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HYDROLOGY OF ARUVIKKUZHI WATERFALLS, KOTTAYAM, KERALA

Arjun S., Anakha Nair and K. S. Anila Kumary*

Post Graduate Department of Zoology, Kuriakose Gregorios College, Pampady, Kottayam, Kerala 686502 India.

***Corresponding Author: Dr. K. S. Anila Kumary**
Post Graduate Department of Zoology, Kuriakose Gregorios College, Pampady, Kottayam, Kerala 686502 India.

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ABSTRACT
To provide information on the physico-chemical characteristics of Aruvikkuzhi waterfalls, monthly samples were taken from three stations along the length of waterfalls for 6 months from September 2019 to February 2020 covering wet and dry seasons. Air and water temperature was low during wet season which can be connected with the rain and cooling of atmosphere itself. Mean pH was comparatively low at the waterfall area (7.28) while the value calculated for TDS was higher at this station (10.8 mg/l) and lower at the upstream station (9.35 mg/l). Chloride content in the water was comparatively higher at station III (upstream) followed by station II (waterfall). Total alkalinity was low at all stations, varied from 1.6 to 4.2 mg/l $CaCO_3$. Total hardness (mean) was comparatively higher at station III (21 mg/l $CaCO_3$) followed by station II (18.5 mg/l $CaCO_3$). There is considerable increase in dissolved oxygen in the waterfall area together with total absence of carbon dioxide. Concentration of the nutrients nitrite and phosphate were comparatively higher at the upstream station and lower in the waterfall area. Low organic enrichment and greater turbulence leads to comparatively better physico-chemical characteristics in the immediate vicinity of waterfall. Low level of sewage mixing from the surrounding human settlements along the banks and the digestion of sewage wastes lead to comparatively higher values of nutrients, chloride, carbon dioxide and total hardness at the upstream station.

KEY WORDS: Physico- chemical parameters, waterfall ecosystem, tourism.

INTRODUCTION
A waterfall is an area where water flows over a vertical drop or a series of steep drops in the course of streams and rivers. Waterfalls are generally considered as natural monuments for revenue generation, because of their ecotourism potentials and as source of quality water for drinking, irrigation and other domestic purposes. Tourism is said to be one of the fastest growing economic activities world over. Tourism planning requires sustainability because its growth usually brings increasing pressure on the natural environment. Sustainable tourism development projects in any aquatic ecosystems can be carried out only if the ecology of these systems in the region is well understood.

Aruvikkuzhi waterfalls, one of the well known waterfalls in Kerala is located at Pallickathodu panchayath in Kottayam district between 9.6035° N latitude and 76.6670° E longitude. The waterfall is about 30ft in height, falling in five steps is a real feast for eyes, especially during monsoon season. Aruvikkuzhi waterfalls are loved for the natural beauty they possess along with the quaint charm of the surrounding rubber plantations. The trails surrounding the area along with the cool water falling from over 100 ft. make it a picnicker's paradise. One gets the distinct feeling of being hugged directly by nature when stand there in this monsoon wonder and it attracts plenty of visitors during season.

The intensity of waterfalls and pressure generated from it due to gravity has given the impression of a lifeless zone and water quality researchers had given little attention to waterfalls. Only few investigations have been carried out so far on parameters of the waterfall ecosystems in Kerala (Priyanka Prabhakaran and Kakkassery, 2018) and absolutely no information of Aruvikkuzhi waterfalls. The present study aimed at the investigation of physical and chemical properties in the ecological system of Aruvikkuzhi waterfalls, Kerala.

MATERIALS AND METHODS
The study was carried out at three selected stations located along the length of Aruvikkuzhi waterfalls for 6 months from September 2019 to February 2020 covering wet and dry seasons. Station I was selected at the downstream part of the waterfalls, about 50 meters away from the falling area, Station II in the immediate vicinity of the waterfall just below the falling steps and Station III in the upstream part of the waterfall about 50 meters upward to the falling steps. The physical and chemical parameters included in the study are air and water

temperature, pH, total dissolved solids, chloride, total alkalinity, total hardness, dissolved oxygen, free carbon dioxide, nitrite-nitrogen and phosphate- phosphorus. The water quality parameters were estimated following the standard methods (Strickland and Parson, 1972; Grasshoff *et al*., 1983; Trivedy and Goel, 1984; APHA, 1998).

Air and water temperature recorded immediately on the site by mercury thermometer. The pH value of water samples are measured by using digital pH meter. TDS of water samples were measured using gravimetric method. Total alkalinity of the water samples were determined by titrating with H_2SO_4 using methyl orange as indicator. The total hardness was determined by the complex titration with EDTA using Erichrome black T as indicator. The chloride was determined by titration against standard solution of silver nitrate using potassium chromate as an indicator. Dissolved oxygen was determined by the modified Winkler method. The carbon dioxide was determined by titrating with NaOH using phenolphthalein as an indicator. Nitrite and phosphate was estimated using spectrophotometer at 543nm and 882 nm respectively.

RESULTS AND DISCUSSION

The water quality characteristics of Aruvikkuzhi waterfalls are shown in Table I.

Water resource is one of the major components of environmental resources threatened by exploitation and pollution due to human activity. Physico-chemical characteristics are very vital water quality monitoring parameters due to their instability once water is extracted from its source. Knowledge of physico-chemical parameters provides information on the productivity of water resource, type of water treatment process to be adopted and permit better understanding of the ability of populations of organisms to survive in them (Boyd and Lichtkpoppler, 1985; Ayodele and Ajani, 1999). As an aquatic ecosystem, the waterfall has several functions such as provide clean water, control pollution and supporting with some critical chemical substances in the ecosystem (Offem, 2011; Shaikh Parveen *et al*., 2013).

Table I. Range and mean of water quality characteristics of Aruvikkuzhi waterfalls (Sept. 2019- Feb. 2020).

Parameter	Downstream		Waterfall		Upstream	
	Range	Mean	Range	Mean	Range	Mean
Air temperature (^{0}C)	29-31.5	29.8	28-32	29.8	28-32	28.8
Water temperature (^{0}C)	27-31.5	28.6	26.5-31	28	27-31.5	28.7
pH	6.74-7.9	7.33	6.7-7.8	7.28	6.66-7.9	7.31
TDS (mg/l)	7.2-14.2	10.02	9.1-15	10.8	6.9-11.1	9.35
Chloride (mg/l)	15.62-24.28	19.83	15.62-24.22	20.08	18.46-34.2	26.23
Total alkalinity (mg/l. $CaCO_3$)	3-4.2	3.4	1.6-4.2	2.85	2.2-4.2	3.15
Total hardness (mg/l. $CaCO_3$)	14-24	18.25	14-24	18.5	13-32	21
Dissolved oxygen (mg/l)	7.2-9.2	8.25	10.2-14.4	11.95	7.6-9.2	8.52
Carbon dioxide (mg/l)	0-1.2	0.6	0	0	0.6-1.4	1.32
Nitrite-nitrogen (µg/l)	15.75-68.46	43.91	17.5-66.4	41.59	26.5-116.3	72.47
Phosphate- phosphorus (µg/l)	1.22-6.06	3.1	1.22-6.06	3.09	1.86-6.34	4.71

Physico-chemical parameters recorded in the present study are an indication of the level of water quality of the different sections of the Aruvikkuzhi waterfall during the period September to February. In general there exists a positive correlation between water level and rainfall which indicate that the water level increases with increasing rainfall. Variation in amount and duration of rainfall had been found to affect physico-chemical parameters of water (Adebisi, 1981; Egborge, 1994). In the present study September - December received considerable amount of rainfall in the area while other months January and February can be considered as low wet period. Air and water temperature was low during wet season (Sept - Dec) which can be connected with the rain and cooling of atmosphere itself. There observed an increase in air as well as water temperature during February since smaller water bodies react quickly with changes in atmosphere. Water temperature (mean) was low at waterfall (28 ^{o}C) compared to that at downstream (28.6 ^{o}C) and upstream (28.7 ^{o}C) stations.

Every water body shows diurnal, monthly as well as seasonal variation in pH. The relationship between CO_2 and pH is also well known in limnology (Boyd, 1990). pH values in the present study indicated slightly acidic conditions during November and December which might be due to higher input of allochthonous organic matter and increased acidification from rain water and land runoff. The dry season pH levels in this study indicate moderate quality of water. pH values obtained in this study agree with those documented by Fakayode (2005) as values most suitable for maximum productivity of aquatic organisms. Total dissolved solids of water sample represents dissolved organic and inorganic matters excepting gases and suspended inorganic substances. None of the samples used for determining TDS in the present study was up to maximum admissible concentration (600 mg/l) of total solids as stipulated by WHO(2004). The chloride concentration was however high in the study area, with increasing trends towards the dry season and also from the downstream towards upstream, is an indication that the area has influence due

to organic pollution by domestic sewage(Goel *et al*.,1980).

Dissolved oxygen level recorded in the waterfall region (station II) of the study area was higher compared to other downstream (station I) and upstream (station III) stations. Low organic enrichment and turbulence nature of waterfall had been suggested as the possible reason responsible for such high oxygen values (Mason, 1992; Offem and Ikpi, 2012). On the other hand, low dissolved oxygen observed downstream of the waterfalls could be attributed to low water velocity, thus reducing the movement of the waters and dissolution of oxygen. The values of dissolved oxygen fell within the ranges 7.2 – 14.4 mg/l can be considered as good water quality suitable for aquatic organisms (Alabaster, 1982). Dissolved oxygen content will be higher during the rains due to lower water temperature and increased aeration due to increased agitation of the water (Offem, 2011). During the present study free CO_2 was totally absent at the water fall region (station II) and the values among the other stations were comparatively higher at the upstream station (station III). Greater turbulence and the associated greater oxygen saturation may be the reason for the absence of CO_2 in the water fall area while sewage mixing and the digestion of sewage wastes may be the reason for the higher values at the upstream station surrounded by human settlements along the banks (Varma and Shukla, 1969).

Total alkalinity is a measure of the capacity of water to neutralize a strong acid (Boyd, 1990). In natural fresh water alkalinity is generally caused by carbonates of calcium and magnesium, calcium forming the major constituent. Total alkalinity values have utmost importance in aquatic habitats as water with low alkalinity is biologically less productive (Sakhare, 2006). Alkalinity in the Aruvikkuzhi waterfalls during this study was very low favouring to low productivity but found to be within tolerance limit of biota. Total hardness indicates the concentration of divalent cations present in water. Total hardness of 13-32 mg/l in Aruvikkuzhi waterfalls was far less than values from Sahastrakund Waterfall, Maharashtra (170 mg/l). The value relates to soft water according to the classification of water in terms of hardness and softness: 0-50 (soft), 50-100 (moderately soft), 100-150 (moderately hard), and 250 and above (hard).

Phosphorus, although present in very small quantity in natural water plays a key role in photosynthesis and intermediary metabolism and forms constituent of nucleic acids and proteins. Phosphorus occurs in natural water in the form of phosphates. The probable source of phosphate-phosphorus of running waters is fertilizer run off, decayed organic matter and phosphate mineral. In the present study phosphate was higher at the upstream section of waterfall where the possibility sewage mixing is found maximum. Nitrite occurs fairly widely in natural waters, which may probably be derived from the reduction of nitrate. High values of nitrite usually occur in regions of low oxygen which is in agreement with the higher concentration at the upstream section of the waterfall. However, the low level of nitrite at all the stations indicates that the biological oxidation of nitrogenous organic matter of both autochthonous and allochthonous origin such as domestic sewage, agricultural runoffs and effluents from industries etc., the major source of aquatic nitrogen, are at their minimum in the study area(Saxena, 1998).

CONCLUSION

A general outlook of the entire results shows that the water of Aruvikkuzhi waterfall is of good quality and relatively clean which may be explained as resulting from high flushing rate in the waterfalls, particularly during wet season. The influx of the stream water has sufficient energy to cause turbulent water movements which could result in flushing of the water body. The cool breeze and affable climate make Aruvikkuzhi waterfalls among the best picnic spots in the district and families are regularly seen camping in this wonderful spot in the landlocked district of Kottayam**.** Recently tourism department of the state is trying to develop this place as a spot of monsoon tourism and giving funds for its development. It is needed to make many facilities in future for the development of this place. However, proper attention should be given for sustainable development of this waterfall for tourism.

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