters of water such as taste, hardness, corrosion properties, influence osmoregulation of freshwater organism and they are not removed by conventional method and finally reduce the utility of water for drinking and irrigation purposes [25].

### 3.2 Nutrients

Supply of nutrients to the hill streams is limited in nature. The fast flowing nature of hill streams dilute the overall nutrients of the water. Most of the nutrients are added to water bodies through dissoliution of substratum or rock above which the river flows and runoff from catchment areas. Anthropogenic activities like mining, construction near river bank and discharge from domestic sewage and agricultural runoff also add nutriets to the river.

Phosphorus is a key element used for the assessment of water quality. Higher levels of phosphorus in water stimulates growth thereby increasing productivity of aquatic system [26-28]. Low concentration of phosphorus at Shergaon region can be related to low human habitation and lower anthropogenic activities while higher concentration at Dirang may be due to high human interference or anthropogenic activity near the aquatic system or river bank. Temporal changes in phosphorous content could be observed evidently. Phosphate is greatly influenced by diffuse input from local sources and release from soil [29]. Higher value pf phosphorous during monsoon may be due to influx of water and sediment from cathment area into the river and resuspension of phosphorous from decaying sediment into the water column. Similar observation were also made by reserchers [30] in Rambiara stream, Kashmir Himalaya.

Ammonia concentration in water mainly gets affected by the metabolic activities of aquatic animals and decomposition of organic matter in water. Aerobic decomposition of ammonia leads to generation of nitrite and nitrate in the presence of bacteria. Concentration of ammonia was maximum at Tenga whereas it was minimum at Munna camp. Ammonium ion is usually measured in rivers with point sources of pollution and is in normal conditions taken up by plants or quickly transformed to nitrate; thus it can be detected only in the water samples taken near the source of pollution [31]. Higher ammonium ion concentration at Tenga might be linked to high tourist pressure, presence of small industries and high population density at Tenga valley, while significantly less population at Munna camp might have avoided ammonium input into the river. Increased nutrients from runoff during monsoon enhances the primary productivity, which in turn result in higher zooplankton during postmonsoon. In postmonsoon the concentration of zooplankton and fish (as monsoon is breeding season for most fishes) generally increases which excrete ammonia as waste product and hence may result in elevated ammonia level in water during postmonsoon.

Nitrite as a rule is found with nitrates and ammonia nitrogen in surface water but generally occurs in low concentration due to their instability (Svobodova *et al* 1993). Nitrite and nitrate concentration was higher in Sangti where it was minimum at Munna camp. If the surrounding canopy is less it means the less scope for input of nitrogen in the form of litter from the riparian vegetation at that point. Nirite in the water can come from the agricultural runoff where it is used as fertilizers. Pesticides and nitrate contaminations are mostly due to the use of inorganic fertilizers and pesticides spray in agricultural sector. Agricultural activities were maximum at Sangti followed by Shergaon resulting in higher nitrate and nitrite concentration. During monsoon months the concentration of nutrients were higher due to runoff from surrounding catchment area. In case of dense human settlement monsoon water brings lots of domestic wastes and effluents. However, substantially low value for dissolved nitrate and nitrite was observed at all sampling stations. If the allochthonous input is high and level of nitrogen is low, it means the effect of dilution is high. The low cropping intensity coupled with low agro – chemical dosing and absence of industries also mean that the pollution load due to chemical is quite low [32].

**Table 1:** Physico-chemical parameters of water in sampling stations during Premonsoon season

| Name of area | **Shergaon** | **Dirang** | **Sangti** | **Rupa** | **Munna** | **Tenga** |
|---|---|---|---|---|---|---|
| Temperature (°C) | 12.15±0.3 | 12.3±0.7 | 15.35±0.8 | 17±0.2 | 14.45±2.1 | 15.9±0.3 |
| DO (mg/l) | 8.9±0.1 | 8.95±0.05 | 8.3±0.3 | 9.8±0.6 | 8.4±0.4 | 8.2±0.3 |
| pH | 7.3±0.3 | 6.9±0.1 | 7.7±0.1 | 7.4±0.2 | 7.8±0.1 | 7.4±0.1 |
| TDS (ppm) | 61.5±1.5 | 56±3.5 | 40.5±5.5 | 38.5±3.5 | 42.5±7.5 | 38±4 |
| Hardness (mg/l) | 50±4 | 58±4 | 64±7 | 40±3 | 44±1 | 56±6 |
| Alkalinity (mg/l) | 29±1 | 40±2 | 55±5 | 25±1 | 47±1 | 62±12 |
| Phosphorus (mg/l) | 0.07±0.03 | 0.34±0.07 | 0.08±0.04 | 0.45±0.18 | 0.25±0.12 | 0.16±0.08 |
| Ammonium (mg/l) | 0.06±0.01 | 0.16±0.01 | 0.11±0.01 | 0.10±0.07 | 0.04±0.01 | 0.24±0.04 |
| Nitrite (mg/l) | 0.07±0.01 | 0.03±0.00 | 0.42±0.32 | 0.03±0.01 | 0.06±0.01 | 0.05±0.01 |
| Nitrate (mg/l) | 1.35±0.8 | 0.42±0.14 | 2.16±0.86 | 0.9±.15 | 0.16±0.01 | 0.61±0.08 |

**Table 2:** Physico-chemical parameters of water in sampling stations during Monsoon season

| Name of area | **Shergaon** | **Dirang** | **Sangti** | **Rupa** | **Munna** | **Tenga** |
|---|---|---|---|---|---|---|
| Temperature (°C) | 13.25±0.35 | 14.8±0.02 | 14.85±0.7 | 16.85±0.35 | 14.15±0.55 | 14±1.4 |
| DO (mg/l) | 8.1±0.1 | 7.14±0.2 | 7.9±0.7 | 8.4±0.4 | 7.3±0.5 | 7.35±0.5 |
| pH | 7.1±0.1 | 6.1±0.2 | 7.1±0.5 | 7.2±0.2 | 7.6±0.1 | 7.3±0.1 |
| TDS (ppm) | 73±2 | 80.5±3.5 | 48.7±7 | 63.5±7.5 | 58.5±0.5 | 57.5±2.5 |
| Hardness (mg/l) | 25±1 | 33±6 | 39±5 | 33±3 | 37.5±7 | 58±8 |
| Alkalinity | 47±5 | 38±2 | 41±7 | 32±4 | 40±2 | 83±15 |
| Phosphorus (mg/l) | 0.22±0.195 | 0.35±0.15 | 0.42±0.08 | 0.67±0.08 | 0.50±0.02 | 0.78±0.01 |
| Ammonium (mg/l) | 0.04±0.005 | 0.12±0.075 | 0.06±0.01 | 0.08±0.07 | 0.06±0.04 | 0.16±0.01 |
| Nitrite (mg/l) | 0.08±0.01 | 0.37±0.33 | 0.24±0.02 | 0.23±0.21 | 0.06±0.01 | 0.16±0.04 |
| Nitrate (mg/l) | 1.95±0.35 | 1.75±0.05 | 2.6±0.10 | 2.2±0.10 | 0.875±0.02 | 2.15±0.15 |

**Table 3:** Physico-chemical parameters of water in sampling stations during Postmonsoon sea

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|---|---|---|---|---|---|---|
| **Name of area** | **Shergaon** | **Dirang** | **Sangti** | **Rupa** | **Munna** | **Tenga** |
| Temperature (°C) | 12.35±0.85 | 12.45±0.95 | 14.1±0.5 | 14±0.15 | 13.2±0.40 | 14.65±0.80 |
| DO (mg/l) | 8.4±0.40 | 7.8±1.1 | 8.6±0.80 | 8.44±40 | 8.2±0.50 | 8.0±0.09 |
| pH | 7.2±0.30 | 6.7±0.05 | 7.6±0.80 | 7.7±0.10 | 7.6±0.20 | 7.3±0.20 |
| TDS (ppm) | 49.5±8.5 | 66±9 | 14.5±2.5 | 51±5 | 56.5±8.5 | 57±3 |
| Hardness (mg/l) | 30±6 | 37±4 | 31±1 | 38±4 | 55±4 | 60±4 |
| Alkalinity | 33±7 | 36±2 | 40±2 | 23±3 | 34±2 | 71±11 |
| Phosphorus (mg/l) | 0.08±0.06 | 0.07±0.02 | 0.15±0.12 | 0.12±0.04 | 0.11±0.02 | 0.44±0.06 |
| Ammonium (mg/l) | 0.11±0.08 | 0.33±0.05 | 0.17±0.01 | 0.18±0.005 | 0.01±0.00 | 0.47±0.03 |
| Nitrite (mg/l) | 0.10±0.04 | 0.24±0.17 | 0.42±0.10 | 0.11±0.08 | 0.13±0.04 | 0.11±0.03 |
| Nitrate (mg/l) | 1.16±0.01 | 0.67±0.22 | 2.85±0.45 | 0.63±0.07 | 0.30±0.01 | 1.01±0.20 |

**Table 4:** Physico-chemical parameters of water in sampling stations during Winter season

| Name of area | Shergaon | Dirang | Sangti | Rupa | Munna | Tenga |
|---|---|---|---|---|---|---|
| Temperature (°C) | 7.7±0.2 | 9±0.2 | 7.95±0.15 | 8.9±0.7 | 8.5±0.65 | 9.8±0.4 |
| DO (mg/l) | 8.2±0.4 | 7.8±0.1 | 8.2±0.4 | 8±0.2 | 7.8±0.3 | 8.04±0.6 |
| pH | 7.1±0.1 | 6.3±0.2 | 6.8±0.2 | 7.6±0.1 | 7.6±0.4 | 7.2±0.4 |
| TDS (ppm) | 65±1 | 57±2 | 62.5±5.5 | 60.5±9.5 | 32.5±1.5 | 73±6 |
| Hardness (mg/l) | 19±1 | 37±7 | 35±3 | 24±4 | 37±3 | 39±1 |
| Alkalinity | 37±3 | 52±4 | 40±4 | 45±3 | 41±3 | 82±6 |
| Phosphorus (mg/l) | 0.09±0.01 | 0.19±0.02 | 0.12±0.04 | 0.16±0.13 | 0.20±0.11 | 0.12±0 |
| Ammonium (mg/l) | 0.05±0.02 | 0.39±0.01 | 0.16±0.08 | 0.12±0.01 | 0.05±0.02 | 0.55±0.1 |
| Nitrite (mg/l) | 0.20±0.02 | 0.31±0.06 | 0.83±0.46 | 0.26±0.05 | 0.16±0.02 | 0.50±0.1 |
| Nitrate (mg/l) | 0.66±0.04 | 0.53±0.46 | 2.6±0.4 | 0.49±0.03 | 0.41±0.02 | 0.29±0.20 |

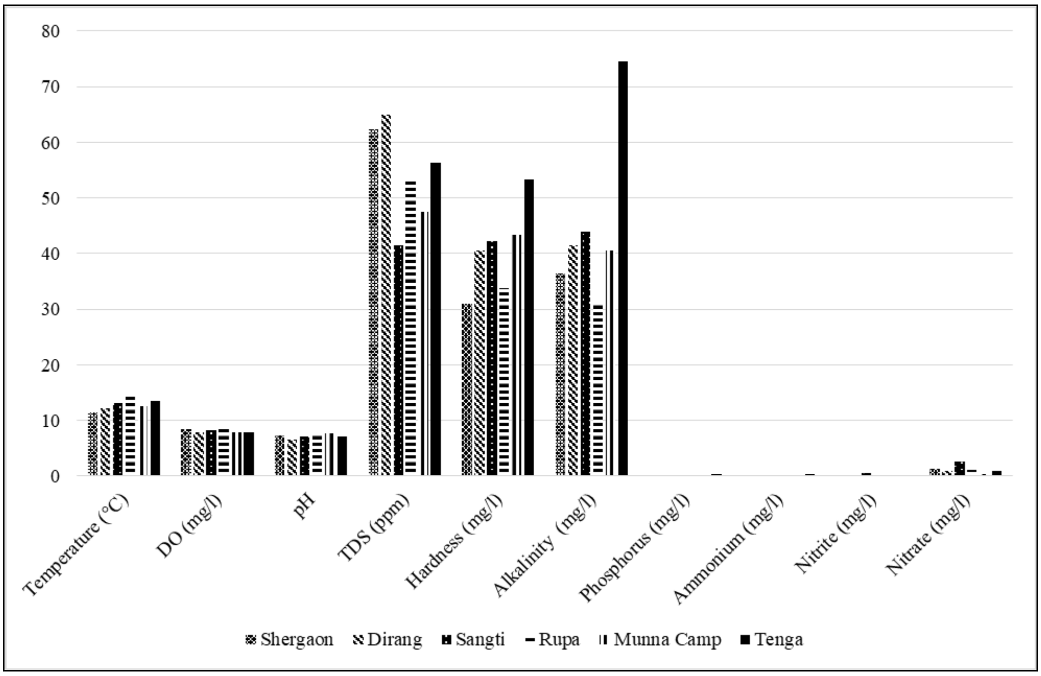


**Fig 2:** Spatial variation in water quality parameters in Kameng drainage

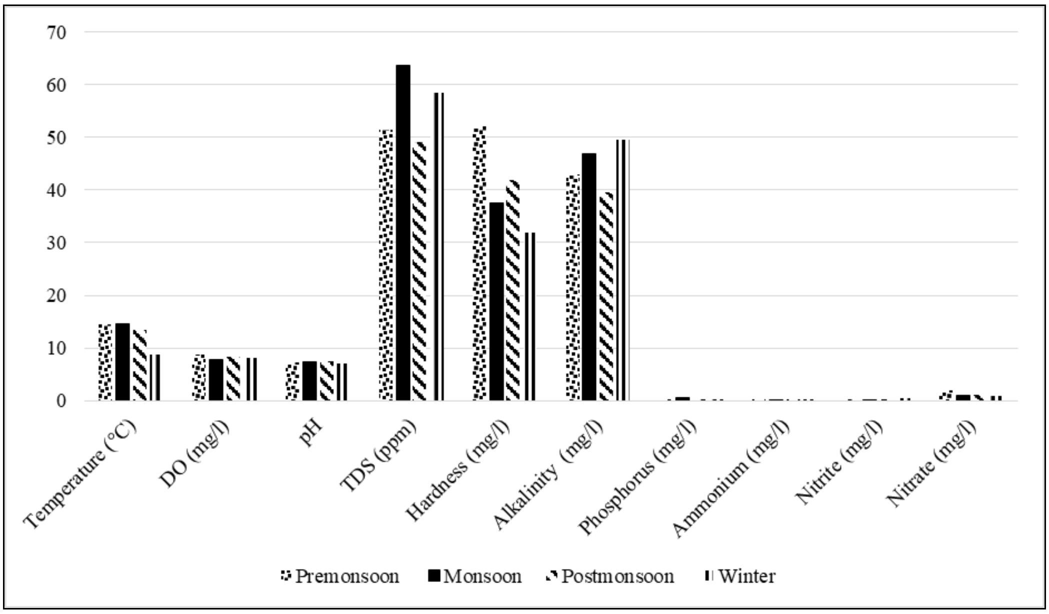


**Fig 3:** Seasonal (temporal) variation in water quality in Kameng drainage

## 4. Conclusion

The aquatic ecosystem is highly dependent on water quality and biological diversity [33]. Any changes in water quality of the river affect the biotic communities of river ecosystem. Water quality characteristics of aquatic environment arise from multitude of physical, chemical and biological interactions [34]. All the river sites of Kameng drainage being snow fed remained clear and transparent during the sampling and the study period. The sampling sites near low human inhabitation areas showed comparatively better water quality.

However, all the essential water quality parameters were within the optimum level at all sampling stations concluding a good health of the water body and conducive for the development and abundance of riverine fauna including fishes.

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**7. References**

1. West PC, Biggs R, McKenney BA, Monfreda C. Feeding the world and protecting biodiversity. Levin S (ed) Encyclopedia of biodiversity, 2nd edn. Academic Press, Waltham, MA 2013, 426-434.
2. Foley J, DeFries AR, Asner GP, Barford C, Bonan G, Carpenter SR *et al*., Global Consequences of Land Use. Science 2005;309:570-574.
3. Goldstein JH, Caldarone G, Duarte TK, Ennaanay D, Hannahs N, Mendoza G *et al*., Integrating ecosystem-service tradeoffs into land-use decisions. Proceedings of the National Academy of Sciences 2012;109(19):7565-7570.
4. de Souza AL, Fonseca DG, Libório RA, Tanaka MO. Influence of riparian vegetation and forest structure on the water quality of rural low-order streams in SE Brazil. Forest Ecology and Management 2013;298:12-18.
5. Pesce SF, Wunderlin DA. Use of water quality indices to verify the impact of Córdoba City (Argentina) on Suquía River. Water research 2000;34(11):2915-2926.
6. Zampella RA, Bunnell JF, Laidig KJ, Procopio NA. Using multiple indicators to evaluate the ecological integrity of a coastal plain stream system. Ecological Indicators 2006;6(4):644-663.
7. Silva LMd, Jardim WF. Trends and strategies of ozone application in environmental problems. Química Nova 2006;29(2):310-317.
8. Lermontov A, Yokoyama L, Lermontov M, Machado MAS. River quality analysis using fuzzy water quality index: Ribeira do Iguape river watershed, Brazil. Ecological Indicators 2009;9(6):1188-1197.
9. Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca GA, Kent J. Biodiversity hotspots for conservation priorities. Nature 2000;403(6772):853-858.
10. Sharma BB, Sarma H. Major ion chemistry of Tenga River at Dahung, Arunachal Pradesh, India. Archives of Applied Science Research 2011;3(6):141-146.
11. Das BK, Kar D. Water analysis of River Siang of Arunachal Pradesh, India. Oceanography and Fisheries. 2017;3(5).
12. Das T, Gupta A, Arunachalam A. Limnology of Dikrong river system in Arunachal Pradesh, India. Pollution Research 2011;30(4):501-509.
13. APHA-AWWA-WPCF, Standard methods for the examination of water and wastewater APHA American Public Health Association 2005
14. Ruttner F. Fundamentals of limnology. University of Toronto Press 1953.
15. Ganie PA, Baruah D, Kunal K, Posti R, Garima, Debajit S. Phytoplankton diversity and abundance in upland streams of Kameng drainage, Arunachal Pradesh. Journal of Entomology and Zoology Studies 2018;6(6):1166-1173.
16. Baruah D, Kunal K, Sarma D, Ahmad P, Sharma P, Singh A *et al*., Aquatic biodiversity in upland streams of kameng drainage in Arunachal Pradesh. Journal of Krishi Vigyan 2018;7(1):10-15.
17. Novikmec M, Svitok M, Kočický D, Šporka F Bitušík P. Surface water temperature and ice cover of Tatra Mountains lakes depend on altitude, topographic shading, and bathymetry. Arctic, Antarctic, and Alpine Research, 2013;45(1):77-87.
18. Laluraj C, Padma P, Sujatha C, Nair S, Kumar N, Chacko J. Base-line studeis on the chemical constituents of Kayamkulam estuary near to the newly commissioned NTPC power station. Indian Journal of Environmental Protection 2002;22(7):721-731.
19. Bailey RT, Ahmadi M. Spatial and temporal variability of in-stream water quality parameter influence on dissolved oxygen and nitrate within a regional stream network. Ecological modelling 2014;277:87-96.
20. Araoye PA. The seasonal variation of pH and dissolved oxygen ($DO_2$) concentration in Asa lake Ilorin, Nigeria. International Journal of Physical Sciences 2009;4(5):271-274.
21. Svobodová Z, Loyd R, Máchová J, Vykusová B. Water quality and fish health. EIFAC Technical Paper no. 54; FAO, Rome 1993, 59.
22. Narasimha R, Dorairaju S, Bujagendra R, Chalapathi P. Statistical analysis of drinking water quality and its impact on human health in Chandragiri, Near Tirupati, India. https://www.eco-web.com/edi/111219.html. Accessed on 10.12.2020. 2014.
23. Boyd CE, Pillai VK. Water quality management in aquaculture. CMFRI Special Publication 1985;22:1-44.
24. Bhatnagar A, Devi P. Water quality guidelines for the management of pond fish culture. International journal of environmental sciences 2013;3(6):1980-2009.
25. Seth R, Mohan M, Singh P, Singh R, Dobhal R, Singh KP *et al*., Water quality evaluation of Himalayan rivers of Kumaun region, Uttarakhand, India. Applied Water Science 2016;6(2):137-147.
26. Wetzel RG. Limnology: lake and river ecosystems gulf professional publishing 2001.
27. Hickman RE, Gray BJ. Trends in the quality of water in New Jersey streams, water years 1998–2007. U.S. Geological Survey Scientific Investigations Report 2010–5088, 2010, 70.
28. Stoddard JL, Van Sickle J, Herlihy AT, Brahney J, Paulsen S, Peck DV *et al*., Continental-scale increase in lake and stream phosphorus: Are oligotrophic systems disappearing in the United States? Environmental Science & Technology 2016;50(7):3409-3415.
29. Xu G, Li P, Lu K, Tantai Z, Zhang J, Ren Z *et al*., Seasonal changes in water quality and its main influencing factors in the Dan River basin. Catena 2019;173:131-140.
30. Mir SA, Qadri H, Beigh BA, Dar ZA, Bashir I. Assessment of nutrient status and water quality index of Rambiara stream, Kashmir Himalaya, India. Journal of Pharmacognosy and Phytochemistry 2019;8(3):172-180.
31. Glavan M, Pintar M. Impact of point and diffuse pollution sources on nitrate and ammonium ion

concentrations in the karst-influenced Temenica river. Fresenius Environmental Bulletin 2010;19(5A):1005-1014.
32. Baruah D, Kunal K, Sarma D, Singh A, Kamut K, Thungon P Trout fisheries in the uplands of Arunachal Pradesh: Resources and opportunities. Aquac. Asia, 2017;22(3):3-11.
33. Bera A, Bhattacharya M, Patra BC, Sar UK. Ichthyofaunal diversity and water quality in the Kangsabati Reservoir, West Bengal, India. Advances in Zoology 2014 2014, 8.
34. Bharti PK. Water quality characteristics of Sahastradhara hill stream, Dehradun (Uttarakhand), India. International Journal of Higher Education and Research 2014;4(1):15-27.