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An assessment of water quality temporal variation in Sri Jayawardenapura Kotte canal, Sri Lanka

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ABSTRACT

Assessment of temporal variation of the water quality is an essential aspect of evaluating temporary changes in a water body caused by natural or artificial contributions. The study aims to assess the water quality temporal variation and the water quality index over the year from 2010 to 2019. Water sampling was carried out near the bridge of the Kotte canal. Water quality parameters such as pH, electrical conductivity (EC), temperature, dissolved oxygen (DO), ammonia, nitrate, phosphate, and chemical oxygen demand (COD) were determined to assess the quality of water at different periods. It has been calculated based on the standard of the central environmental authority of Sri Lanka. The weighted arithmetic index method has been used to calculate the water quality index. The water quality index of the study area was recorded as good (33.60760) in 2010 and poor in 2013 (56.95663), 2016 (52.37269), and 2019 (69.04417). The study revealed that the water temperature in the canal fluctuates with the time and climate of the area. The EC of the water is registered within the reference range. However, pH, COD, DO, and ammonia are the main water parameters deviating from the reference range. It is observed that the leading causes of the deterioration of water quality are human activities, the illegal discharge of sewage and industrial wastewater, the lack of adequate sanitation facilities, and urban runoff.

***Keywords*:** Water quality, WQI, COD, Weighted Arithmetic Index, Sri Jayawardenapura Kotte canal

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1. INTRODUCTION

Water is one of the most important natural resources necessary for all living organisms without any substitute. Maintaining this productive environment is essential for human, animal, and plants life. This environment faces several threats from harmful human activities. Water pollution generally occurred due to unplanned urban development, which creates a critical issue in developing countries (Bibi, Qureshi and Arshad, 2014). Water quality degradation occurred by the direct discharge of pollutants, arbitrary developments, and other developmental activities such as constructions of buildings, highways, alteration of natural channels, and land clearing. The driving factor influencing water quality is essential to identify the significant pollutants affecting water bodies (Edwards, Schoonover and Williard, 2015).

Water pollution point sources can be identified as direct and uncontrolled discharges of waste from residential, industrial, and commercial land use sites. Urban storm water runoff is the primary non-point pollution source of water bodies (Juahir *et al.*, 2011). These pollutants affect the chemical, physical and biological parameters of water. Water pollution can occur in two ways as a point source and a non-point source. Point sources are directly identifiable points such as wastewater from municipal and industrial, deposits from waste disposal, factory sales, industrial waste, and wastewater (Garnache *et al.*, 2016).

Non-point sources are pollutants that cause sources from unidentifiable sources in the environment, such as polluted runoff from agriculture, urban severed and unserved areas with a population (Singh, Gupta and Chaudhary, 2014). Developing countries have a common practice that dumping municipal waste at open landfills affects water bodies. Two hundred sixty open landfills except for the Dompe landfill have been built without environmental impact assessments in Sri Lanka. Gohagoda is an open dumpsite adjacent to the largest Mahaweli River, widely used for drinking water, power generation, industry, and irrigation (Basnayake, Ariyawansha and Karunarathna, 2020).

The water quality is determined by the components of the water, which vary with the biological, chemical, and physical factors determined by the geochemical and geomorphological condition of the water mass and the environmental climate. Water quality depends on physical, chemical, and biological parameters (Zhu, 2011). The physical parameters are turbidity, temperature, color, taste and smell, solids, electrical conductivity (Ajibade, Ayodele and Agbede, 2008). The chemical parameters are pH, acidity, alkalinity, chloride, residual chlorine, sulfate, nitrogen, fluorine, iron and manganese, copper and zinc, hardness, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), toxic inorganic substances, toxic organic substances, radioactive substances (Ojo, Otieno and Ochieng, 2012).

The biological parameters are bacteria, algae, viruses and protozoa. The water quality in urban water ways is very variable, an important determining factor for the general condition of the watershed. Surface runoff carries a variety of materials of chemical and biological origin to the nearest water body. These contaminants can cause toxicity to aquatic organisms and affect the water content of nutrients. The intake of polluted water may cause epigenetic modifications, leading to various cancers in the human body (Dushanan *et al.*, 2017; R Dushanan *et al.*, 2020; Ramachandren Dushanan *et al.*, 2020).

In Sri Lanka, surface and groundwater contamination with nitrates and bacteria is due to poor sanitation and untreated or insufficient water treatment and discharges of toxic chemicals from industrial and agricultural activities (Hanjra *et al.*, 2012).

Low lands are converted to built-up lands due to rapid urbanization. These built-up areas produce a high amount of wastewater that discharge into the canal without a proper piped collection system and domestic and industrial polluted water treatment. Thus the water bodies and wetlands are highly polluted by these activities (Kumar, Sharif and Ahmed, 2019). Also, this behavior causes severe water pollution and enormous economic and social costs (Nishanthi and Kaleel, 2021). However, several studies were conducted on the water quality assessment in the Colombo basin, but any researchers did not consider the Sri Jayawardenapura Kotte canal. Thus, this study can provide comprehensive water quality details for the Sri Jayawardenapura Kotte canal that can be useful to this waterbody's policy planning and decision-making. Also, it can be a source for the researcher in future studies. Therefore, this study aims to assess the temporal variation of water quality and index based on the weighted arithmetic index method in the Sri Jayawardenapura Kotte canal, Sri Lanka.

2. METHODOLOGY

2. 1. Study area

The study area, the Sri Jayawardenapura Kotte canal, has been located in the Colombo district, with rapid urbanized and high-rise buildings. Heenela surrounds this administrative capital in the north, the Diyawannaoya branch in the south, Kaduwela pradeshiya sabha, and the Maharagama urban council in the west Dehiwala-Mountlavania municipal council in the east. The land area of Sri Jayawardenapura Kotte is 17.04 square meters in 2002, and 26 percent of the area is water bodies and marshlands. Thus, the canal prioritizes this urban area (Perera, Wattavidanage and Nilakarawasam, 2012) (Figure 1).

The average rainfall is between 2000 mm and 2500 mm, and the high precipitation usually occurs in the Southwest monsoon. The average annual rainfall is 170 mm but varies from April to May and September to October due to the northeast monsoon and the southwest monsoon.

The yearly evaporation is 102 mm, and the average daily maximum temperature varies from 29.35 °C to 32.55 °C and the minimum from 22.81 °C to 27.09 °C (Illangasinghe, Saito and Fujiwara, 1999).

2. 2. Data Collection and Analysis

Water sampling was carried out near the bridge of the Kotte canal. The handheld water quality meter and laboratory analysis have been done for data formation. The sample was collected in a sterile 250 ml Schott bottle during 2010, 2013, 2016, and 2019. Samples were triplicated in composite water from the sampling point. The sample was preserved at 4 °C until analysis.

Water quality parameters such as pH, electrical conductivity (EC), temperature, dissolved oxygen (DO), ammonia (NH_3), nitrate (NO_3^-), phosphate (PO_4^{3-}) and chemical oxygen demand (COD) were determined to assess the quality of water at different periods (Islam *et al.*, 2013).

It has been calculated based on the standard of the central environmental authority of Sri Lanka. The weighted arithmetic index method has been used to calculate the water quality index (Ramakrishnaiah, Sadashivaiah and Ranganna, 2009; Bouslah, Djemili and Houichi, 2017; Tyagi *et al.*, 2020).

The three steps have followed for data analysis as mentioned below;

Step 1: Calculate the unite weight (Wn) factors for each parameter by using the following formula:

$$Wn = K/Sn$$

where:

K = Proportionality constant
Sn = Standard desirable value of the n^{th} parameters on the summation of all selected parameters unit weight factors Wn = 1 (unity).

Step 2: Calculate the sub-index (Qn) through the following formula,

$$Qn = \frac{[(Vn - Vo)]}{[(Sn - Vo)]} * 100$$

where:

Vn = Mean concentration of the n^{th} parameters
Sn = Standard desirable value of the n^{th} parameters
Vo = Actual values of the parameters in pure water (Vo =0 for most of the water parameters except ph = 7.0 and DO = 14.6 mg/L)

Step 3: Combining step 1 and step 2 and WQI is calculated as follows:

$$\text{Overall WQI} = \frac{\Sigma\, Wn\, Qn}{\Sigma\, Wn}$$

Table 1. Water quality rating as per the weighted arithmetic water quality index method.

WQI value	Rating of W Quality	Grading
0-25	Excellent water Quality	A
26-50	Good Water Quality	B
51-75	Poor Water Quality	C
76-100	Very Poor Water Quality	D
Above 100	Unsuitable for drinking purpose	E

3. RESULTS AND DISCUSSION

3. 1. pH

pH value is an important physical property of water. It ranges from 0 to 14, and 7 is neutral. The pH value from 0 to 7 is acidic, while the pH value from 7 to 14 is alkaline. Sri

Lanka's pH standard ranges from 6 to 8.5 to sufficient to meet human and agricultural needs (Opallage, Piyadasa and Dharmasoma, 2019). Water with a lower pH value can dissolve heavy metals in the water. According to the Kotte Canal records, the pH value changes with the year. The pH value of the water body from January to April 2010 was less than 6, which is not suitable for human use. Subsequently, the pH value fluctuates within the standard range (Figure 2).

3. 2. Electrical Conductivity

The electrical conductivity (EC) of water is used to measure the current-carrying capacity of a solution. If the concentration of iron in the solution increases, the conductivity of the water will increase. Conductivity is measured in microsiemens / centimeter (μS/cm) and millisiemens / meter (mS/m) or decisiemens / centimeter (dS/cm). Pure water cannot be an electrical conductor. 0.7 dS/cm is the conductivity standard for irrigation in Sri Lanka (Opallage, Piyadasa and Dharmasoma, 2019). The conductivity of the Kotte Canal water is mostly less than 0.7 dS/cm (Figure 3).

3. 3. COD

Chemical oxygen demand (COD) is used to measure the level of oxygen required to break down organic and inorganic substances in water. According to the Central Environmental Authority of Sri Lanka, the COD standard is 15 mg/L, which is suitable for aquatic organisms (Opallage, Piyadasa and Dharmasoma, 2019). For more than 70% of the year, the Kotte canal COD standard is above 15 mg/L (Figure 4).

3. 4. Temperature

Water temperature determines the pH value, chemical reaction, dissolved oxygen, biological oxygen demand (BOD), solubility, palatability, smell, conductivity, and water viscosity. The water temperature in the Kotte Canal ranges from 26.5 °C to 32.4 °C. The temperatures in April, May, and June of the calendar years (2010, 2013, 2016, 2019) are higher, and November and December are also recorded as low water temperatures. This is determined by Sri Jayawardenapura Kotte weather (Figure 5).

3. 5. Dissolved oxygen (DO)

Dissolved oxygen is used to measure the concentration of water oxygen. It is determined by the temperature of the water, salt, and pressure. It is an essential parameter of water quality to measure the level of water contamination. The CEA standard is 3 mg/L (Opallage, Piyadasa and Dharmasoma, 2019). Kotte Canal was significantly contaminated for many years. The water level of the canal is greater than the standard level. The canal located in the center of urban areas can easily release domestic wastewater. It was the main reason for the high contamination of water quality (Figure 6).

3. 6. Ammonia

The water contains high ammonia and is not suitable for aquatic organisms. According to the CEA standard for aquatic organisms, the ammonia content is 1 mg/L (Opallage, Piyadasa and Dharmasoma, 2019). If it is increased, the water will not be suitable for organisms. According to the investigation, the ammonia content of the Kotte canal water is in poor condition for a quarter of the year. Nitrogen waste discharge into the canal, air deposition, runoff, and nitrogen fixation may be the reasons for the increase in ammonia in the canal. The chart shows high ammonia levels from 2010 to early 2019. Runoff may be the root cause of this situation because Sri Jayawardenapura Kotte has heavy rain from December to February. It was more than 4 mg/L in 2016 and 2019 (Figure 7).

3. 7. Nitrate

The nitrate form is an important nutrient for plant growth. If the nitrate concentration in surface water increases, it will cause algae development and water pollution. Concentrations in drinking water exceeding 10 mg/L nitrates can affect babies' health, which causes infant hemoglobinemia (blue baby). However, the nitrate levels of the Kotte canal are in good condition. The standard for nitrate in Sri Lanka is 5 mg/L (Opallage, Piyadasa and Dharmasoma, 2019). According to the chart, no months are recorded in the 5 mg/L range (Figure 8).

3. 8. Phosphate

Phosphate is an essential element for plant growth, but as the water content increases, it will reduce the oxygen content in the water. This condition can lead to eutrophication (algal bloom). Eutrophication reduces sunlight in bodies of water and increases the concentration of carbon dioxide through the death and decomposition of algae. However, the norm for phosphate in water bodies used for irrigation purposes in Sri Lanka is 0.7 mg/L (Opallage, Piyadasa and Dharmasoma, 2019). The study was recorded above the standard in June and July 2019 (Figure 9).

3. 9. Water quality assessment based on weighted arithmetic WQI method

The results of water quality parameters of the Kotte canal were used to analyze the standard of water quality. The weighted arithmetic index method uses to classify water quality based on purity. The analysis results are shown below:

Table 2. Calculation of water quality index on 2010.

Water Quality parameters (n)	Sn[a]	Wn[b]	Vn[c]	Qn[d]	WnQn[e]
pH	8.5	0.025716	6.55	-30.00000	-0.77149
Conductivity	0.7	0.312270	0.19	27.14286	8.47591
Dissolved Oxygen (DO)	3.0	0.072863	5.18	81.20600	5.91692
Ammonia (NH_3)	1.0	0.218589	0.27	27.00000	5.90191
Nitrate (as N)	5.0	0.043718	0.28	5.60000	0.24482
Phosphate (PO_4^{3-})	0.7	0.312270	0.24	34.28571	10.70641
Chemical OxigenDemand (COD)	15.0	0.014573	32.25	215.00000	3.13311

[a] Standard Value; [b] Unit Weight; [c] Observed Value; [d] Quality Rating; [e] Water Quality Index

As per the calculation, the total water quality index of 2010 is 33.6076. The rating as per the weighted arithmetic WQI is good water quality, and it can be grading as "B".

Table 3. Calculation of water quality index on 2013.

Water Quality parameters (n)	Sn[a]	Wn[b]	Vn[c]	Qn[d]	WnQn[e]
pH	8.5	0.025716	6.99	-0.666	-0.01712
Conductivity	0.7	0.312270	0.27	38.57143	12.04471
Dissolved Oxygen (DO)	3.0	0.072863	4.47	87.32750	6.36295
Ammonia (NH_3)	1.0	0.218589	0.99	99.00000	21.64034
Nitrate (as N)	5.0	0.043718	0.73	14.60000	0.63828
Phosphate (PO_4^{3-})	0.7	0.312270	0.28	40.00000	12.49082
Chemical OxigenDemand (COD)	15.0	0.014573	39.08	260.53330	3.79665

[a] Standard Value; [b] Unit Weight; [c] Observed Value; [d] Quality Rating; [e] Water Quality Index

As per the calculation, the total water quality index of 2013 is 56.95663. The rating as per the weighted arithmetic WQI is poor water quality, and it can be grading as "C".

Table 4. Calculation of water quality index on 2016.

Water Quality parameters (n)	Sn[a]	Wn[b]	Vn[c]	Qn[d]	WnQn[e]
pH	8.5	0.025716	7.11	7.333	0.18858
Conductivity	0.7	0.312270	0.2534	36.2000	11.30419
Dissolved Oxygen (DO)	3.0	0.072863	5.7350	76.3793	5.56523
Ammonia (NH_3)	1.0	0.218589	0.5300	53.0000	11.58523
Nitrate (as N)	5.0	0.043718	0.4700	9.4000	0.41095
Phosphate (PO_4^{3-})	0.7	0.312270	0.4730	67.5714	21.10056
Chemical Oxigen Demand (COD)	15.0	0.014573	22.8300	152.2000	2.21795

[a] Standard Value; [b] Unit Weight; [c] Observed Value; [d] Quality Rating; [e] Water Quality Index

As per the calculation, the total water quality index of 2016 is 52.37269. The rating as per the weighted arithmetic WQI is poor water quality, and it can be grading as "C".

Table 5. Calculation of water quality index on 2019.

Water Quality parameters (n)	Sn[a]	Wn[b]	Vn[c]	Qn[d]	WnQn[e]
pH	8.5	0.025716	6.99	-0.66	-0.01697
Conductivity	0.7	0.312270	0.31	44.28571	13.82912
Dissolved Oxygen (DO)	3.0	0.072863	4.26	89.13793	6.494865
Ammonia (NH_3)	1.0	0.218589	1.49	149.00000	32.5698
Nitrate (as N)	5.0	0.043718	0.34	6.80000	0.297281
Phosphate (PO_4^{3-})	0.7	0.312270	0.300	42.85714	13.38302
Chemical Oxigen Demand (COD)	15.0	0.014573	25.60	170.66670	2.48706

[a] Standard Value; [b] Unit Weight; [c] Observed Value; [d] Quality Rating; [e] Water Quality Index

As per the calculation, the total water quality index of 2019 is 69.04417. The rating as per the weighted arithmetic WQI is poor water quality, and it can be grading as "C".

4. CONCLUSIONS

The study was used to analyze the limited amount of data of 2010, 2013, 2016, and 2019 with two years gap. It was recorded different patterns of water quality parameters. The water quality index of the study area can be concluded easily for understanding as follows,

The calculated water quality index values of the Sri Jayawardenapura Kotte canal in 2010, 2013, 2016, and 2019 are 33.60760, 56.95663, 52.37269, and 69.04417, respectively. The results revealed that the quality of the water was good in 2010, and the grading is B, whereas from 2013 to 2019, the quality of the water is poor, and the corresponding grade is C.

As per the location of the Kotte canal, land development is the main determining factor of water quality. As per the study temperature of the canal water fluctuates with weather and the climate of the area over the years. The pH of the water does not record in problematic level. The electrical conductivity of the water is neutral over the year. Sri Lanka standard of EC is 0.7 mg/L. It was recorded for only one month in January 2019 as 0.74 mg/L, slightly increasing than the standard level. COD level of water is higher than the standard level of the country for irrigation purposes from 2013 to 2019.

The temperature of the water body was also recorded as normal within the study period. The dissolved oxygen level of the water is higher than 3 mg/L. It is a high-risk standard for the living organism of the water body. Ammonia level of the canal water was also recorded as a bad condition. The nitrate level is neutral. Phosphate was recorded only June and July months of 2019 as a higher level. The salinity level of the Kotte canal is less than 0.01 percentage throughout the study period.

However, pH, COD, DO, and ammonia are the main water quality parameters that deviate from the standard level of Sri Lanka over the year. The reason for this increased pollution is population growth. The public used to dispose of domestic wastewater without any treatment and their waste along the canal. Industrial wastes of the city also affect the water quality of the canal.

Even at present, the Sri Jayawardenapura Kotte canal is currently in such an environmentally deteriorated condition due to rapid development and urbanization. Thus it is essential to implement water body improvement activities, including all open drainage canals of the Colombo catchment.

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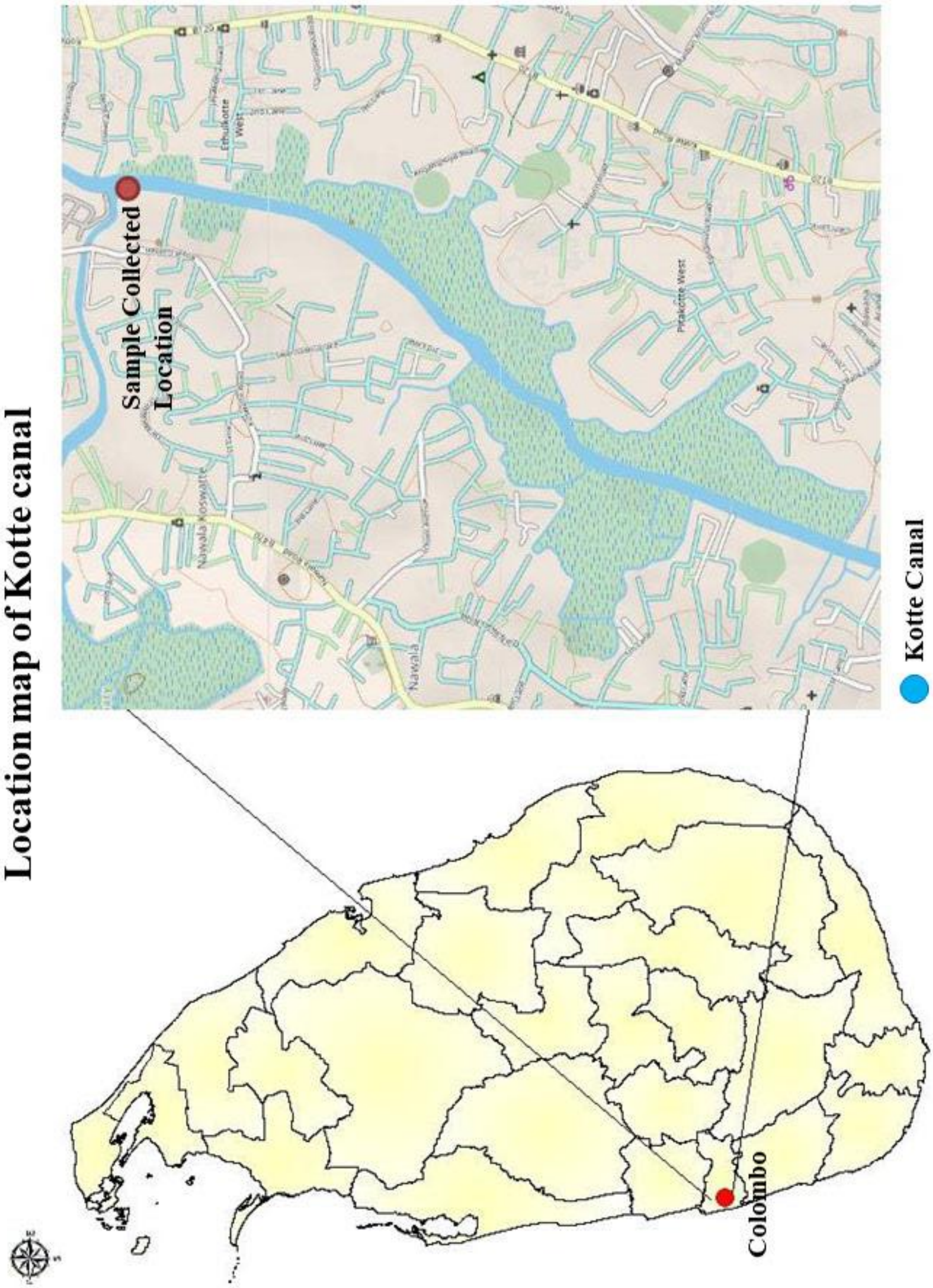

Figure 1. Location map of Kotte canal

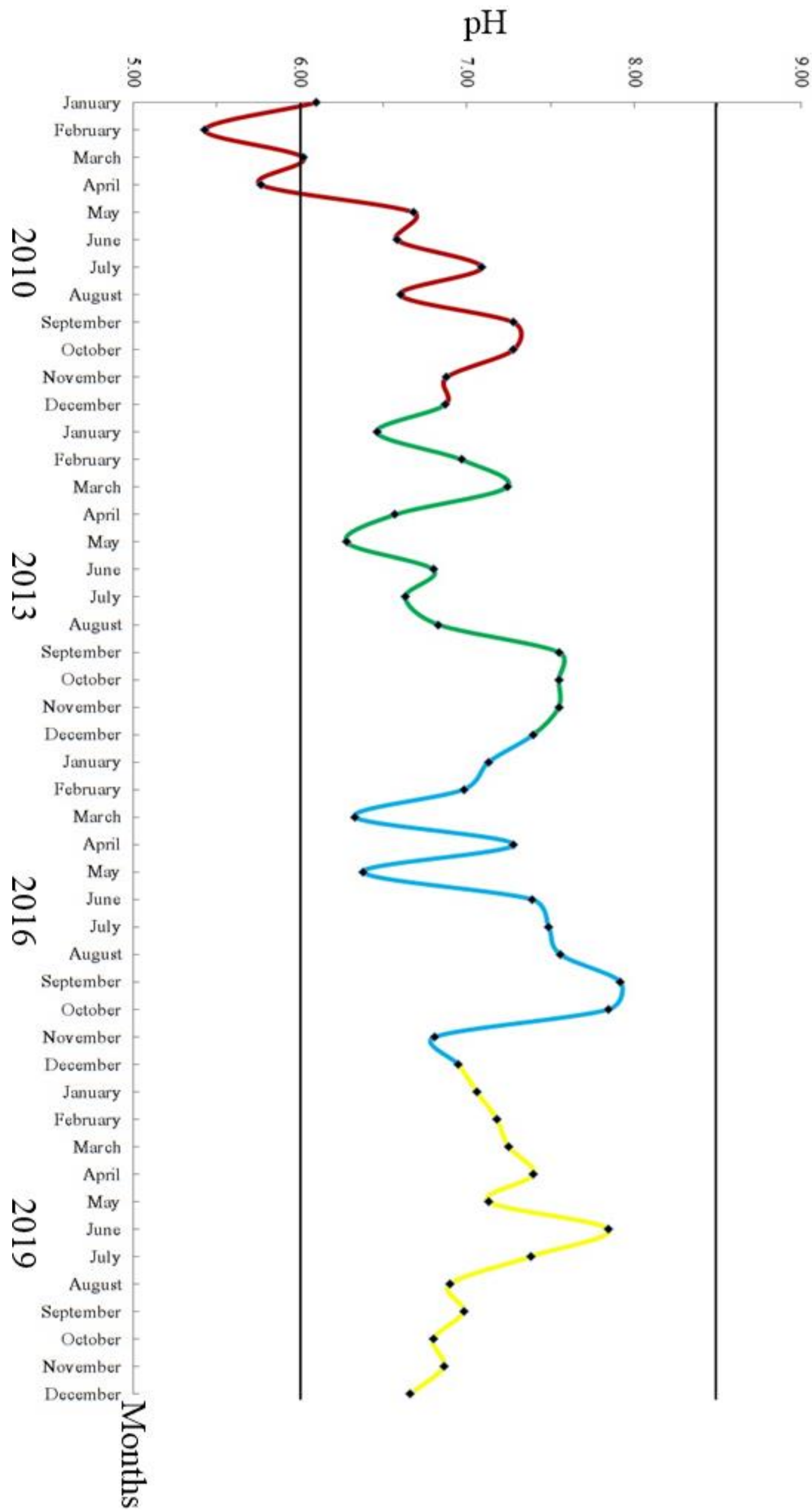

Figure 2. pH variation of Kotte canal from 2010 to 2019.

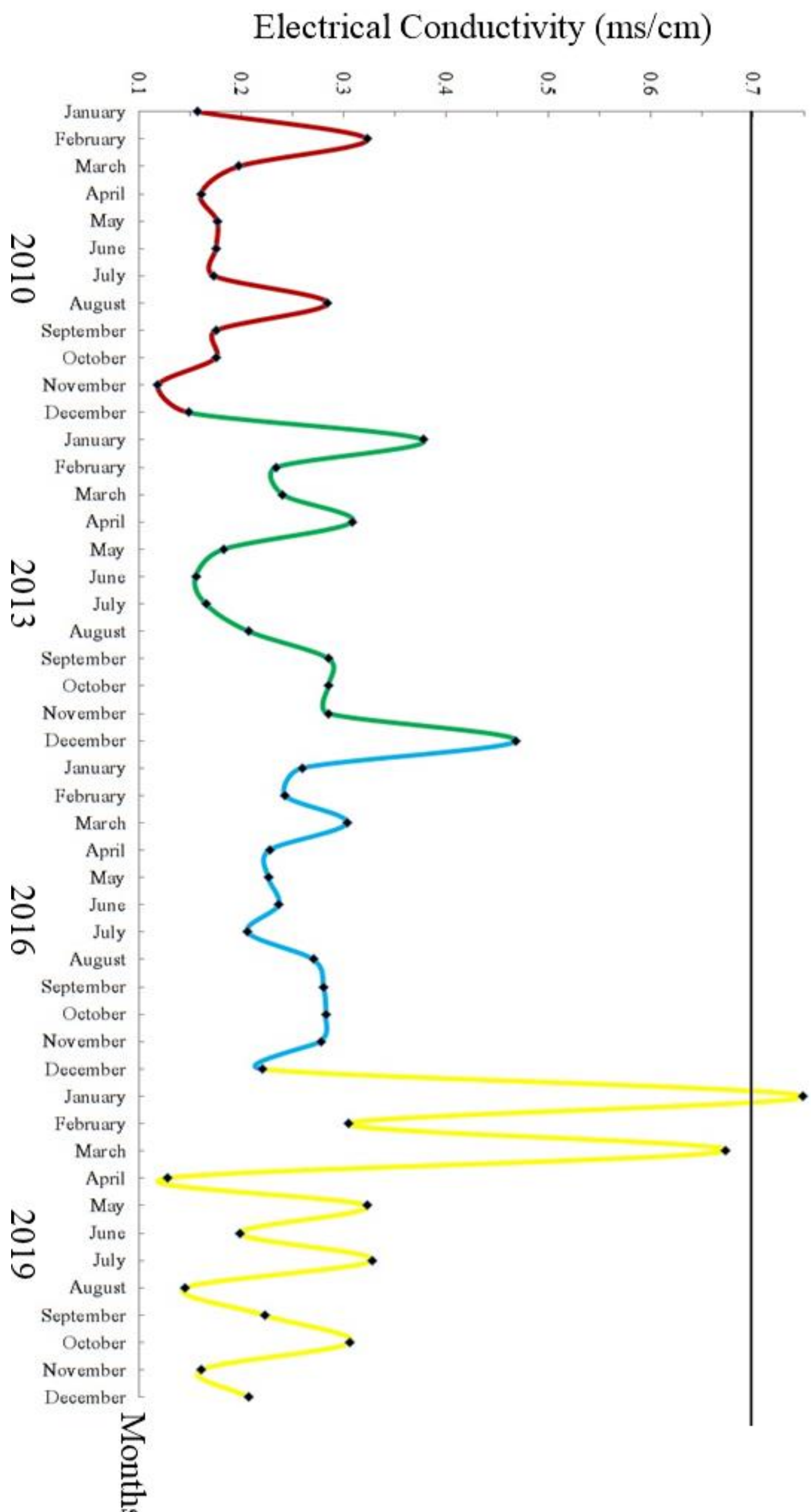

Figure 3. Electrical conductivity variation of Kotte canal from 2010 to 2019

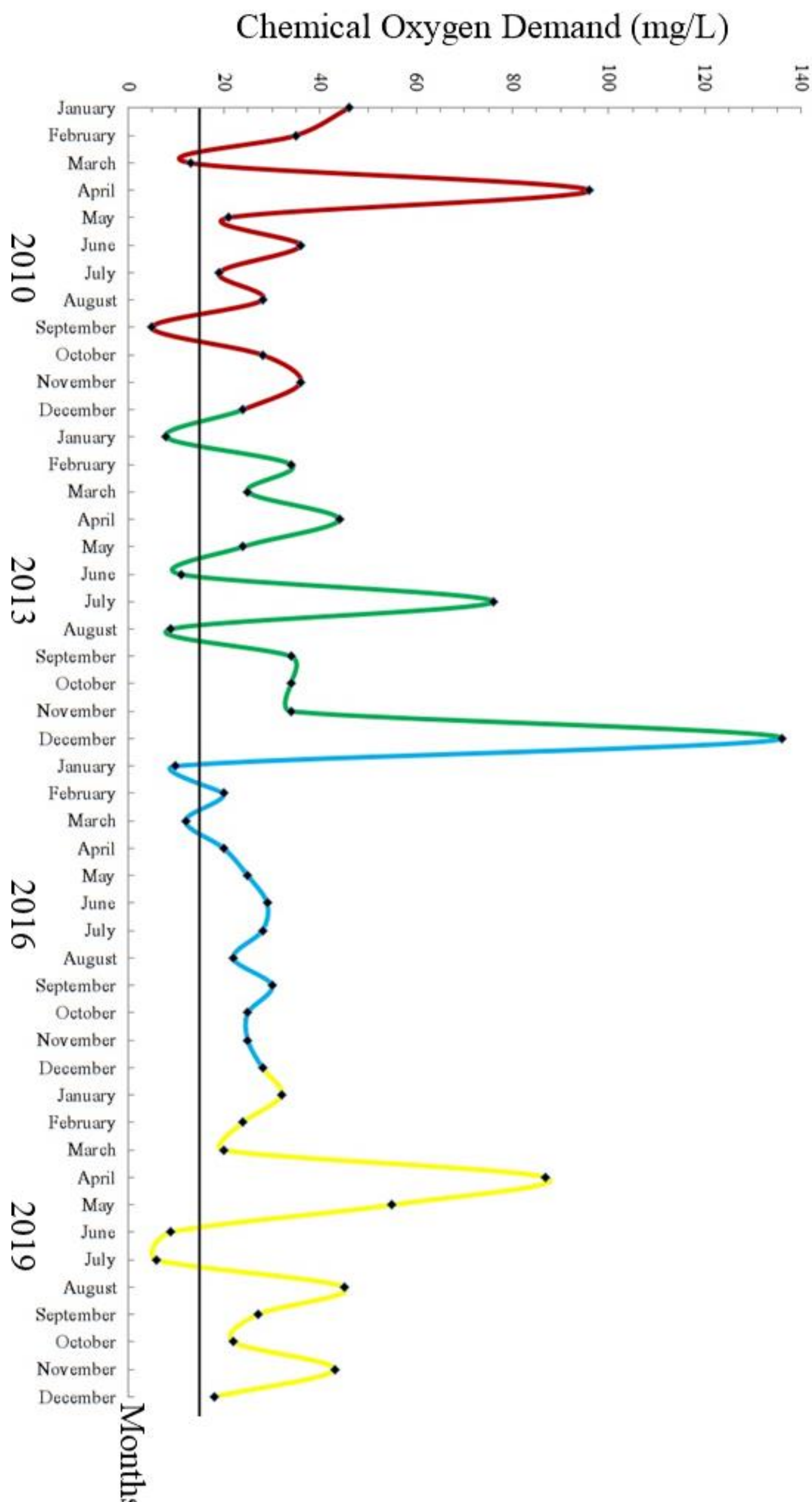

Figure 4. Chemical Oxygen Demand variation of Kotte canal from 2010 to 2019

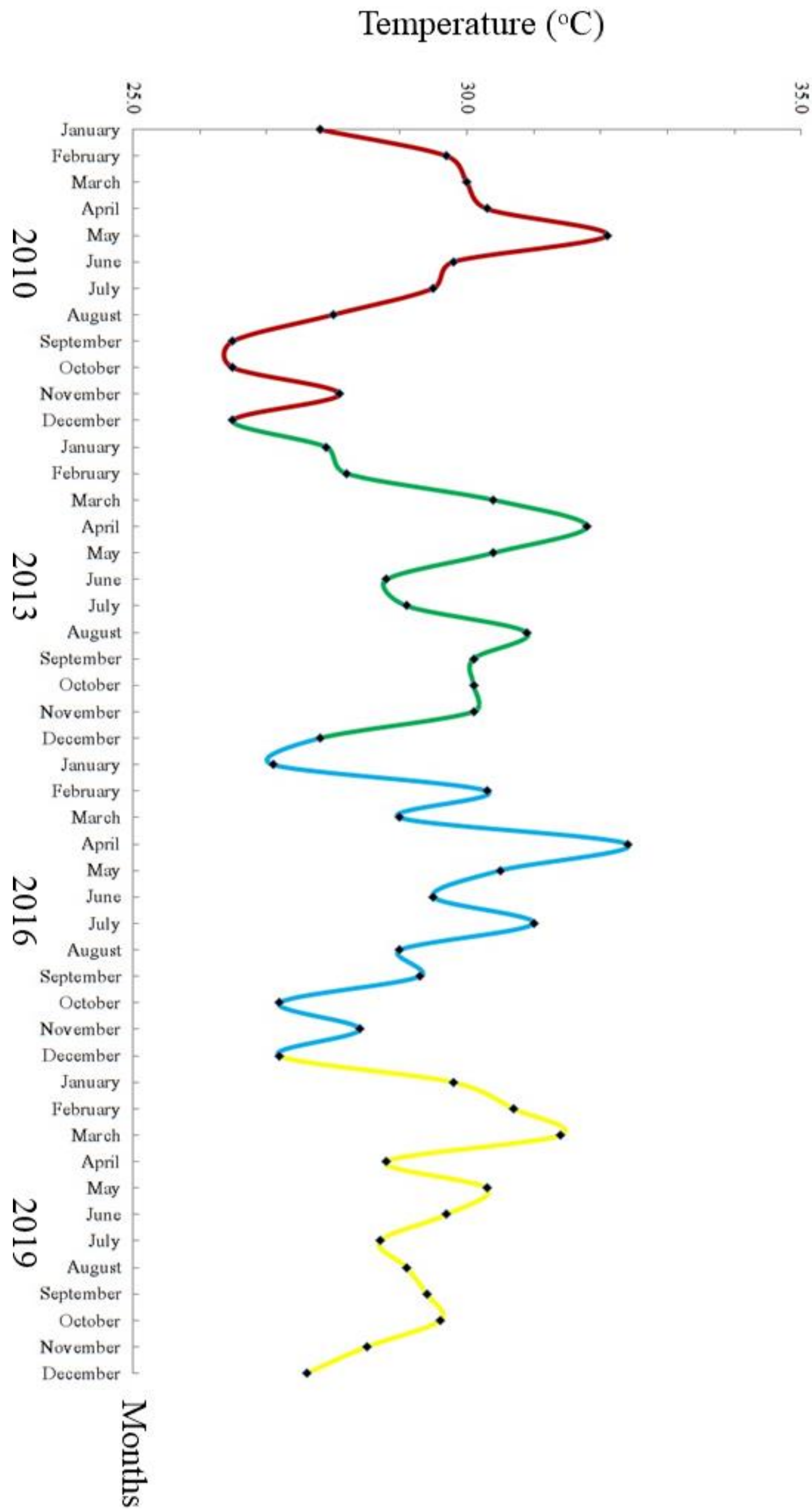

Figure 5. Temperature variation of Kotte canal from 2010 to 2019

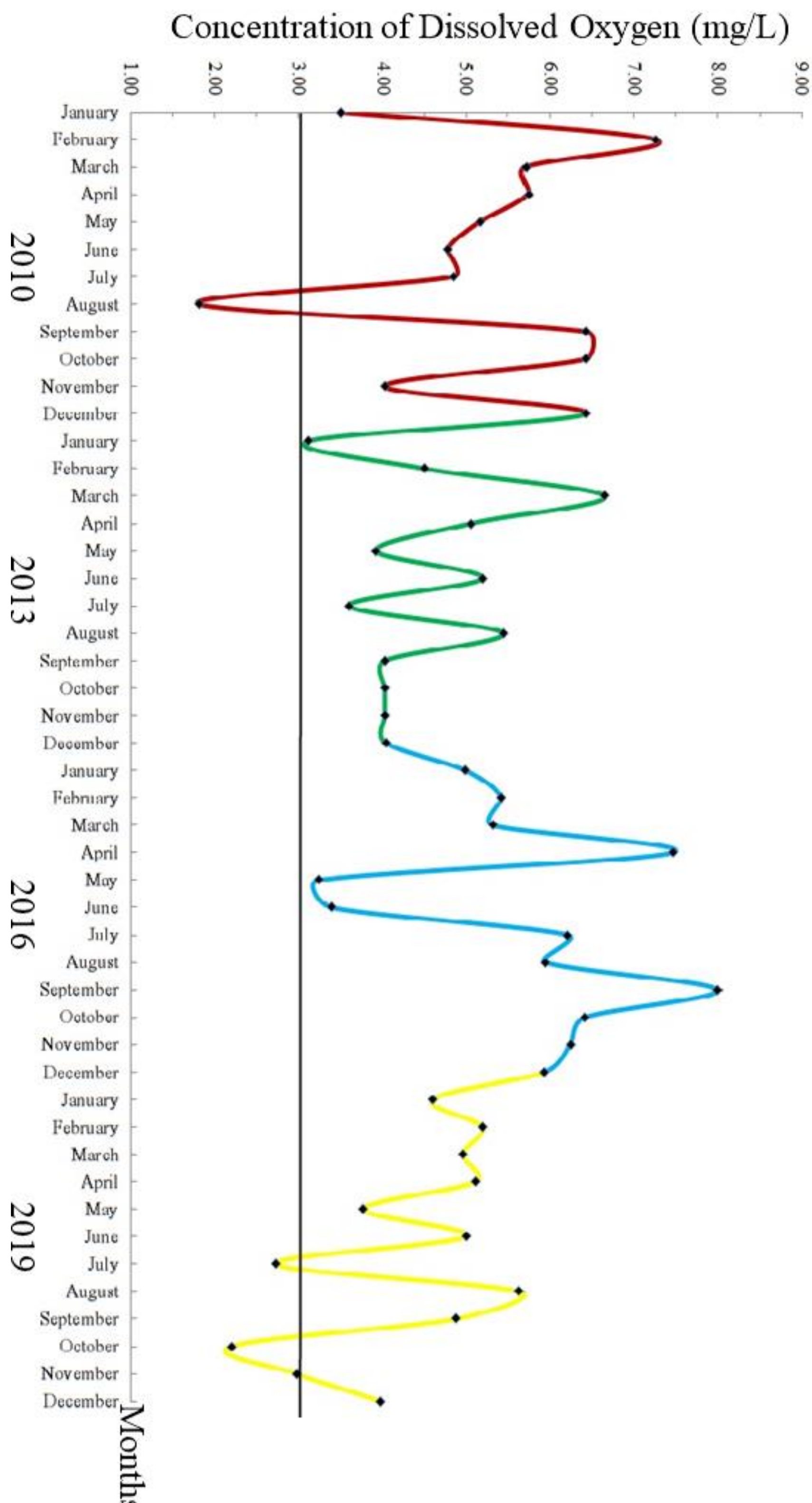

Figure 6. Dissolved Oxygen variation of Kotte canal from 2010 to 2019

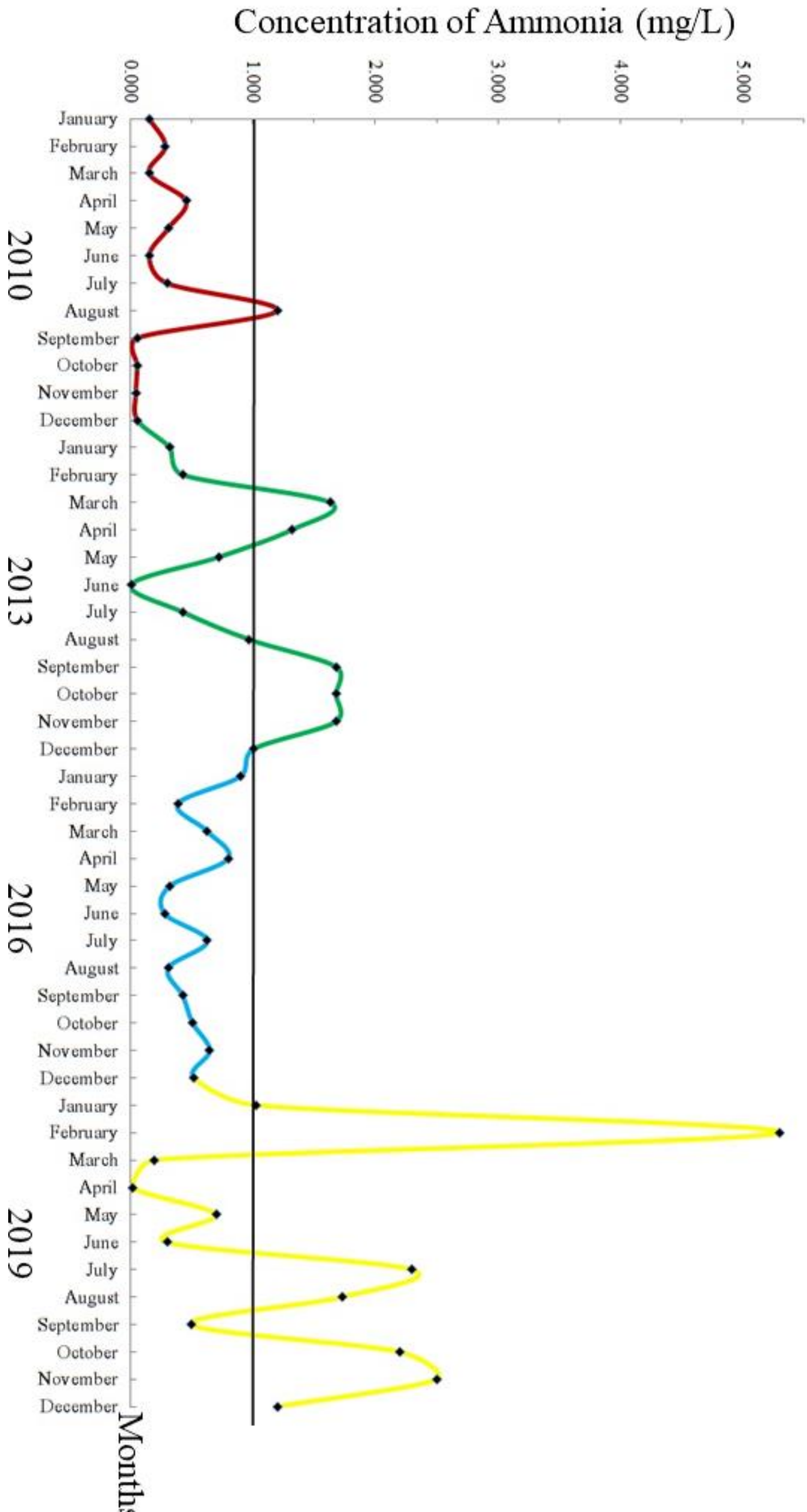

Figure 7. Ammonia variation of Kotte canal from 2010 to 2019

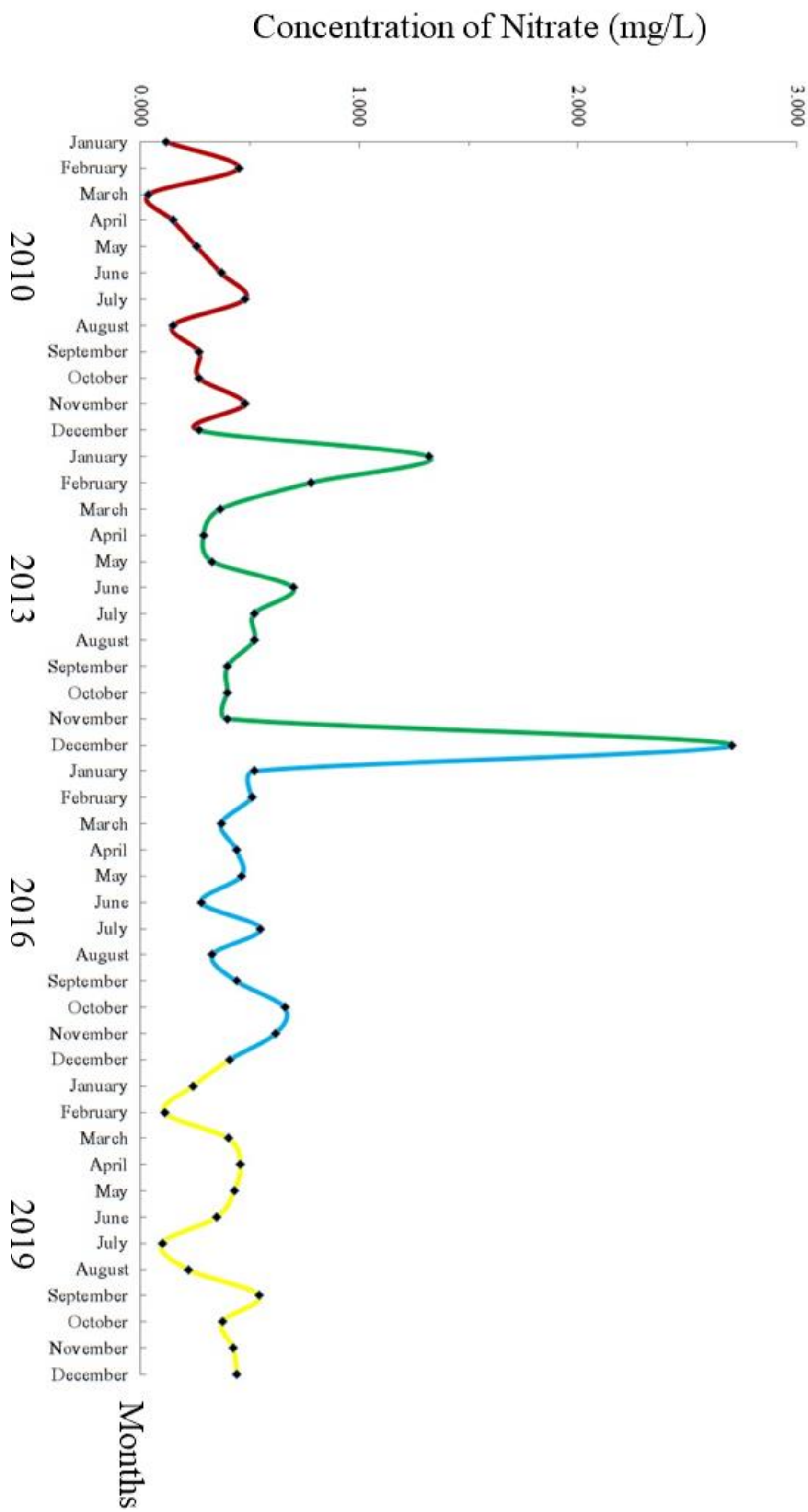

Figure 8. Nitrate variation of Kotte canal from 2010 to 2019

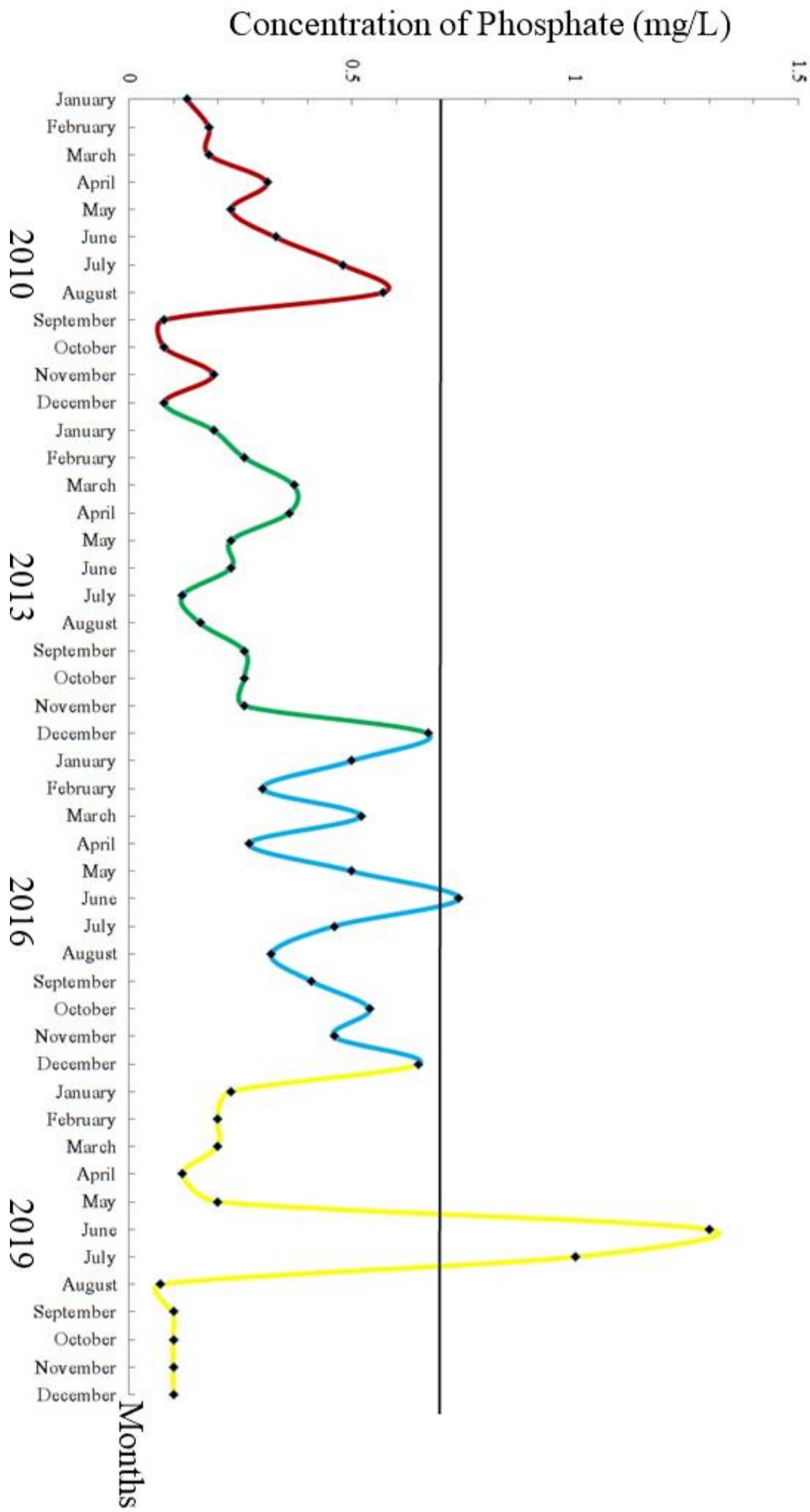

Figure 9. Phosphate variation of Kotte canal from 2010 to 2019