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Research Paper

A SPATIAL STUDY ON THE PHYSICO-CHEMICAL (WATER QUALITY) VARIABLES IN THE SURFACE WATER OF RIVER LAKSHMANATHEERTHA IN MYSORE DISTRICT, KARNATAKA

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Abstract

This is the first comprehensive spatial study along the full length of river Lakshmanatheertha. This is an important tributary of river Cauvery originates in the Brahmagiri range of Davasibetta in the Western Ghats of Karnataka state. As in other ecosystems, populations of riverine organisms are controlled by a variety of abiotic factors. Mid-stream surface water was collected between 07.30 am and 12.30 pm by using a clean, well rinsed 15 litre capacity polythene bucket and transferred to 5 liters polythene container. Detailed methodology for the determination of physico-chemical (water quality) variables was followed based on APHA. The study revealed that the physico-chemical variables studied show abrupt pattern; this may be due to different geographical condition or addition of waste water from different point and nonpoint sources. Further, it was confired that, the site LTR-5 of river Lakshmanatheertha was more polluted, because most of the water quality variables such as temperature, conductivity, turbidity, SWV, DO, CO_2, Chloride, TASA, Calcium, Phosphate and Chlorophyll-a responded differently with respect to spatial variation in the site LTR-5. The low water level with reduced or no water flow, more anthropogenic activities, sewage and other effluent contamination, solid garbage on the water surface, might be the reason. Hence, in this investigation the content of some of the parameters could be minimized and indiscriminate entry of domestic sewage, agricultural runoff and other effluents into this water course is prevented. Finally, the present study also warrants for strict vigilance and continuous monitoring of these natural water bodies for conservation and sustainable management.

Key words: Water quality, Permissible limit, Anthropogenic, SWV, Riverine ecosystem, Mid stream.

INTRODUCTION

Aquatic ecosystems play an important ecological role on a global scale, as the greater part of many natural microbial conversions occur in water. The environmental persistence of various synthetic chemicals and plastics, bio-magnification of pollutants, eutrophication, and a plethora of other environmental problems reflect unintended interactions of human activities with the microbial component of the global ecosystem. The composition of the microflora and microfauna of a stream or river may be a good indicator of the extent of pollution. Heterotrophic bacteria in fresh waters are important in the processing of natural organic matter and in bio-purification of water, which receives organic pollution. Degradation of organic matter contributes to the purification of the ecosystem and is therefore a major process controlling water quality [1]. As in other ecosystems, populations of riverine organisms are controlled by a variety of abiotic factors. There is evidence that physico-chemical factors in rivers, for examples, temperature, discharge and concentration of suspended solids [2-7], influence the abundance and distribution of micro-organisms. Further, the anthropogenic nutrients inputs to rivers may be profound impact on the microbial loop and the river as a whole. Literatre survey shows that, over the years enormous research literature has piled up on the hydrobiology of marine waters and lentic fresh waters. Only available reports are on physico-chemical parameters of lotic waters / rivers [8-21]. River Lakshmanatheertha is an important tributary of river Cauvery originates in the Brahmagiri range of Davasibetta in the Western Ghats of Karnataka state; it flows North direction and finally joins the main River Cauvery at Krishna Raja Sagar (KRS) reservoir. The total length of this tributary is 95 km, and the total catchment area is 1502 sq. km [22]. This tributary serves as the main source of drinking water after conventional treatment and disinfection to the town of Hunsur. During the entire period of seasonal study, the water surface was always covered with algal bloom and aquatic plants; such as, *Pistia*, *Hydrilla*, *Ipomia aqutica*, *Limna minor* and *Limna major*. Anthropogenic activities like washing of cloths, bullock cart and cattle, and entry of effluents with lot of foams were noticed at the sampling spot. Because of the leakage in the pipe carrying the sewage, there was mixing of the sewage effluent at the sampling spot. Open toileting on banks of this river was a regular practice. Materials of witchcraft pooja were also noticed at the sampling spot. Waste plastic covers, cups, bottles, and old cloths, flowers, slippers, and coconut husk, electric bulbs and tubes were observed along with the solid garbage at the sampling spot. Probably due to dumping of all these, the surface water was dirty with fowl smell. Turbid and muddy nature of the water was observed some times during the monsoon period. Based on seasonal study, the surface water of river Lakshmanatheertha is more polluted. The evidence for these conclusions is that, most of the environmental variables studied were more and also significantly different in river Lakshmanatheertha. Further, in the river Lakshmanatheertha comparatively more number of water quality variables such as Phosphate, Calcium, TASA, Rainfall, COD, Conductivity, Chlorophyll-a, Temperature, Turbidity, SWV, TSS, Nitrate, DO etc., were responsible for variation in microbial parameters studied. This realization that the river Lakshmanatheertha is different led to a detailed study of spatial variation in the river Lakshmanatheertha. Its main aims were 1) To describe the horizontal variation of physico-chemical (water quality) variables along the river Lakshmanatheertha and 2). To investigate causes of this variation.

MATERIALS AND METHODS

Description of sampling sites

Based on sampling convenience and anthrophogenic activities around catchment area, five sampling sites (LTR-1, LTR-2, LTR-3, LTR-4 and LTR-5) were located horizontally to know the spatial variation in physico-chemical (water quality) parameters along the entire length of the river Lakshmanatheertha (Figure. 1). The sampling spot (site LTR-1) was located at Kanur village Road Bridge near Nagarahole National Park approximately 40 Kms away from the Hunsur Town of Mysore district. In this site the water level was very low; the flow was observed occasionally during Monsoon, due to previous day rain. Human activities like washing cloths, cattle and swimming was observed. The site LTR-2 was located near the Nittur village of Hunsur taluk of Mysore district. The actual distance from this sampling spot to Hunsur town is 29 Kms. The water level was very low, very slow flow was noticed during rainy day. The aquatic plants such as *Pistia* were observed on the water surface. However, human activities like fishing and swimming was regular. Site LTR-3 was located at Kolavi village road bridge 24 Kms away from the Hunsur Town. Water was greenish and the water surface was covered with algal patches with foams. The increased water level, high velocity with muddy nature was recoreded during rainy season. Human activities like washing cloths, bathing and washing bicycles noticed occasionally in this sampling spot. The sampling site LTR-4 was located at Hangund village road bridge of Hunsur taluk. The distance from this spot to Hunsur Town is 15 Kms. Few submerged and also free floating aquatic plants like *Nimphea, Pistia* and *Ichornia* were noticed. The site LTR-5 was the routinely sampled site during seasonal study and it was located at Kattemalawadi Anicut (Latitude 12^0 17″N and Longitude 76^0 17″E) near Hunsur town of Mysore district. Here, the water level was very low with very little water flow. The water surface was always covered with algal bloom and aquatic plants; such as, *Pistia*, *Hydrilla*, *Ipomia aqutica*, *Limna minor* and *Limna major*. Regular anthropogenic activities and entry of effluents with lot of foams was noticed at the sampling spot. Materials of witchcraft pooja, waste plastic covers, cups, bottles, and old cloths, flowers, slippers, and coconut husk, electric bulbs and tubes were observed along with the solid garbage at the sampling spot, hence the surface water was dirty with fowl smell.

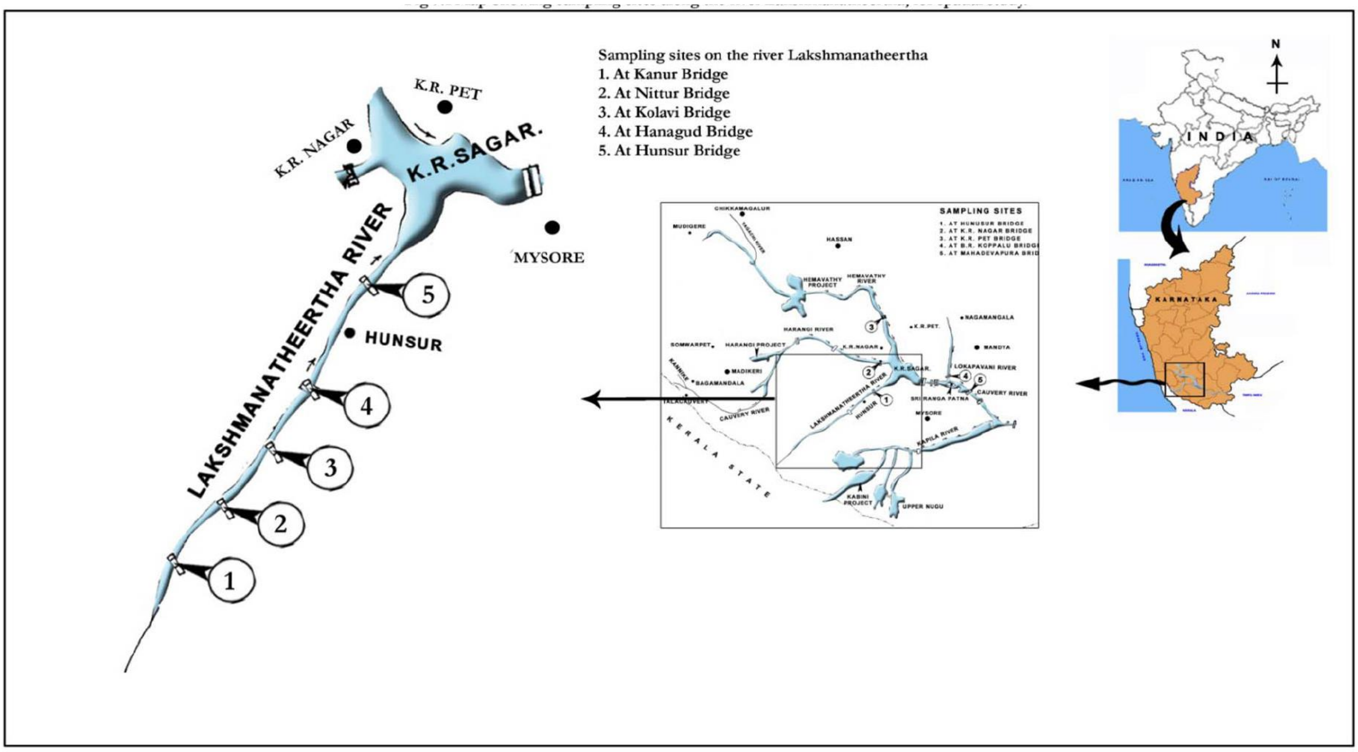

Figure. 1. Map showing sampling sites along the river Lakshmanatheertha, for spatial study

Sampling

Mid-stream surface water was collected along the river Lakshmanatheertha from five different sites at Kanur village, at Nittur village, at Kolavi village, at Hangund village and at Hunsur Road Bridge between 07.30 am and 12.30 pm. The water samples were collected in a clean, well rinsed, 15 litre capacity polythene bucket and transferred to

5 liters polythene container for the determination of physico-chemical (water quality) variables, care being taken not to disrupt the bottom sediment. However, at sites where the water level was shallow, the samples were collected by slowly immersing the bucket in mid-stream. Water samples were transported back to laboratory in wooden box.

Methodology

Detailed methodology for the determination of physico-chemical (water quality) variables was followed based on [23, 3, 21]. Surface water pH was measured in the field using Griph-D-pH meter with glass electrode. The electrode was calibrated against pH 7.0 buffer each time before measurements. However, pH of the surface water samples in the laboratory were measured by using µ-pH meter which was previously calibrated with pH 4.0, 7.0 and 9.2 buffers at laboratory temperature. The surface water temperature was measured with a hand held mercury-in-glass thermometer. The conductivity was determined in the laboratory using microprocessor controlled conductivity meter it was previously calibrated with 0.1 M KCl solutions at 25^0C. Turbidity was measured in the laboratory using digital-nephelo-turbidity meter, which was set up using ultra pure water as zero and respective range (0-1, 1-10, 10-100 and 100-1000 NTU) using Farmazine solution. The surface water velocity (SWV) was determined by timing a semi submerged float (Lemon fruit) over a measured distance. The dissolved oxygen (DO) content of these water samples were estimated by Wrinkler's method. The DO in the sample was immediately fixed with 2 ml potassium iodide and 2 ml of manganese sulphate in the field itself soon after collection. BOD of water sample was determined as described in [24]. The difference between the initial and final DO concentration i.e., DO_0 - DO_5 gave the BOD value. The chemical oxygen demand (COD) of the surface water samples were detrmined by dichromate method as described by [25]. The free carbon-di-oxide (CO_2) of the water sample was estimated by titrimetric method. Chloride concentration of the surface water sample was determined by argentometer method. Calcium contenet of the water sample was estimated by titrimetric method (APHA). Nitrate concentration in the water sample detrmined by brucine method. Inorganic phosphate concentration of the water sample was analysed by using stannous chloride method and the optical density of the samples for both parameters were measured by using UV-VIS Spectrophotometer. The concentration of nitrate and phosphate were calculated from the standard curve. Sulphate concentration of the surface water sample was determined by turbiditimetric method. The standard curve was used to calculate the sulphate concentration [26]. Total Anions of Strong Acids (TASA) was calculated by adding the concentrations of chloride, nitrate and sulphate. Total Suspended Solids (TSS) and Particulate Organic Matter (POM) of surface water sample was detrmined gravimetrically as described in [3]. And the Chlorophyll-a of surface water sample was determined spectrophotometrically as described by [27].

RESULTS AND DISCUSSION

This is the first comprehensive spatial study along the full length of river Lakshmanatheertha. The investigation of water quality variables revealed significant differences only in few important parameters between the sampling sites (Table. 1). The pH is an important variable in water quality assessment as it influences many biological and chemical processes within the aquatic ecosystem. The mean pH measured was above 8 in the sites LTR-1, LTR-2 and LTR-3, but it was less than 8 (*i.e.,* 7.86 and 7.68) in sites LTR-4 and LTR-5 respectively. It was noteworthy that the highest pH of 9.02 (LTR-1) and lowest pH of 7.46 (LTR-4) were the highest and lowest recorded values among the five sites studied. The mean pH (L) ranged from 7.61 in site LTR-4 to 7.82 in site LTR-1. The pH measured in the laboratory was below 8 throughout the study period. The both field and laboratory measured pH did not show much difference and water was always in alkaline nature (>7.5 to 8.20). The increased anthropogenic activities and reduced flow of water are responsible for pH (>8) [12]. Further, the alkaline nature of water samples in these sites may also be due to mixing of water with river basin soil and runoff from adjacent agricultural lands, which is in agreement with [28], in Pirapó River. However, in this investigation the pH level was within the limits set for protection of aquatic life 6.5 to 9.0 [29, 33], for domestic use 7.0 to 9.0 [30]. Most of the aquatic organisms are adapted to an average pH and do not withstand abrupt changes [31, 18, 21]. Temperature is responsible for the biochemical and physiological processes in the aquatic organisms. In the present study mean temperature was similar in sites LTR-1 (26.96^{0}C) and LTR-2 (25.98^{0}C), but was less and was also significantly different in site LTR-4 (22.7^{0}C), while the mean water temperature of LTR-3 and LTR-5 sites showed similarity with LTR-1, LTR-2 and LTR-4 also. This variation in temperature among sites may be due to differential time of collection and the influence of season [16, 32, 21]. Conductivity or specific conductance is a measure of the ability of water to conduct an electric current. It is sensitive to variations in dissolved solids, mostly mineral salts. The mean conductivity was similar in sites LTR-1 (335.4 µS cm^{-1}), LTR-2 (270.2 µS cm^{-1}) and

LTR-3 (397.6 µS cm^{-1}), but it was more in site LTR-4 (717.0 µS cm^{-1}) and site LTR-5 (1094.6 µS cm^{-1}). Further, the conductivity was significantly high (1094 µS cm^{-1}) in the site LTR-5. This was probably due to low level of water, maximum anthropogenic activities, discharge of sewage, and other effluents contamination, eutrophic nature of water, all of which enriches the nutrient level in water, might be the reason. This was in agreement with the similar, findings of [12, 18, 33] has advocated the desirable limit of electrical conductivity as 250 µS cm^{-1}, but in the present investigation the conductivity ranged between 106 to 1540 µS cm^{-1}, and most of the sampling period during spatial study the conductivity reached above 250 µS cm^{-1}. Turbidity is an expression of optical property that causes light to be scattered and absorbed rather transmitted in straight lines through the water sample. The mean turbidity concentration showed clear cut spatial variation with less LTR-5 (5.24 NTU), moderate LTR-3 (17.54 NTU) and LTR-4 (15.94 NTU), and high in LTR-1 (29.22 NTU) and in LTR-2 (26.96 NTU). Further, the mean turbidity of 5.24 NTU in LTR-5 was the less and was also significantly different than the other four sites. The turbidity of river water is mainly caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, colloidal organic matter and plankton and other microscopic organisms [23]. The results of the present investigation, exhibited much lower turbidity values as compared to other Indian rivers like Pinder [34, 8, 35-36]. But the turbidity recorded in all the five sites studied, were above the permissible limit (5 NTU), [37-38]. Total suspended solids (TSS) include the solids that are suspended in water bodies in the form of inorganic and organic particles of immiscible liquids. The inorganic substances include clay, silt and other soil constituents, while organic materials consists of plant fibres and biological solids such as, algal cells, plankton and bacteria. Suspended solids influence the turbidity of waters which in turn affect light penetration resulting in reduced photosynthesis [19]. In this investigation the TSS did not show any significant spatial variation, and it was well below the permissible limits of 25 mg l^{-1} throughout the study period in all the five sites, [33] and [39]. In contrast to the present investigation, less (4.0 – 14 mg l^{-1}) TSS was recorded in the river Dudhsagar of Goa [40]. Velocity of a water body can significantly affect its ability to assimilate and transport pollutants. Thus, the measurement of velocity is extremely important in any assessment programme. The mean SWV was more in the sites LTR-1 (0.29 m Sec^{-1}), LTR-2 (0.31 m Sec^{-1}) and LTR-3 (0.24 m Sec^{-1}), and was also significantly different when compared to LTR-4 (0.00 m Sec^{-1}) and LTR-5

(0.00 m Sec^{-1}) sites. The zero SWV of the sites LTR-4 and LTR-5 may be due to low water level or non availability of water in the upstream barrages. Further, the water velocity can vary within a day, as well as from day to day and season to season, depending on hydro-meteorological influences and the nature of the catchment area [39]. Determination of dissolved oxygen (DO) concentration is a fundamental part of water quality assessment since; oxygen is influences all chemical and biological processes within water bodies. The mean DO was more and also similar in sites LTR-1 (6.99 mg l^{-1}), LTR-2 (7.06 mg l^{-1}) and LTR-3 (5.88 mg l^{-1}), whereas, in sites LTR-4 (4.27 mg l^{-1}) and in LTR-5 (2.39 mg l^{-1}) the mean DO was less and was also significantly different when compared to other four sites studied. Further, the mean DO in site LTR-4 and in site LTR-5 was also significantly different from one another. DO is essential to all forms of aquatic life especially for those organisms responsible for self purification process in natural waters. Any fluctuation in DO may be due to season, current velocity, temperature and biological activities [41]. The LTR-5 was the site showed lesser DO concentration; this was probably due to reduced water flow, intense human activities, contamination sewage and other effluents, and eutrophic nature of water. In general, low DO has been attributed mainly to the process of decomposition of organic matter by the microorganisms, which involve utilization of Oxygen [42] or due to reduced water flow [43]. Further, it was suggested that minimum DO of 4.0 mg l^{-1} should be maintained in water for healthy growth of fishes and other planktonic populations [44]. However, in the present investigation the DO measured in the site LTR-5 was within the prescribed DO level throughout the study period. Whereas, the high DO in the remaining sampling sites may be due to high photosynthetic activity by phytoplankton, [45] and [21]. The mean Carbon di-Oxide was significantly more (30.36 mg $^{-1}$) in site LTR-5, when compared to other four upstream sampling sites of river Lakshmanatheertha. Spatial variation in CO_2 revealed that more concentration (range 14.3 to 48.4 mg l^{-1}) was recorded in site LTR-5. Generally, it was noticed that, the concentration of DO was less in the site LTR-5; thus there was inverse proportion of O_2 with that of CO_2 concentration in this site. The permissible limit of CO_2 is < 10 mg l^{-1} [23]. But, the mean concentration of free CO_2 in sites LTR-3, LTR-4 and LTR-5 was more than the permissible limits. Higher levels of free CO_2 in these water courses might have resulted by the respiration of faunal population and decaying products of organic matter [20, 21]. The mean BOD did not show any spatial variations in in this investigation. BOD is the quantity of Oxygen utilized by micro-organisms in 5 days at 20^0C for the bio-chemical degradation of organic matter in water. The drinking water standard for BOD is 3 mg l^{-1} (ISI) and 5 mg l^{-1} (ICMR). Whereas, the BOD values recorded in this investigation was below the permissible limit of 5 mg l^{-1} as suggested by [30] throughout the study period, except, for a high BOD value of 6.48 mg l^{-1} in site LTR-3. Chemical oxygen demond (COD) is defined as the amount of Oxygen (in mg l^{-1}) consumed under specific conditions in the chemical oxidation of organic and oxidisable inorganic matter. The COD recorded in all the sampling sites LTR-1(40.16 mg l^{-1}), LTR-2 (49.76 mg l^{-1}), LTR-3 (47.20 mg l^{-1}), LTR-4 (44.48 mg l^{-1}) and LTR-5 (45.80 mg l^{-1}) were above the permissible limit of 4.0 mg l^{-1} [46]. Increased concentration of COD may be due to high temperature and increased evaporation of water, [47, 18, 21]. However, high COD values are indicative of the presence of chemically oxidisable carbonaceous matter as well as inorganic matter such as nitrate and sulphate [48]. Further, in the present investigation the concentration of COD was higher than the concentration of BOD; generally, this may be due to presence of non-degradable oxygen demanding pollutants in the water [49, 19]. The chloride ion (Cl^{-1}) concentration is used as an important parameter for detection of extent of contamination. Mean Chloride was more in the sites LTR-4 (91.82 mg l^{-1}) and LTR-5 (86.42 mg l^{-1}) when compared to other three sampling sites. The high chloride contents in the water may be due to inflow of domestic sewage and other human wastes [16, 20, 21] Similar observations were made by [40] in Khandepur river; [18] in Vamanapuram river. However, the concentration of chloride in the present investigation was well within the higher desirable limit of 200 mg l^{-1} [38] and 250 mg l^{-1} [30, 33]. Nitrate ion is the common form of combined nitrogen found in natural waters. It may be biochemically reduced to nitrite by denitrification processes under anaerobic conditions. Nitrate that is present in aquatic ecosystem will either be assimilated by algae and aquatic macrophytes or transferred to underlying sediments where it undergoes denitrification [20]. The mean Nitrate did not show any spatial variation, it was noticed generally that, highest NO_3 content of 0.32 mg l^{-1} (LTR-5) and the lowest NO_3 content of 0.02 mg l^{-1} (LTR-2). Nitrate level in this study is well below the highest desirable limit of 45 mg l^{-1} [33, 38]. Sulphate is a naturally occurring anionic nutrient found in all kinds of water bodies which may undergo transformation to sulphur or hydrogen sulphide [20]. The mean sulphate concentration also did not show any significant variation between the five sampling sites. It was noted that the highest concentration (9.60 mg l^{-1}) of SO_4 (LTR-4) and the lowest concentration (0.20 mg l^{-1}) of SO_4 was noticed in site LTR-1. The sulphate content in this study is well within the permissible limit of 250 mg l^{-}[33, 38]. The sum total of chloride, sulphate and nitrate gives the Total Anions of Strong Acids (TASA). The TASA showed highest concentration in sites LTR-4 (95.30 mg l^{-1}) and LTR-5 (90.16 mg l^{-1}) and was also significantly different than the other three upstream sites (range 16.95 to 28.77 mg l^{-1}). The increased TASA in this investigation was mainly responsible for increased concentration of Chloride, when compared to Nitrate and Sulphate. Calcium is one of the most abundant elements in natural waters imparting hardness. The mean calcium was more and also significantly different in the sites LTR- 4 (32.76 mg l^{-1}) and LTR-5 (33.24 mg l^{-1}). Calcium content of all the water courses in this investigation is below the highest desirable limit of 75 mg l^{-1} [30]. Phosphate is an essential nutrient for living organisms, but it is a limiting nutrient for algal growth and therefore controls the primary productivity. The mean phosphate did not show any significant variation in all the sampling sites of the river Lakshmanatheertha. The phosphate concentrations in the present investigation in the sites LTR-1 (0.08 mg l^{-1}) and LTR-2 (0.09 mgl^{-1}) showed lesser concentration of phosphate and were above the permissible limit of 0.1 mg l^{-1}, whereas, it was more in the sites LTR-3 (0.33mgl^{-1}) and in LTR-4 (0.29mgl^{-1}), while in LTR-5 it was moderate (0.18mgl^{-1}), in all these three sampling sites the phosphate concentration was above the permissible limit [46]. The concentration of phosphate in aquatic ecosystem may be due to leaching from the minerals or agricultural runoff [26, 50] or due to maximum anthropogenic activities like washing and discharge of sewage load [9, 19, 21]. The mean POM did not show any spatial variation in all sampling sites on river Lakshmanatheertha. POM indirectly depends upon the TSS, i.e. organic matter content in the form of particulate matter, which will burn at 400ºC in a furnace [9, 21]. POM in the water is important for the growth of micro-organisms, which fluctuated due to phytoplankton and other organic substances. The mean Chlorophyll-a was significantly more in sites LTR-4 (12.03 μg l^{-1}) and LTR-5 (12.53 μg l^{-1}) as compared to other three sampling sites. Chlorophyll-a is a measure of phytoplankton biomass and is an index of productivity, its increased concentration in water may be due to increase of nutrients such as phosphate and nitrate. In general, water with low nutrient content decreases the concentration of Chlorophyll-a (<2.5 μg l^{-1}) in contrast high nutrient content increases it up to 140μg1^{-1} [39.]

Table. 1. Spatial study in the physico-chemical (water quality) variables in the surface-water of River Lakshmanatheertha

Sl. No.	Environmental Parameters $	Site-1 LTR-1	Site-2 LTR-2	Site-3 LTR-3	Site-4 LTR-4	Site-5 LTR-5	F-value[1]	P-value[1]
1	pH(F)	8.20ᵃ±0.61	8.16ᵃ±0.53	8.17ᵃ±0.28	7.86ᵃ±0.32	7.68ᵃ±0.12	1.6314	0.2055^{NS}
2	pH(L)	7.82ᵃ±0.50	7.68ᵃ±0.45	7.66ᵃ±0.23	7.61ᵃ±0.26	7.64ᵃ±0.18	0.2800	0.8875^{NS}
3	Temperature	26.96ᵃ±2.01	25.978ᵃ±1.66	24.60ᵃᵇ±2.70	22.70ᵇ±1.68	24.60ᵃᵇ±1.67	3.1834	**0.0355***
4	Conductivity	335.4ᵃ±181.13	270.2ᵃ±140.43	397.6ᵃ±335.54	717.0ᵇ±363.42	1094.6ᶜ±435.49	6.0493	**0.0063***
5	Turbidity	29.22ᵃ±7.51	26.96ᵃ±17.64	17.54ᵇ±10.93	15.94ᵇ±16.31	5.24ᶜ±3.93	3.9982	**0.0332***
6	SWV	0.29ᵃ±0.41	0.31ᵃ±0.28	0.24ᵃ±0.33	0.00ᵇ±0.00	0.00ᵇ±0.00	3.7032	**0.0312***
7	DO	6.99ᵃ±0.55	7.06ᵃ±1.55	5.88ᵃ±1.50	4.27ᵇ±1.81	2.39ᶜ±1.06	10.3151	**0.0001*****
8	BOD	2.06ᵃ±1.22	2.15ᵃ±1.75	2.76ᵃ±2.65	1.96ᵃ±2.16	2.42ᵃ±1.04	0.1491	0.9612^{NS}
9	CO_2	5.41ᵃ±1.17	8.80ᵃ±2.58	9.99ᵃ±4.25	14.56ᵃ±6.41	30.36ᵇ±14.18	8.9579	**0.0003*****
10	COD	40.16ᵃ±10.14	49.76ᵃ±8.58	47.20ᵃ±9.99	44.48ᵃ±9.47	45.80ᵃ±19.87	0.4250	0.7888^{NS}
11	Cl_2	19.88ᵃ±3.29	21.07ᵃ±5.53	35.56ᵃ±22.15	91.82ᵇ±45.36	86.42ᵇ±38.77	7.6710	**0.0006****
12	NO_3	0.15ᵃ±0.07	0.18ᵃ±0.10	0.17ᵃ±0.07	0.14ᵃ±0.08	0.19ᵃ±0.09	0.3173	0.8630^{NS}
13	SO_4	2.20ᵃ±3.02	1.84ᵃ±2.24	2.08ᵃ±1.57	3.34ᵃ±3.73	3.54ᵃ±2.45	0.4177	0.7939^{NS}
14	TASA	22.23ᵃ±2.35	23.08ᵃ±6.30	37.81ᵃ±22.16	95.30ᵇ±43.20	90.16ᵇ±39.35	8.2884	**0.0004*****
15	Calcium	10.79ᵃ±2.73	9.30ᵃ±3.29	18.23ᵃ±10.25	32.76ᵇ±3.88	33.24ᵇ±9.46	14.7212	**0.0000*****
16	PO_4	0.08ᵃ±0.06	0.09ᵃ±0.08	0.33ᵇ±0.29	0.29ᵇ±0.21	0.20ᶜ±0.18	7.4026	**0.0009****
17	TSS	16.58ᵃ±11.75	13.38ᵃ±10.42	11.36ᵃ±4.54	16.34ᵃ±17.89	11.04ᵃ±8.82	0.1554	0.9583^{NS}
18	POM	6.58ᵃ±4.87	6.16ᵃ±5.12	5.74ᵃ±3.96	7.68ᵃ±7.82	4.32ᵃ±1.22	0.1822	0.9449^{NS}
19	Chlorophyll-*a*	1.93ᵃ±1.36	1.09ᵇ±1.02	1.83ᵃ±1.46	12.03ᵇ±10.53	12.53ᵇ±11.40	7.6950	**0.0008****

Values are Mean ± SD, [1]value obtained from ANOVA post hoc nonparametric test.* = Significant, p<0.05. NS = Non Significant, p>0.05. Mean values with different superscripts are significantly different (p<0.05, Student-Newman-Keuls test).
pH (F) = pH measured in the field, pH (L) = pH measured in the laboratory, Temp = Temperature, Cond = Conductivity, Tur = Turbidity, SWV = Surface Water Velocity, DO = Dissolved Oxygen measured in the Field, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, CO_2 = Free Carbon di-Oxide, Cl_2= Chloride, NO3=Nitrate, SO_4 = Sulphate, TASA = Total Anions of Strong Acids, Cal = Calcium, PO_4= Phosphate, TSS = Total Suspended Solids. POM = Particulate Organic Matter, Chl-a= Chlorophyll-a.

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CONCLUSION

The study was concluding that the site LTR-5 (at Kattemalwadi anicut near Hunsur) was significantly different when compared to remaining sampling sites studied. The site LTR-5 on river Lakshmanatheertha was the regular sampling spot which was routinely sampled during seasonal study also. Further, the spatial investigation revealed that site LTR-5 of river Lakshmanatheertha was more polluted, because most of the water quality variables measured during present investigation showed more significant variations in this site, for e.g., the environmental parameters such as temperature, conductivity, turbidity, SWV, DO, CO_2, Chloride, TASA, Calcium, Phosphate and Chlorophyll-a responded differently with respect to spatial variation in the site LTR-5. This may be due to low water level with reduced or no water flow, more anthropogenic activities, sewage and other effluent contamination, solid garbage on the water surface, and entire water surface was covered with algal bloom and other aquatic plants, might be the reason. Hence, in this investigation the content of some of the parameters could be minimized and indiscriminate entry of domestic sewage, agricultural runoff and other effluents into this water course is prevented. Finally, the present study also warrants for strict vigilance and continuous monitoring of these natural water bodies for conservation and sustainable management.

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