Journal of Aquatic Biology & Fisheries | 2020 | **8** | S | pp. 40-46
Special Issue on Rivers
ISSN 2321–340X

Degradation Volume Development Along Killiyar, A Rivulet of Karamana River, Thiruvananthapuram, Kerala

Jyothylakshmi, K. and Kurian Mathew Abraham*

Department of Aquatic Biology and Fisheries, University of Kerala,
Kariavattom, Thiruvananthapuram 695 581, Kerala
**Email: kurianma@gmail.com*

Abstract

The Killiyar, a tributary rivulet of the Karamana river system in Thiruvananthapuram city, was evaluated for degradation volume development, i.e., deterioration increment along rivulet continuum to lower stretches in terms of water quality parameters due to urban pollution. Since the rivulet originate in pristine forest area and input load of municipal, agriculture and sewage wastes increases as rivulet pass through an urban area which deteriorates water quality of the system. Water samples were collected from four stations representing three different segments of Killiyar, representing non-polluted upper stretch near to Western Ghats section, middle stretch representing the semi-urban area and lower stretch representing the urban area, during January to September 2019. A total of 11 water quality parameters, including nutrients were evaluated on a monthly basis following standard methodologies. The results revealed that, many parameters registered significant difference ($P < 0.05$) between stations and seasons. Nutrients and other parameters increased, whereas dissolved oxygen decreased multifold as the river passes through the urban areas. As the volume of the water develops, the degradation of water quality parameters were also found to elevate even though the water quality parameters were within the standard limits of BIS. Further, the results suggest that the quality along the middle and lower stretch of the river become non-potable due to pollution accumulation and outdoor bathing without proper disinfection and treatment, especially during Premonsoon or the summer season.

Keywords: Killiyar – Karamana River, Water quality degradation, Urban sewage, Pollution accumulation

1. Introduction

Aquatic ecosystems play a significant role in regulating the life processes, of which purity and quality of water determine the health of the ecosystems. Human civilization and urbanization occur mainly at surface water accessible areas and as global population increases, modernization, the rapid expansion of industrial and urban activities and unscientific agricultural practices increases and results in the dumping of waste materials in water bodies, causing its degradation (Subhendu, 2000), referred to as 'tragedy of commons'. Wastes generated in urban cities are carried into the water bodies through a rainwater runoff, urban canals and public sewage systems. This waste contains huge amounts of organic and inorganic matter and makes it unsuitable hardly for any use (Floehr *et al.*, 2013). The impacts of anthropogenic activities are unpredictable and unidirectional, which may induce serious threat to biota and create environmental alteration and affect evolutionary events of species (Allendorf *et al.*, 2013). The contamination level in the water bodies changes according to season and region (Tiwari *et al.*, 2016).

River ecosystems are the main resource of fresh water to human beings for domestic use, irrigation, industrial use etc. and it plays an important role in regulating the water cycle, nutrient cycle, recreation, balancing the aquatic food chain and controls the spread of pathogenic organisms (Allan *et al.*, 2005; Dwivedi *et al.*, 2016). State of Kerala known as God's own country has 44 rivers, of which 41 are west-flowing and three east-flowing. The rivers originating from the Western Ghats, the biological hotspot are rich in freshwater biodiversity. The physical, chemical and biological characteristics of a river plays a vital role in maintaining the quality of its water (Suthar *et al.*, 2010). Any alteration in the parameters will result in a change in water quality and ultimately affects the diversity of fauna and flora in the system (Suthar *et al.*, 2010). The equilibrium of the river ecosystem and physicochemical parameters are correlated. Urbanization, industrialization and over-exploitation of water resources for agricultural, domestic and industrial purposes diminish water quality of a river ecosystem and will transform to a waste sink. Majority of rivers in urban areas are the endpoints of hazardous effluents discharged from industries (Suthar *et al.*, 2010). The municipal and domestic sewage discharge to river system increases as the river pass through the city. Floehr *et al.* (2013) extensively reviewed the spatio-temporal increment of pollution level as water quality degradation, which may be diluted by volume development of water along Yangtze river continuum. Lee *et al.* (2016) and Wang *et al.* (2017) stressed the necessity of pollution load increment assessment along a river continuum and Budai *et al.* (2020) developed an automatic water sampler to monitor the urban run-off pollution load of canals. The volume development, the increment of water volume in a river continuum has been described by Abraham (2002) at Karamana river system. Killiyar is the main tributary of the Karamana River, one of the most stressed river systems in Thiruvananthapuram district and Anukumar (2006) reported the health status of Killiyar and the public health issues due to Killiyar pollution. Later Jyothylakshmi (2018) studied the biomonitoring with special emphasis on aquatic insects and indicator microbes

Received on: 02-04-2020; Revised on: 05-11-2020; Accepted on: 27-11-2020

of Killiyar, and Jyothylakshmi *et al*. (2020) reported the microbiological quality degradation of Killiyar along its longitudinal distribution. The assessment of rivulet reveals that it faces severe problems of pollution, especially by dumping of domestic or municipal sewage, market waste and hospital waste. The present study focuses on the deterioration of water quality along Killiyar continuum and to evaluate the seasonal changes in physico-chemical parameters for assessing the degradation volume development of water quality due to urban pollution.

2. Materials and Methods

Study area

The Killiyar (latitudes 8°40’30"N, 8°27’0"N and longitudes 76°57’E, 77°2’0"E) is a ground fed or spring-fed rivulet forms major tributary of Karamana river and originates from Ottakompukunnu and Karimchathimala at Theerthankara, in Nedumangadu taluk of Thiruvananthapuram district (Kerala state). The river enters Thiruvananthapuram city at Vazhayila and flows through Mannammoola, Maruthankuzhi, Edapazhinji, Jagathy, Killippalam, Attukal, Kalady south and merges with Karamana River at Pallathukadavu near Thiruvallam flowing a total stretch of 35km in North West direction towards the Arabian Sea**.** Four sites (Fig.1) representing four segments (pristine area, low pollution, medium pollution and high pollution) along the rivulet were selected as collection sites for the present investigation.

Theerthankara (Site 1): Theerthankara (8°38’30.69"N and 76°59’19.43"E), the origin of the Killiyar with gravel and cobbles substratum with low water volume but with good water flow. The catchment area has a canopy cover of trees and rubber plants. Anthropogenic disturbances are virtually absent along this segment.

Vazhayila (Site 2): Vazhayila (8°32’44.45"N and 76°58’29.90"E) segment is characterized by the rocky and sandy bottom. Riverbanks densely populated by human settlements and they depend on the rivulet for irrigation and household activities, especially laundry.

Jagathy (Site 3): Jagathy (8°29’33.56"N and 76°57’55.63"E) segment receives city/municipal waste/ sewage discharge. Along the banks of the river, there is a dense human settlement. Dumping of garbage and sewage from households along the banks contaminate the site.

Pallathukadavu (Site 4): Pallathukadavu (8°27’19.55"N and 76°57’31.94"E) segment is the rivulet mouth region, joins with Karamana River. The urban runoff, domestic and municipal discharge along with waste/sewage disposal makes the water turbid and blackish in colour with comparatively high pollution load.

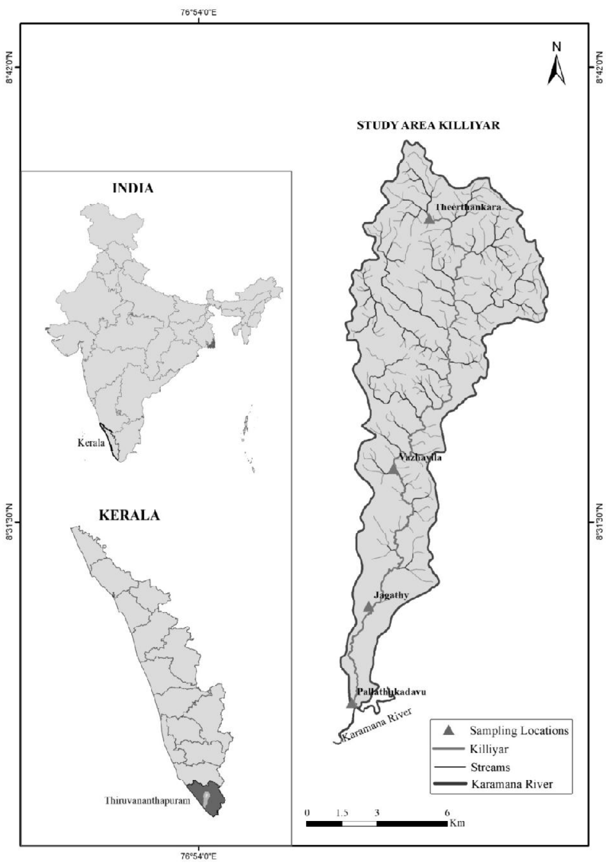

Fig. 1. Location map of the study area with sampling sites

Sampling and Physicochemical Analysis

Water samples were collected monthly from January to September 2019 and were divided into two seasons Premonsoon (Jan - May) and Monsoon (June – Sep). Water pH and temperature (^{0}C) was measured using an electronic pH meter cum thermometer (Eutech) in situ. Total hardness, electrical conductivity (µS/cm), total dissolved solids (TDS) (mg/L), dissolved oxygen (mg/L), carbon dioxide (mg/L), biological oxygen demand (BOD) (mg/ L) and nutrients (mg/L) like phosphate, nitrate and nitrite were estimated following the standard procedures (APHA, 2012). The data obtained were subjected to two-way analysis of variance (ANOVA) to compare sites and seasons using R software (R Core Team, 2020).

3. Results and Discussion

Degradation of water quality parameters along the Killiyar rivulet was assessed during premonsoon and monsoon season by sampling four sites representing rivulet origin segment, middle segment and river mouth segment and the results are provided in Table 1. The water quality parameters were found to significantly deteriorate from its upper region to lower region as it passes through the urban area, receiving urban and household sewage, hospital and agricultural wastes. Jyothylakshmi *et al.* (2020) reported the microbiological quality assessment of the Killiyar along different stretches and found the microbial quality deterioration of water towards the lower stretch of the rivulet as it receives pollution load from domestic sewage disposal. Hence the degradation in terms of its physico-chemical quality of water increases spatially as rivulet advances and also registered significant seasonal difference except for a few parameters. Floehr *et al*. (2013) reported an increment of pollution load in Yangtze river as it passes through cities of China and in addition, they stated that if the river system receives more water volume through joining of different rivulets, the chance of pollution dilution also increases.

The physico-chemical analysis of Killiyar revealed that the temperature was highest during Premonsoon at Pallathukadavu (Site 4) and was lowest at Theerthankara (Site 1) throughout both the seasons. The temperature at

Table 1. Physico-chemical parameters (Mean ± SD) of water at different study sites of Killiyar

Parameters	Period	Site 1	Site 2	Site 3	Site 4	F value$
Temperature (°C)	Premonsoon	24.34 ± 0.32	25.92 ± 0.39	26.42 ± 0.31	26.44 ± 0.40	38.631**
	Monsoon	23.87 ± 0.22	25.27 ± 0.25	25.42 ± 0.12	25.52 ± 0.09	5.769*
pH	Premonsoon	6.79 ± 0.03	7.27 ± 0.05	7.56 ± 0.06	7.91 ± 0.12	39.704**
	Monsoon	7.07 ± 0.13	7.90 ± 0.03	8.10 ± 0.17	8.35 ± 0.05	46.329**
TDS (mg/L)	Premonsoon	38.13 ± 0.44	99.24±0.53	152.12 ± 0.39	176.90 ± 0.67	23.228**
	Monsoon	40.13 ± 0.19	100.5 ± 0.96	152.90 ± 0.55	177.90 ± 0.42	545.771***
Conductivity (µS/cm)	Premonsoon	78.49 ± 0.62	201.40 ± 2.46	301.40 ± 1.09	399.40 ± 2.08	15.533**
	Monsoon	88.52 ± 1.79	203.60 ± 1.11	307.50 ± 1.09	406.70 ± 1.45	7107.415***
Total hardness (mg/L)	Premonsoon	7.50 ± 2.88	13.70 ± 2.5	16.20 ± 2.50	17.50 ± 2.88	26.898**
	Monsoon	6.00 ± 2.23	11.00 ± 2.23	15.00 ± 3.53	16.00 ± 2.00	181.487**
Dissolved oxygen (mg/L)	Premonsoon	7.28 ± 0.08	6.76 ± 0.16	6.20 ± 0.24	5.40 ± 0.20	27.894**
	Monsoon	7.55 ± 0.10	6.90 ± 0.11	6.60 ± 0.16	5.70 ± 0.34	187.101***
Free CO_2 (mg/L)	Premonsoon	0.77 ± 0.22	0.99 ± 0.22	1.32 ± 0.35	1.87 ± 0.22	10.469*
	Monsoon	1.05 ± 0.24	1.14 ± 0.24	1.49 ± 0.24	2.40 ± 0.21	38.951**
BOD (mg/L)	Premonsoon	0.90 ± 0.10	1.77 ± 0.05	2.27 ± 0.05	3.35 ± 0.05	10.177*
	Monsoon	1.14 ± 0.05	2.30 ± 0.07	3.26 ± 0.05	3.70 ± 0.10	41.700**
Phosphate (mg/L)	Premonsoon	0.011 ± 0.001	0.36 ± 0.03	0.49 ± 0.04	0.65 ± 0.03	10.214*
	Monsoon	0.03 ± 0.008	0.47± 0.095	0.68 ± 0.01	0.84 ± 0.01	60.313**
Nitrite (mg/L)	Premonsoon	0.02 ± 0.008	0.25 ± 0.01	0.15 ± 0.008	0.46 ± 0.01	0.653
	Monsoon	0.03 ± 0.005	0.26 ± 0.005	0.15 ± 0.005	0.45 ± 0.01	1732.911***
Nitrate (mg/L)	Premonsoon	0.01 ± 0.008	0.18 ± 0.01	0.06 ± 0.008	0.34 ± 0.01	0.403
	Monsoon	0.02 ± 0.008	0.19 ± 0.005	0.07 ± 0.005	0.33 ± 0.008	893.014***

$ F value: Upper value comparing seasons and lower value comparing sites for each parameter
* P < 0.05; ** P < 0.01; *** P < 0.001

Vazhayila (Site 2) and Jagathy (Site 3) also showed fluctuation during Premonsoon and monsoon. The temperature (Table 1.) has increased from upper reaches of the river to the lower reaches as upper reaches were under canopy and consist of pristine mountain fast-flowing canals contributing to the river formation. The increment of temperature along downstream stations were significantly different (P<0.01) in both the seasons. The high temperature reported during the dry season may be due to high solar flux resulting temperature rise of surface water (Das *et al.*, 1997; Karuppasamy and Perumal, 2000). The carbon dioxide content increment due to pollution accumulation along river downflow might also be contributed to the temperature rise towards river mouth region, which may also indicate the increment in pollution load towards the lower stretches as the river passes into the city region. Heavy and regular rainfall during monsoon season causes a reduction in temperature at all sites. Similar observations reported by many researchers in rivers of Kerala, including the Killiyar - Karamana river (Madhusoodhanan Nair, 1992; Synudeen Sahib, 1992; Abraham, 2002; Anukumar, 2006).

The pH is a good quality indicator of any water including river water as the river water may show high pH fluctuations as it receives terrestrial runoff, rivulets and aquifer water, moreover the river water properties are altered by anthropogenic interference. The pH of Killiyar water varied between 6.79 – 8.35 at all sites. An average pH of 6.79 was observed at Theerthankara site, during Premonsoon season. The pH varied from acidity to alkalinity with significant (P < 0.01) increment in pH from site to downstream sites, which may be due to dissolution of detergents and soap into rivulet water through laundry and bathing activity as the Killiyar passes into an urban area. The pH increment was noted both in monsoon as well as premonsoon seasons with a significant seasonal difference with more alkaline waters during monsoon season. During monsoon, pH was slightly acidic or near neutral at the origin, and an alkaline pH was observed in all other study sites (Table 1). The longitudinal fluctuation of pH in several rivers of Kerala shows a wide difference from alkaline to acidic as reported in the Kallada river, 5.85 – 7.35 (Madhusoodhanan Nair, 1992), 6.37 – 7.53 in Karamana river (Harikrishnan, 1993). Fluctuations in pH values during different seasons are mainly due to the removal of carbon dioxide by photosynthesis, temperature, and decomposition of organic material (Rajasegar, 2003). The pH levels of water in Killiyar are within the standard limits 6.5 to 9 for the protection of aquatic life (BIS, 2004). Similar observations were made in Killiyar by Anukumar (2006) and reported high alkalinity content towards the downstream stretches of the rivulet.

The total dissolved solids (TDS) values ranged between 38.13 – 40.13 mg/L at Theerthankara and 99.24 – 100.5 mg/L at Vazhayila segment. Jagathy site registered an average TDS range of 152.12 – 152.9 mg/L, and at Pallathukadavu segment, near river mouth registered 176.9 – 177.9 mg/L. The TDS gradually increases as rivulet flows with site 2 and 3 registered 160% and 299% increment respectively. Whereas the lower stretch of Killiyar, i.e., site 4, registered 363% increment in TDS form site 1, which (Fig. 2) can be referred to as degradation in TDS volume development due to urban waste influx and results in pollution load increment. Many of the previous reports also registered similar kind of TDS level in many river systems of Kerala and elsewhere (Subhendu, 2000; Abraham, 2002; Anukumar, 2006). The higher amount of TDS was found in the monsoon season and was particularly higher at Jagathy segment and Pallathukadavu segment this might be due to rainwater runoff from agricultural fields and wastelands during monsoon season. Water having high dissolved solids indicate the presence of more ions and can induce an unfavourable physico chemical reaction. High TDS indicates pollution by extraneous sources (Neilson *et al.*, 2003). The permissible limit for TDS in drinking water is 500 – 2000 ppm (WHO, 2008) and hence the rivulet water was well under safety standards. A similar pattern of increment was noted for conductivity also. The conductivity of water samples ranged between 78.49 – 88.52 µs/cm at Theerthankara and 201.4 – 203.6 µs/cm at Vazhayila site. At Jagathy, conductivity varied between 301.4 – 307.5µs/cm and Pallathukadavu segment showed an average conductivity range of 399.4 – 406.7 µs/cm (Table 1). Conductivity also registered a volume development towards the lower stretch of the river (Fig. 2) with a gradual increment of 408% at site four compared to site 1. The conductivity value was also high in the monsoon season. High conductivity value at Pallathukadavu segment is an indication of the presence of more ions due to pollution and its accumulation. Anukumar (2006) also described a similar pattern in Killiyar. TDS has a great influence on the conductivity values and correlated (Abraham, 2002); hence conductivity and TDS accumulate as rivulet flows downstream and receives discharges from surrounding runoff and waste disposal. The total hardness of water also tends to increase as the rivulet flow down as well as receives more effluent discharge and dissolution. The water hardness has increased to 133% at site four compared to the pristine site 1 (Fig. 2) and showed the volume increment in hardness. The peak value of total hardness was recorded at Pallathukadavu and Jagathy 17.5 mg/L and 16.2 mg/L respectively. At Vazhayila it was 13.7 mg/L on an average. At the same time, the total hardness at Theerthankara showed an average value of 7.5 mg/L (Table 1). Total hardness was high during Premonsoon season and increased hardness in summer season might be due to a high rate of evaporation, absence of freshwater inflow, sewage water discharge into the river. Hardness was comparatively low during monsoon due to the influx of freshwater. Similar results reported for Ganga River (Bhowmick and Singh, 1985). In Killiyar, hardness progressively increased from upstream to downstream Studies in Amaravathy River has also reported an increase of hardness at downstream (Karthikeyani *et al.*, 2002).

The percentage increment along a longitudinal scale of Killiyar with respect to dissolved free carbon dioxide (CO_2) and biological oxygen demand (BOD) is depicted in figure 3, which can be considered as a true indication for degradation of rivulet water due to pollution load along the rivulet continuum. The CO_2 and BOD have increased to 142% and 272% respectively at site 4, the river mouth region from that of site one at the pristine rivulet origin area. CO_2 and BOD increment can very well explain the degradation volume development due to urban waste disposal and terrestrial wastewater runoff to rivulet along the course of the rivulet. The free CO_2 was high during the monsoon period and least during Premonsoon seasons in all sites. The CO_2 was high at Pallathukadavu and Jagathy, low at Vazhayila, and the least value was recorded at Theerthankara, and the differences in CO_2 content between sites were statistically significant ($P < 0.01$). Free carbon dioxide values were found high during monsoon, which was found to differ significantly from premonsoon values in each site. An increase in free CO_2 indicates an increase in pollution load (Chandraprakash *et al.,* 1978; Ghose and Sharma, 1988; Dwivedi *et al.*, 2016). Comparatively higher carbon dioxide concentration in the downstream reaches of Killiyar was an indication of a high degree of water pollution along downstream regions as well as accumulation of pollution load (Anukumar, 2006). The BOD values were also showed the same pattern that of CO_2 and BOD values were high during the monsoon period at all segments (Table 1). Site 4 of Killiyar registered high BOD values of 3.35 and 3.72 mg/L, whereas site one registered 0.90 and 1.14 mg/L during premonsoon and monsoon respectively. Site and season difference of BOD content was statistically significant. The high amount of organic matter results in the excess decomposition of organic waste into carbon dioxide and creates an oxygen-depleted condition and results in high BOD levels (Divya *et al.*, 2011). Higher BOD observed during monsoon might be due to the high microbial load

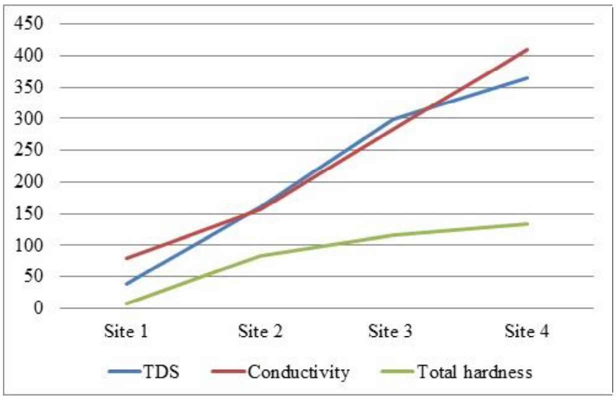

Fig. 2. Degradation volume development in terms of percentage increment of TDS, conductivity and hardness along Killiyar

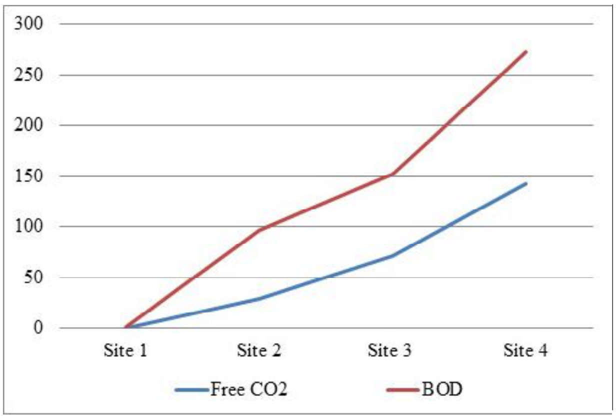

Fig. 3. Degradation volume development in terms of percentage increment of free CO_2 and BOD along Killiyar

discharged to rivulet from domestic and hospital wastes emanated along the catchment area of the rivulet and Joseph and Srivatsava (1993) reported such high BOD during monsoon season, which implied that high demands of oxygen need to support the life process. BOD fluctuations between seasons may be due to additional organic matter introduced into the river as a result of runoff and soil erosion caused by continuous rainfall during the rainy season (Odokuma and Okpokwasili, 1997). BOD values generally approximate the amount of oxidisable organic matter, and is, therefore, used as a measure of the degree of water pollution and waste level (Mayank and Dwivedi, 2015; Tiwari *et al.*, 2016).

In a water body, dissolved oxygen (DO) is an important parameter determining the intensity of organic pollution and water quality (Kataria *et al.*, 1996). The DO content was observed in the range of 5.4 – 7.55 mg/L in the present study. The maximum of DO was found at the river origin segment, site 1 (monsoon 7.28 and postmonsoon 7.55 mg/L) and a decreasing trend in other sites towards downstream showing the degradation of the water quality as the rivulet enters and flows through the urban area. The oxygen content decreased to 25% at site four from that of site 1 (Fig. 4). The DO content registered significant ($P<0.01$) difference between sites and seasons. It can be noticed that dissolved oxygen content at Pallathukadavu, downstream Killiyar was very low throughout the period of the study, which indicated a high degree of pollution at downstream stretches of river (Table 1). In a water body, dissolved oxygen is an important parameter determining the intensity of organic load and the water quality (Kataria *et al.*, 1996). Even though the DO level reduced towards the lower reaches of the rivulet, it was very well within the standard limits of water quality (BIS, 2004) for domestic purpose and health status of a river (Anukumar, 2006). DO levels between 5.0 and 8.0 mg/l are satisfactory for the survival and growth of aquatic organisms (Mayank and Dwivedi 2015; Tiwari *et al.* 2016). Temperature and carbon dioxide affect the dissolution of oxygen in water (Vijayakumar *et al.*, 2000), which might also contribute to the fluctuation of DO in the Killiyar. In the present study, higher values of dissolved oxygen were recorded during monsoon, which might be due to cumulative effects of higher rainfall, wind velocity (Das *et al.*, 1997), high flow rate and turbulence (Abraham, 2002).

The nutrient contents, phosphate, nitrate and nitrite concentrations of the river water showed increment towards lower reaches and registered 5809%, 2200% 3300% increment respectively (Fig. 5) at site 4 to that of site 1. The eutrophication due to nutrient influx from agricultural runoff and barren land leaching will increase the nutrient load and result in accumulation towards downstream. The values of nutrients were very high during the monsoon season and showed a significant difference form premonsoon season (Table 1). Increased phosphate due to the addition of phosphates in the agricultural field might have washed off into the water bodies during the season (Tiwari and Nair, 1993). Moderate nutrient content during Premonsoon period due to the reduced water flow and possibly also to the laundry activities, especially at Vazhayila segment. The nitrite and nitrate values were also high during the monsoon season. The peak values of nitrite and nitrate were recorded at Pallathukadavu segment in both seasons. Such increase in nitrites and nitrate was due to decomposition of organic materials (Aravindkumar and Gupta, 2002). Discharge of agricultural fertilizers, untreated wastewater may result in the higher levels of nutrients such as nitrogen and phosphates in water bodies. Analysis of variance showed a significant difference in physico-chemical parameters between sites and between seasons except for nitrite and nitrate within seasons (Table 1). Monitoring of physico-chemical parameters in the river Killiyar revealed that the water quality was severely impaired during the study period so that the midstream and downstream segments of the river become unsuitable for drinking and domestic purposes and bathing, especially during Premonsoon season. Anukumar (2006) also reported a similar pattern of nutrient fluctuations in particular and the health status of the Killiyar in particular.

The spatial variation in water characteristics at different segments of the Killiyar river revealed the water quality changes along the basin and very well depicted the volume development of pollution leading to degradation of water quality. The water quality was found to be fair to poor in all stations except the river origin. The spatial trends in water quality degradation can be clearly observed throughout the river system from upstream to downstream,

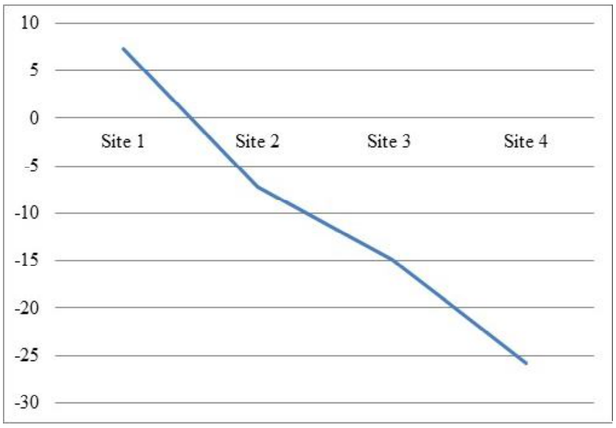

Fig. 4. Degradation volume development in terms of percentage decrement of DO along Killiyar

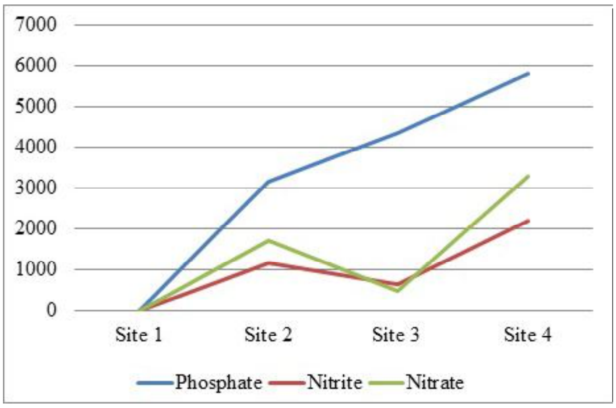

Fig. 5. Degradation volume development in terms of percentage increment of nutrients along Killiyar

which was not reported for the Killiyar system. At the upstream site the trend of dissolved oxygen to be higher, while significant shifts were noticed for sites towards the midstream and downstream, especially the densely populated regions of the river. The drop of dissolved oxygen and the increase of other parameters like BOD, carbon dioxide, nutrients and hardness have a significant impact on water quality degradation due to human activities besides, a high temperature in most of the studying sites, except origin. Otherwise, the excess concentration of nutrients like phosphate, nitrite and nitrate in some areas of the basin at Jagathy and Pallathukadavu segments could also be a concern with organic pollution leading to water quality degradation. According to present understanding, the degradation of water quality in the river channel may be caused by the polluted low-quality inputs from industries, markets, hospitals, household waste and other sources. Under the influence of monsoon, the seasonal changes of flow could induce the variation in water quality in all sites, especially significant changes in all parameters were noticed in downstream sites after the monsoon. But all the parameters are within the standard limits (BIS, 2004). Hence the river water is potable, after proper disinfection and treatment.

4. Conclusion

In spite of the multiple pressures from the point and non-point sources of pollution, canals, rivulets and rivers are the main discharge sites of anthropogenic wastes from neighbouring area. As the rivers flow through the urban region, pollution load accumulates downstream and the degradation rate of water quality increases. This further suggests that rivers accumulate pollution as it flows downwards. The Killiyar, a main tributary of Karamana river system in Thiruvananthapuram District, Kerala also no exemption from the situation. A two season assessment of eleven water quality parameters has shown an increased perturbation and degradation volume development at three segments other than river origin. Killiyar has to be given immediate attention to cease its ecosystem degradation and to ensure pollution-free water to the population that relies upon this rivulet.

Acknowledgements

Authors are thankful to Dr. A. Bijukumar (Department of Aquatic Biology and Fisheries) and Dr. Sabu Joseph (Department of Environmental Science), the University of Kerala for the laboratory facilities. The first author acknowledges the University of Kerala for the MPhil scholarship.

5. References

Abraham, K.M., 2002. Nutrient dynamics and Biological processes in the Ecotone of a river-estuarine interface, PhD Thesis, University of Kerala, Thiruvananthapuram, 720pp.

Allan, J.D., Abell, R., Hogan, Z.E.B., Revenga, C., Taylor, B.W., Welcomme, R.L. and Winemiller, K., 2005. Overfishing of inland waters. *BioScience*, 55(12): 1041-1051.

Allendorf, F.W., Luikart, G. and Aitken, S.N., 2013. Conservation and the genetics of populations. Wiley & Sons, Hoboken, 587pp.

Anukumar, A., 2006. Health status of Killiyar, Trivandrum district and the associated public health problems. PhD Thesis, University of Kerala, 328pp.

APHA, 2012. Standard methods for the examination of water and waste water. American Public Health Association. 22nd ed.Washington D C.948pp.

Aravind Kumar and Gupta, H.P., 2002. Ecobiodiversity of aquatic biota in certain freshwater ecosystems of Santhal Paraganas (Jharkhand), India. In: *Ecology and Ethology of Aquatic Biota.* Kumar, A. (Ed.), Daya Publishing House, Delhi, India, 1-69.

Bhowmick, B.N. and Singh, A.K., 1985. Phytoplankton population in relation to physico-chemical factors of River Ganga at Patna. *Indian Journal of Ecology*, 12(2): 360-364.

BIS, 2004. Indian drinking water standard - Specification: IS 10550 (The Bureau of Indian Standards, New Delhi), 138 pp.

Budai, P., Kardos, M.K., Knolmar, M., Szeman, G., Turczel, J. and Clement, A., 2020. Development of an autonomous flow-proportional water sampler for the estimation of pollutant loads in urban runoff. *Environ. Monit. Assess*., 192: 572- (DOI: http://doi.org/10.1007/s10661-020-08536-3).

Chandra, P., Rawat, D.C. and Grover, P.P., 1978. Ecological study of the river Jamuna (Yamuna). *IAWPC Tech. Annual*, 5: 32-45.

Das, J., Das, S.N. and Sahoo, R.K., 1997. Semidiurnal variation of some physico-chemical parameters in the Mahanadi estuary, east coast of India. *Ind. J. Mar. Sci.,* 26: 323- 326.

Divya Rani Thomas, Sunil, B. and Latha, C., 2011. Physico-chemical analysis of well water at Eloor industrial area-seasonal study. *Curr. World Environ*., 6(2): 259-264.

Dwivedi, A.C., Mayank P. and Tiwari A., 2016. The River as transformed by human activities: the rise of the invader potential of *Cyprinus carpio* and *Oreochromis niloticus* from the Yamuna River, India. *Journal of Earth Science and Climatic Change,* 7(7): 361 (DOI: 10.4172/2157-7617.1000361)

Floehr, T., Xio, H., Starke, B.S., Wu, L., Hou, J., Yin, D., Zhang, X., Ji, R., Yuan, X., Ottermanns, R., Nickoll, M.R., Schaffer, A. and Holert, H., 2013. Solution by dilution? – A review on the pollution status of the Yangtze River. *Environ. Sci. Pollut. Res*., 20: 6934-6971. (DOI: 10.1007/s11356-013-1666-1).

Ghose, N.C. and Sharma, C.D., 1988. Effect of drain water on the physico-chemical and bacteriological characteristic of River Ganga at Patna, Bihar. In: *Ecology and Pollution of Indian Rivers,* R.K. Trivedy Ed., Asian Publishing House, NewDelhi, pp. 255-269.

Harikrishnan, K., 1993. *Zooplankton ecology of certain aquatic biotypes in Kerala*. (Doctoral dissertation) Ph. D. Thesis, University of Kerala, India.

Joseph, K.O. and Srivastava, J.P., 1993. Heavy metal load in edible oyster, *Crassostrea madrasensis* (Preston) from the Ennore Estuary in Madras. *Journal of Environmental Biology*, 14(2): 121-127.

Jyothylakshmi K., 2018. Biomonitoring of Killiyar, A tributary of Karamana river with special emphasis on aquatic insects and indicator microbes.

Jyothylakshmi K., Abraham, K.M., Nandakumar, S., and Sanal Kumar, M.G., 2020. Screening of indicator microbes, A strategy for pollution assessment of Killiyar, A rivulet of Karamana river, Thiruvananthapuram, Kerala. *Journal of Advanced Scientific Research*, 11(3)Sppl.7: 203-206.

Karthikeyani, T.P., Sashikumar, J.M. and Ramesh, M., 2002. Physico-Chemical, Biological and Bacteriological Study of Kadathur Canal Water of Amaravathi River, Tamil Nadu. *Pollution Research*, 21(1): 21-23.

Karuppasamy, P.K. and Perumal, P., 2000. Biodiversity of zooplankton at Pichavaram mangroves, South India. *Adv. Biosci.*, 19(2): 23-32.

Kataria, H.C., Iqbal, S.A. and Shandilya, A.K., 1996. Assessment of water quality of Kolar reservoir in Bhopal (MP). *Pollution Research*, 15: 191-193.

Lee, C.J., Hirsch, R.M., Schwarz, G.E., Holtschlag, D.J., Preston, S.D., Crawford, C.G. and Vecchia, A.V., 2016. An evaluation of methods for estimating decadal stream loads. *Journal of Hydrology*, 542: 185–203 (https://doi.org/10.1016/j.jhydrol.2016.08.059).

Madhusoodhanan Nair, K.C., 1992. Studies on Certain Ecological Aspects of Two River Systems of the Western Ghats. Ph. D. Thesis, University of Kerala, India.

Mayank, P. and Dwivedi, A.C., 2015. River health and commercially important catfishes from the Yamuna river, India. *Journal of the Kalash Science*, 3(3): 23-26.

Nielsen, D. L., Brock, M.A., Rees, G.N. and Baldwin, D.S., 2003. Effects of increasing salinity on freshwater ecosystems in Australia. *Australian Journal of Botany*, 51(6): 655-665.

Odokuma, L.O. and Okpokwasili, G.C. 1997. Seasonal influences of the organic pollution monitoring of the New Calabar River, Nigeria. *Environmental Monitoring and Assessment*, 45(1): 43-56.

R Core Team, 2020. R: A language and environment for statistical computing. R foundation for statistical computing. Vienna, Austria (http://www.R-project.org/.)

Rajasegar, M., 2003. Physico-chemical characteristics of the Vellar estuary in relation to shrimp farming. *Journal of Environmental Biology*, 24(1): 95-101.

Sahib, S.S. and Azis, P.K., 1989. Post impoundment water quality of the Kallada River – A preliminary report. In: *Proceedings of the Kerala Science Congress,* 1989, pp. 153-160.

Subhendu, D., 2000. Effects of aquatic pollution on fish and fisheries. Pollution-An International problem for fisheries. *Can. J. Fish. Aquat. Sci*., 66: 400-480.

Suthar, S., Sharma, J., Chabukdhara, M. and Nema, A.K., 2010. Water quality assessment of river Hindon at Ghaziabad, India: Impact of industrial and urban wastewater. *Environmental Monitoring and Assessment*, 165(1-4): 103-112.

Tiwari, A., Dwivedi, A.C. and Mayank, P., 2016. Time scale changes in the water quality of the Ganga River, India and estimation of suitability for exotic and hardy fishes. *Hydrology Current Research, 7*(3): 254. (DOI:10.4172/2157-7587.1000254).

Tiwari, L.R. and Nair, V.R., 1993. Zooplankton composition in Dharamtar creek adjoining Bombay harbor. *Indian J. Mar. Sci.*, 22: 63- 69.

Vijayakumar, S., Rajesh, K.M., Mendon, M.R. and Hariharan, V., 2000. Seasonal distribution and behavior of nutrients with reference to tidal rhythm in the Mulki estuary, Southwest coast of India. *J. Mar. Biol. Ass. India*, 42(182): 21-31.

Wang, Q., Zhang, Q., Wu, Y., and Wang, X.C., 2017. Physicochemical conditions and properties of particles in urban runoff and rivers: implications for runoff pollution. *Chemosphere*, 173: 318–325 (https://doi.org/10.1016/j. chemosphere.2017.01.066).