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Depletion of dissolved oxygen concentration in the river water and its relationship with surface water temperature: A case study

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Abstract

Research revealed that the dissolved oxygen concentration in the Sitalakhyariver has been gradually deteriorated over the last decade and the temperature pattern of river water is also changing gradually. To assess the ecological integrity of river Sitalakya, this study is aimed at determining the relationship among surface water temperature, DO, and COD in the river as they affect each other, particularly to assess whether DO depletion of the river water is occurring due to water temperature changes or for the anthropogenic pollution made to the river. Subsequent to water quality testing for a period of five years following the standards methods in the laboratory, the statistical regression analysis of the concentration of DO in the raw water and the corresponding temperature and also the corresponding COD concentration in the water during the study period was made. The correlation analysis shows a poor relationship between DO and temperature of the raw water. The coefficient of determination is also derived showing R^2 value 0.30 indicating a very weak relationship between surface water temperature and dissolved oxygen in this river. The correlation analysis between COD and DO was also made and the coefficient of determination is also derived showing R^2 value 0.70 indicating a very good correlation between the two. It is apparent that with the increase of COD concentration in the surface water DO concentration decreases proportionately. These results showed clearly that DO content of this river depend on the organic waste dumped in the river and not surface water temperature.

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Introduction

The sustainability of natural surface waters in terms of quality & quantity is a vital issue today as it was from the time immemorial. Indeed, civilizations have developed and flourished beside natural water bodies. Lakes, rivers, and streams have important multi-usage components, such as sources of drinking water, irrigation, fishery, and energy production. Water is a scarce and fading resource, and its management can have an impact on the flow and the biological quality of rivers and streams (Hacioglu and Dulger, 2009). On the other hand surface waters are the most vulnerable sources to pollution and worldwide deterioration of water quality from both anthropogenic influences such as urban, industrial and agricultural activities, increasing consumption of water resources and natural processes such as changes in precipitation inputs, erosion, and weathering of crustal materials impair their use for drinking, industrial, agricultural, recreation or other purposes The river under study & river elsewhere in general, during its course receives pollution load both from the point and non-point sources. It receives agricultural run-off from its catchments area directly or through its tributaries and wastewater drains. In the recent past, the expanding human population, industrialization, intensive agricultural practices and discharges of a massive amount of wastewater into the river and stream have resulted in deterioration of water quality. The impact of these anthropogenic activities has been so extensive that the water bodies have lost their self-purification capacity to a large extent (Serajuddin *et al.*, 2018).

The quality of water is typically determined by monitoring microbial presence, especially fecal coliform bacteria (FC) and physicochemical parameters (EPA, 1999). These parameters could be affected by the water body external and internal factors. There is an intricate relationship between the external and internal factors in aquatic environments. Meteorological events and pollution are a few of the external factors which affect physicochemical parameters such as temperature; pH and dissolved oxygen (DO) of the water. These parameters have major influences on biochemical reactions that occur within the water. Sudden changes of these parameters may be indicative of changing conditions in the water. Internal factors, on the other hand, include events, which occur between and within bacterial and plankton populations in the water body (Bezuidenhout *et al.*, 2002).The microbiological and physicochemical parameters of different freshwater systems (river, stream, ocean etc.) have been studied by various researchers(Bezuidehout *et al.*, 2002; IWM,2005; Naushad *et al.*, 2006; Shishir *et al.*, 2009; Moskovchenko *et al.*, 2009; Shahidul, 2011; Sania *et al.*,2012; Roy *et al.*, 2014; Ibrahim and Ashraf,2015; Serajuddin and Islam, 2017).

The DO defines the capacity of the body of water to assimilate the imposed load by itself or with the help of reaeration through oxygen absorbed mainly from the atmosphere and also through photosynthesis. The amount of dissolved oxygen that can be held by the water depends mainly on the water temperature. The determination of dissolved oxygen concentration relative to its saturation value and the rate of oxygen utilization measured as its BOD (Biochemical Oxygen Demand) /COD(Chemical Oxygen Demand) become a good measure for identifying the pollution status of a water body. The knowledge of the progressive utilization of oxygen in a water body has been widely used as a measure of the amount of decomposable or organic matter contained in it at a given time. In rivers and streams, the turbulence ensures that the oxygen is uniformly distributed across the water and in every shallow stream the oxygen may be supersaturated. The connection between dissolved oxygen concentration and water temperature and COD is important given the fact that the river is impaired by both high water temperatures and low dissolved oxygen concentrations.

Therefore, a study to ascertain relation between water temperature, DO and COD is very important to know the quality status of the water body. No such study in near past in the reach from where raw water is drawn for Dhaka treatment plant on the Sitalakhya river was made.

Surface water being a major source of water supply is going to be a dependable option for fulfilling water demands of Dhaka if the pollution level is under specified limit. Though Dhaka City is surrounded by a number of peripheral rivers but if we cannot control their contamination level it will have their limitation to be used as a potable water source in very near future. On the other hand before treatment, it is imperative to have ideas on the level of pollution of these peripheral river waters.

The oxygen content of water is often an important indicator of water quality and directly influences the organisms' development within the water environment. In general, the higher the DO concentration, the more diverse the biological population will be. Oxygen gas dissolves in water through several different avenues. Simple diffusion from the air and aeration from water movement affect the dissolved oxygen (DO) content. For example, water in a shallow, fast-moving stream is more likely to have more DO than a stagnant pool of water. Biological factors that affect DO content are photosynthesis by aquatic plants, the amount of decaying organic material, and even human activities that occur in a body of water. During the day, photosynthesis by aquatic plants increases the DO content of water. At night, plants and animals continue to consume the DO, resulting in a decrease in DO concentration. Decaying organic material is broken down by aerobic bacteria, and this process depletes the DO concentration of water as well. Physical factors like temperature, altitude, and atmospheric pressure also affect the DO content of water. Research on regional and global climate changes and variability and their impacts on water resources have received considerable attention in recent years. Potential impacts of climate change and its effects have been much in the discussion but relatively fewer studies are being done on changes in water quality. From a global perspective, climate change is usually perceived as an increase in average air temperature. So with the increase in air temperature, surface water temperature increases. This affects the water quality of the river.

The water temperature is one of the most important physical characteristics of the ecosystem. It affects a number of water quality parameters that are the concern for domestic, environmental, industrial and agricultural applications. The chemical and biological reaction rates increase with an increase in water temperature which reduces the dissolved oxygen in the river(Akaahan *et al.*, 2015; Parashor, *et al.*, 2007; UNEP, 2006).

In addition to these processes, dissolved oxygen concentrations are affected by salinity, and atmospheric pressure. Oxygen is soluble, or "dissolved" in water. The solubility of oxygen is a function of water temperature, salinity, and atmospheric pressure; decreasing with rising temperature and salinity, and increasing with rising atmospheric pressure. At sea level (1 atm of pressure) fresh water has a saturation dissolved oxygen concentration of about 14.6 mg/L at 0°C and 8.2 mg/L at 25°C.

Biochemical oxygen demand (BOD) is a measure of the capacity of water to consume oxygen during the bio-decomposition of organic matter and the bio-oxidation of inorganic chemicals such as Ammonia and nitrite. The dissolved oxygen (DO) and the biochemical oxygen demand (BOD) are two useful parameters in tracing pollution profile and natural purification of rivers upon which engineering calculations of permissible pollution loadings are based. Chemical Oxygen Demand (COD) is an important water quality parameter because, similar to BOD, it provides an index to assess the effect of discharged wastewater will have on the receiving environment. Higher COD levels mean a greater amount of oxidizable organic and non-organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions, which is deleterious to higher Aquatic life forms.

Typically both BOD and COD are the main parameters analyzed to indicate the degree of pollution in the natural water (river, lake, canal, spring etc.).

BOD is the measurement of the amount of oxygen required to decompose biologically organic matter under aerobic condition at 20°C in 5 days; whereas COD is the measurement of total oxygen required to oxidize chemically into carbon dioxide all organics and non-organic material available under specific conditions (pH, temperature, time etc.). BOD values thus, are always smaller than COD values while it takes longer time for BOD measurement usually five days as compare to COD measurement that only a few hours. Thus BOD and COD are two widely used parameters for organic pollution measurements. Nevertheless, COD is a useful, rapidly measured, variable for many industrial wastes and has been in use for several decades.

The Sitalakhya river, in Bangladesh plays a fundamental role in Dhaka city, as a source of drinking & irrigation water, and also as a sink for wastewater. In fact, it is the prime source of domestic water supply through surface water treatment plant for the millions of citizens of the capital city. Thus the water quality of this river without any doubt has a tremendous effect on the economy & social wellbeing of the entire nation. The water quality of this river is being deteriorated over the last three decades, which is evident from its DO profile, making any water pursuit very difficult.

With this background this study is aimed at determining the extent of relationship of surface water temperature, COD and DO in the river Sitalakhya thus to enable understand the dynamics and status of water quality in this river.

This study also aims to assist in thinking about a possible strategy for water resources managers of critical pollution parameter, if any, to lay the foundations for efficient control mechanism against indiscriminate pollution. This study may also facilitate decision makers to efficiently brainstorm a suitable water treatment alternative for present raw water quality, if it found vulnerable, for the time being in order to continue water production with acceptable water quality and therefore amenable to greater withdrawal to meet the anticipated additional demand.

Materials and methods

Study area

The study area is Dhaka the capital city of Bangladesh with a population of around fifteen millions located in the central part of Bangladesh. The city has a distinct monsoonal season, with an annual average temperature of 26°C and monthly means varying between 19°C in January and 29°C in May, sometimes reaching to 40°C. Approximately 87% of the annual average rainfall of 2,123 millimeters occurs between May and October. Dhaka is located at 23°42′N 90°22′E, on the banks of the Burigangariver and surrounded by other peripheral rivers. The largest water treatment plant of the country is situated beside the river Sitalakhya in the eastern periphery of Dhaka city at Latitude N 23° 43' 11.25" & Longitude E 90° 26' 14.25" (Serajuddin *et al.*, 2018).

Sample collection and analysis

Raw Water samples were collected from the treatment plant intake. Samples were collected in clean plastic cans of 2 lit capacities for physico-chemical analysis. The collected samples were transferred to the laboratory of the plant, by following the precautions laid by standard methods (APHA, 1995). pH, DO, temperature, were determined within the field of collection, the other parameters like COD (Chemical Oxygen Demand), etc., were analyzed in the laboratory within the stipulated period.

As per Bangladeshi guideline (ECR, 1997) BOD & DO concentration for the source water for drinking purpose should be respectively <6 mg/L and >6 mg/L, from a correlation study it stands to COD14 mg/L (Serajuddin *et al.*, 2018). Statistical analysis

Mean, maximum and minimum of DO, Temperature and COD data were used to present monthly values for these parameters. Correlation equations were developed with statistical analysis and Coefficient of determination (R2) was calculated to show the degree of correlations between DO & COD and between DO & water temperature.

Results and discussion

The concentration of three important physical & chemical raw water quality parameters namely DO, temperature & COD is tested. The study covers a period of a full year (2017), and the monthly average values of concentration of all the three parameters in the year are analyzed.

This study gives a comprehensive picture of the raw water quality of these three important water quality parameters for a drinking water treatment plant in Dhaka over a long period of time covering all the months and seasons of the year.

Table 1. Monthly maximum & minimum concentration of DO, COD and Temperature.

Year	Month	DO		COD		Temp.	
		Minm.	Maxm.	Minm.	Maxm.	Minm.	Maxm.
2017	January	0.3	1.3	20	71	20.8	24.4
2017	February	0.3	0.7	50	127	22.3	27.2
2017	March	0.2	0.8	46	87	25.3	30
2017	April	0.3	3.1	17	61	27.5	31.5
2017	May	1	2.8	12	30	29.6	32.8
2017	June	1.1	2.7	13	29	28.9	32.6
2017	July	1.5	3.1	8	18	30.4	32.5
2017	August	1.3	3.7	8	24	30.4	33.3
2017	September	0.9	2	7	16	31.1	32.7
2017	October	1.1	3.5	8	18	28	32.4
2017	November	2.3	3.9	10	22	26.3	29
2017	December	0.5	2.8	7	24	24.4	26.2

Monthly average concentrations of DO and COD as well as value of temperature are shown respectively in Fig. 1 through Fig. 3. The average DO across the months is found to be always below 3 mg/L, it varies between 0.4mg/L to 2.7mg/L(Fig, 1-3). The maximum average DO concentration of 2.7 mg/L is found in November and the lowest average is 0.4 mg/L in February.- March (Fig.1). The investigation shows that during the study period the maximum DO recorded was 3.9 mg/L in 1 November and the minimum DO is 0.2 mg/L in 4 March (Table.1).

Table 2. Monthly % DO saturation at corresponding average temperature.

Month	DO	Temp	DO saturation %
January	0.8	22.7	9.3
February	0.4	24.9	4.82
March	0.4	27.1	5
April	1.2	29.8	15.8
May	1.7	31.3	22.98
June	1.7	30.8	22.98
July	2.4	31.6	32.75
August	2	32	27.5
September	1.3	32.1	17.88
October	2.2	30.8	29.76
November	2.7	28	34.6
December	1.6	25.3	19.53

Fig. 2 shows that the average monthly temperature varies between 22.7°C (in January) and 32.1°C (in August – September).The maximum temperature and minimum temperature recorded during the study period is 33ºC & 20.8ºC respectively in 26 August and 14 January (Table.1). Fig. 3 shows the monthly average concentration of COD in the study period.

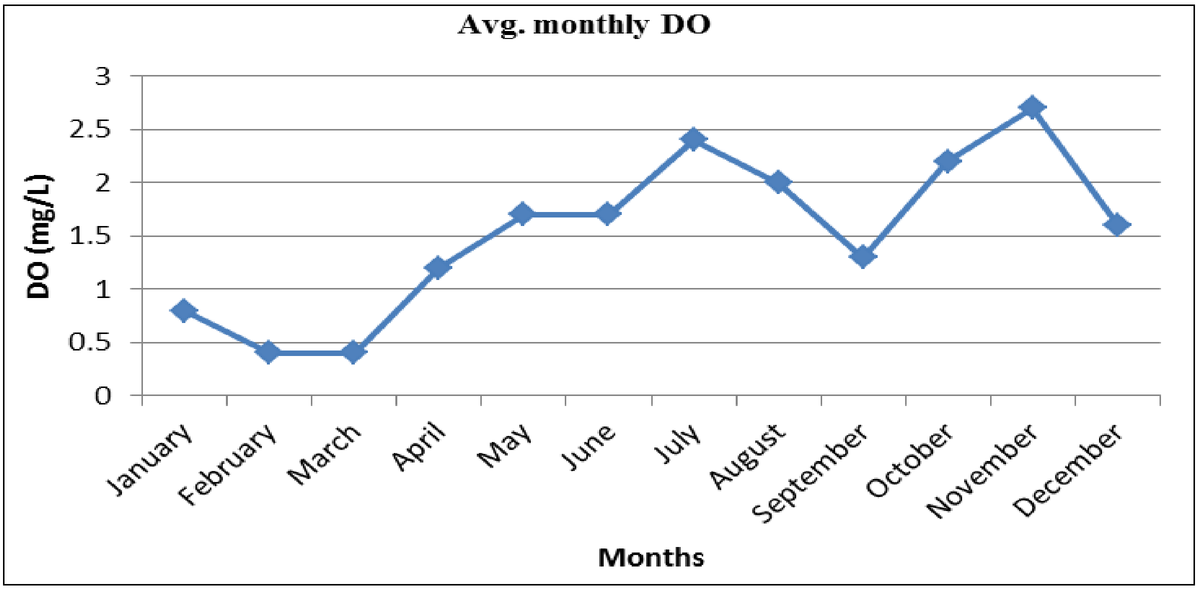

Fig. 1. Avg. monthly DO vs. Months.

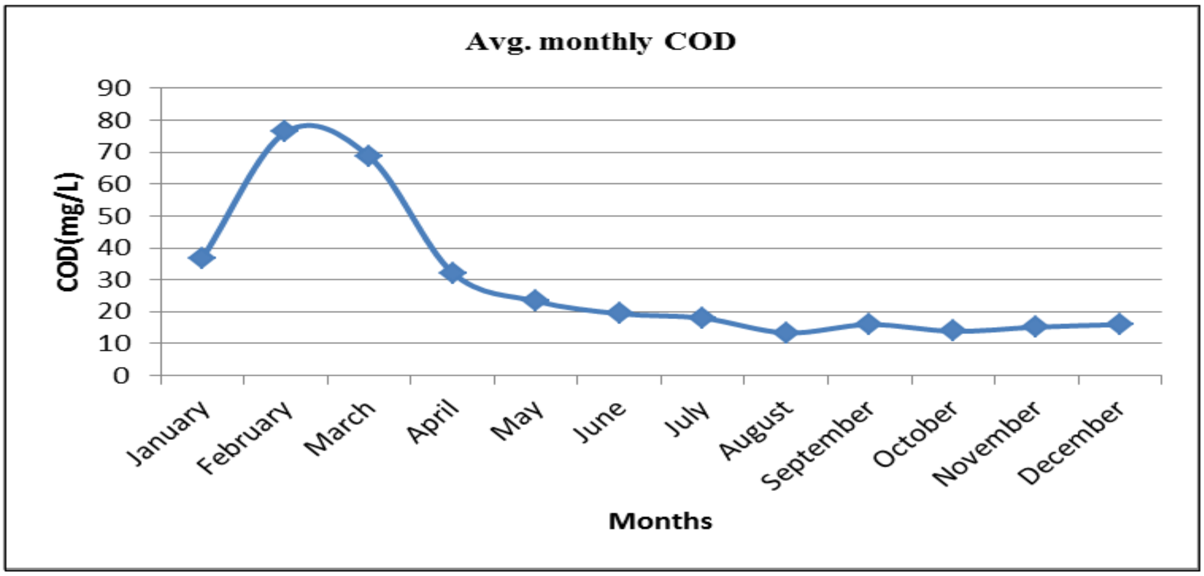

Fig. 2. Avg. monthly COD vs. Months.

The maximum monthly average COD is found to be around 76.3 mg/L in February which gradually decreases and the minimum values are in August with a value of 13.4mg/L (Fig.2). The maximum COD concentration recorded is 127mg/L on 15 February & the minimum is 7 mg/L in 22 September (Table.1).

It is noted that the average temperature & COD over the past few years are gradually increasing whereas the average DO is decreasing (Fig. 4-6) (Serajuddin *et al.*, 2018).

Fig. 7 shows COD vs. DO and DO vs. Temperature in a single graph. The X axis represents DO and Y1 axis COD and Y2 axis temperature.

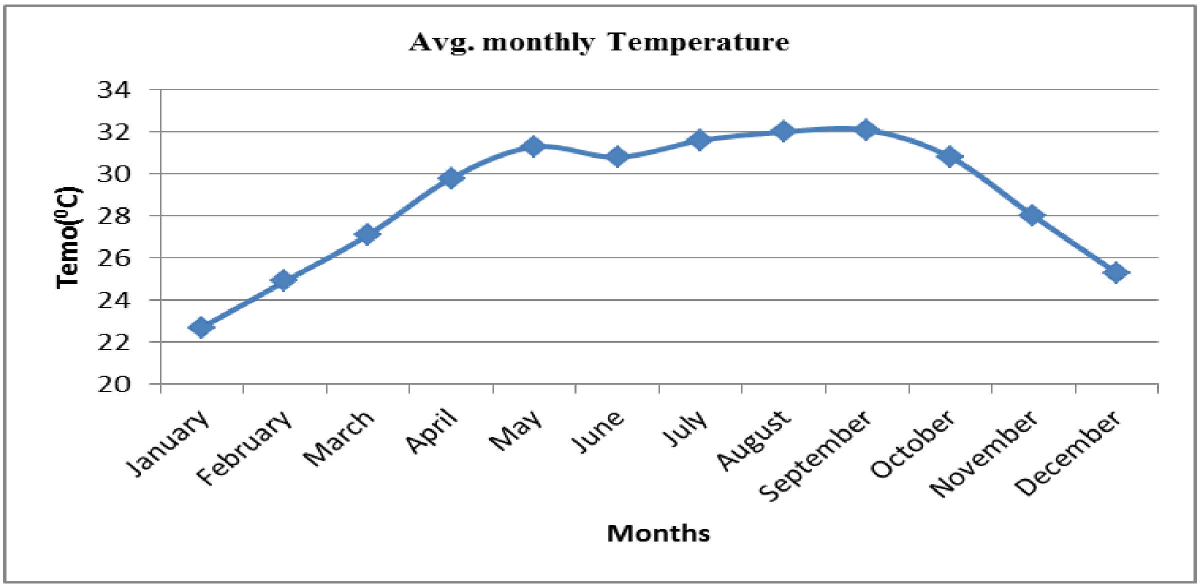

Fig. 3. Avg. monthly Temp.vs. Months.

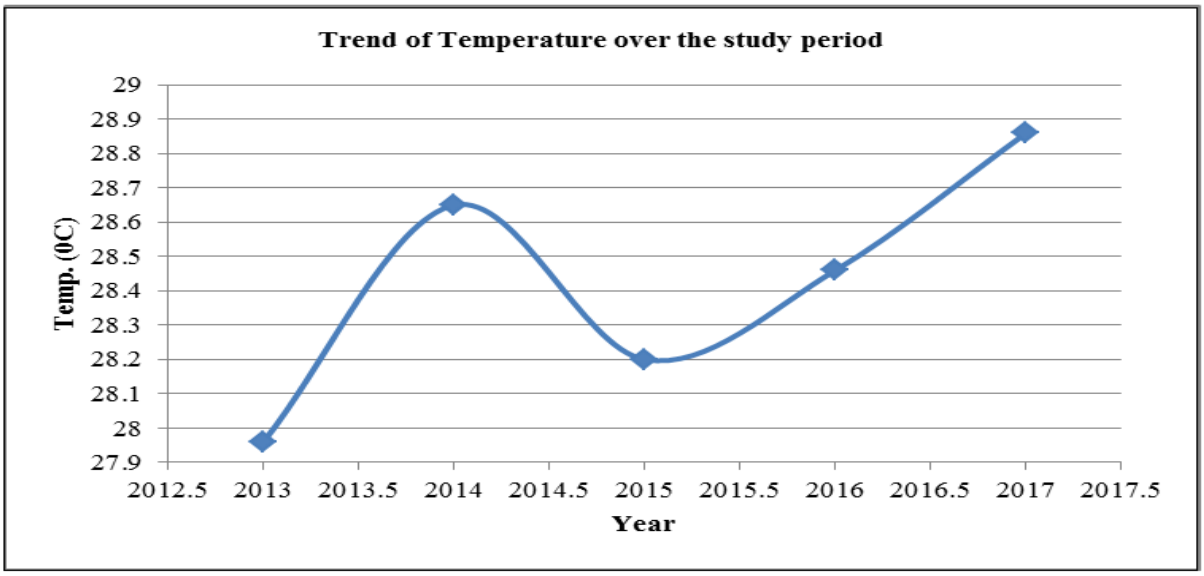

Fig. 4. Trend of Temperature over the past years (Serajuddin *et al.*, 2018).

It is evident that COD values have more or less a visible definite trend – with the decreasing value of COD, the corresponding DO values are increasing. This type of definite trend is absent in case of temperature & DO. With decreasing temperature the corresponding DO is not increasing. Almost in the same temperature or nearby there is a number of corresponding DO concentration is observed during the study period (Fig.7).

Table 1 shows the Monthly maximum & minimum concentration of DO, COD and Temperature and Table 2 shows monthly average DO, temperature & the approximate % saturation of oxygen at that temperature.

It is found that the % saturation varies from 5% to 33% in different monthly average corresponding temperatures (Table .2), but in general water is 80-90% saturated in the corresponding temperature. It indicates that the depletion of DO in the water under study is not due to rise or fall of temperature, rather there are other factors which is responsible for the oxygen depletion.

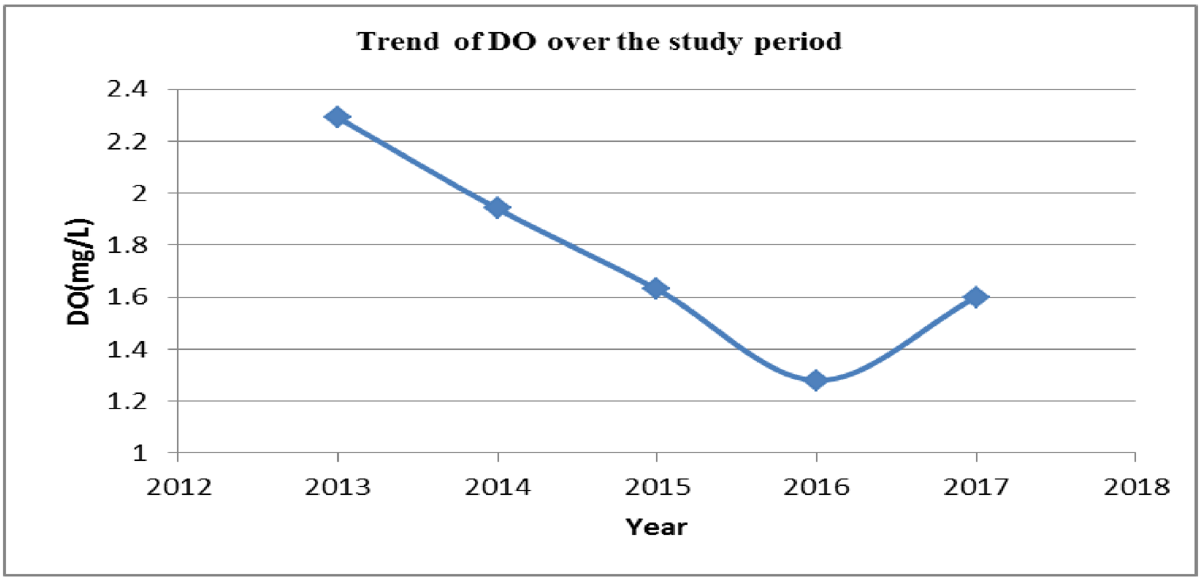

Fig. 5. Trend of DO over the past years (Serajuddin *et al.*, 2018).

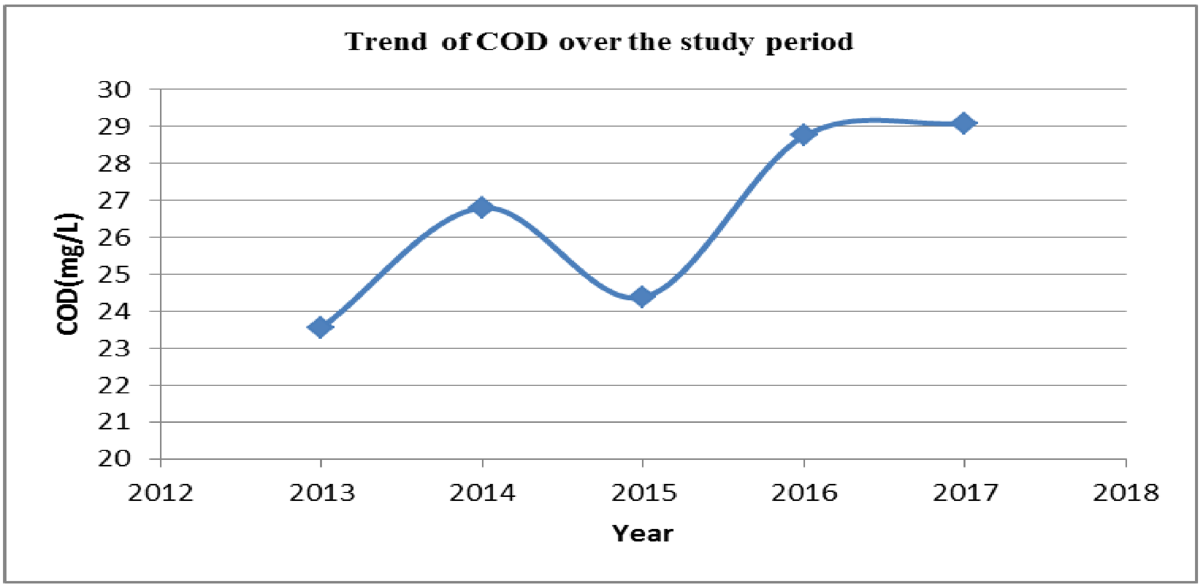

Fig. 6. Trend of COD over the past years (Serajuddin *et al.*, 2018).

Fig. 8 shows result of regression analysis of DO vs. COD in the study period, the regression equation is DO=-0.029COD+2.377, with coefficient of determination R^2= 0.71 which signifies a linear negative relationship with excellent correlation i.e., with the increase of COD concentration in the water the DO is decreasing proportionately. On the other hand Fig. 9 shows the result of regression analysis of temperature vs. DO with a regression equation Temperature = 2.383 DO+ 25.21 with a coefficient of determination R^2 = 0.31 which indicates poor correlation and most amazingly the equation signifies that with the increase of temperature DO is also increasing which is absurd.

This means that this particular correlation equation is not valid and that there is some other criteria that impacts the DO concentration that are not part of the developed model (atmospheric pressure, water turbulence, salinity etc.). We can conclude that the deterioration of DO is in no way contributed by increasing temperature rather increasing COD has a tremendous effect on the depletion of DO in this particular surface water.

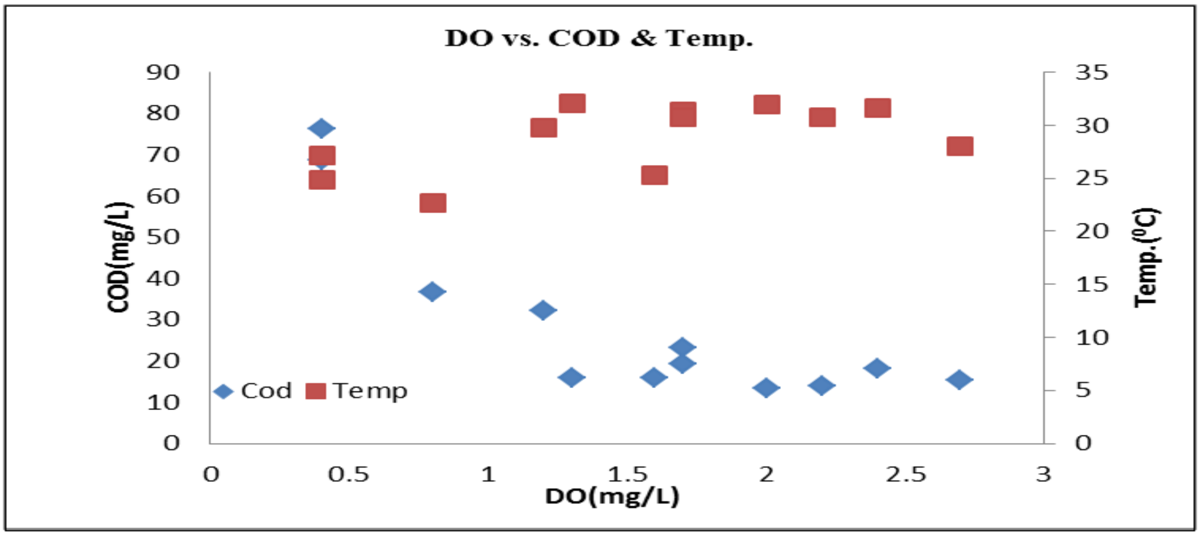

Fig. 7. DO vs. COD& Temp. over the study period.

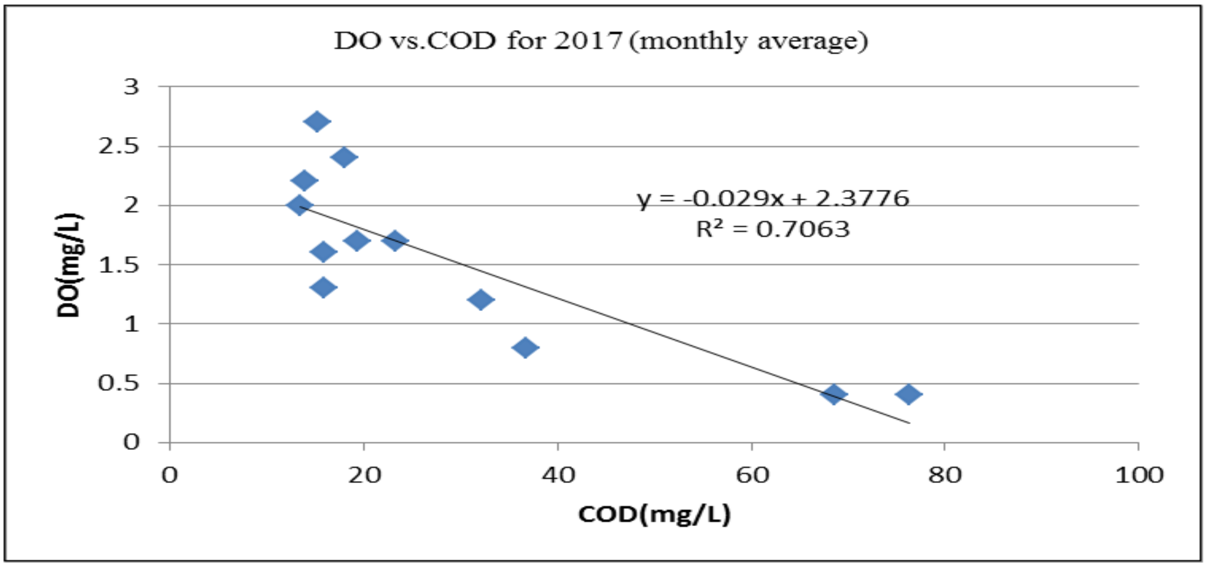

Fig. 8. DO vs. COD over the study period.

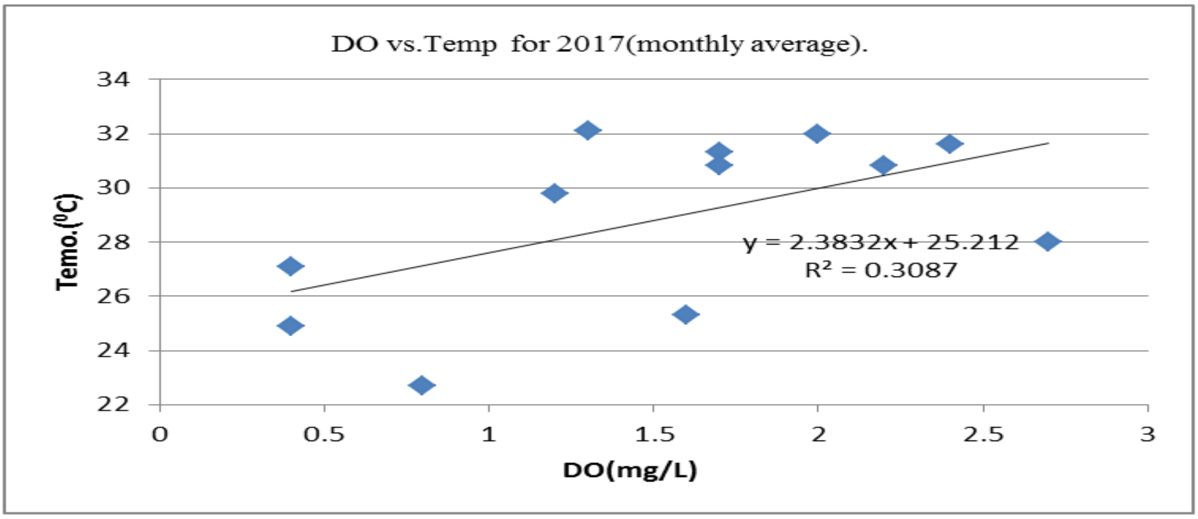

Fig. 9. DO vs. Temperature over the study period.

Conclusion

The deteriorating DO concentration in the Sitalakhya river water is mostly due to the organic waste load dumped into the river from various sources without any control & not due to the increasing surface water temperature. This is very much clear from the analysis that the COD showed very good relationship & association with DO, which is evident from the coefficient of determination value R^2= 0.70. The relationship between temperature & DO as shown is impractical and also the coefficient of determination value is found around 0.30 which is relatively low.

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