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A Review on pH, DO and BOD of the Sitalakhya River during Last Four Decades

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

As a developing country, industrialization is rapidly growing up in Bangladesh. Most of the cases, the industrialization process don't considering any impact on environmental body. In this study, the impact of unplanned industrialization on the surface water is the main focus. In between several resources, the water quality of the Sitalakhya River is our study area. Quality of the Sitalakhya River water is getting polluted day by day through industrial effluents and household wastewater, lube oil and oil spillage around the operation of river ports. The Sitalakhya river water quality analysis is considered between 1975 to 2018, qualitative and quantitative results for pH, DO and BOD were analyzed and also trends of these parameters were also analyzed. Day by day river water quality going far away from EQS value, which is significantly harmful to flora fauna. In this circumstance, industrial effluent and other environmental impacts from unplanned industrialization is main goal of this study. This study shows, how unplanned industrialization can damage an environmental system which is very harmful to our entire ecological cycle. If cannot control this unplanned industrialization, water body will damage and all related ecosystem will be effected.

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Keywords: Water pollution; water quality; waste water; unplanned urbanization; river water.

ABBREVIATION

Abbreviation		**Meaning**
BBS	:	*Bangladesh Bureau of Statistics*
BGMEA	:	*Bangladesh Garment Manufacturers and Exporters Association*
BOD	:	*Biochemical Oxygen Demand*
BUET	:	*Bangladesh University of Engineering and Technology*
BWDB	:	*Bangladesh Water Development Board*
CUMEC	:	*Cubic Meter per Second*
DOE	:	*Department of Environment*
DOH	:	*Department of Hydrology*
DTW	:	*Deep Tube Well*
EPB	:	*Export Promotion Bureau*
FGD	:	*Focus Group Discussion*
GIS	:	*Global Information System*
GPCD	:	*Gallon per Capita per Day*
IDI	:	*In-depth Interview*
SWTP	:	*Surface Water Treatment Plant*
WARPO	:	*Water Resource Planning Organization*
WHO	:	*World Health Organization*

1. INTRODUCTION

The Sitalakhya river is one of the Brahmaputra's Distributary Rivers in Bangladesh. It runs in a southwesterly direction at first. Later, it takes a different route to the east of Narayanganj, eventually meeting up with Dhaleswari near Kalagachhiya. The upper course of the river is known as the Banar River. Near Narayanganj, this river is 70 miles/110 kilometers long, with a width of about 300 meters. When measured at Demra, the flow of the Sitalakhya River is 74 cubic meters per second [1]. The Sitalakhya River has previously changed its course twice. The flow of water has been altered inadvertently as a result of the transformation. While passing through Jamalpur and Mymensingh, the Shitalakhya outlet formed, and the Brahmaputra's main flow loped to the Dhaleshwari. The Brahmaputra River flowed alongside the Sitalakhya River before entering Dhaleshwari [2].

Many factories have sprung up along the Sitalakhya River riverbank as a result of its strategic position. Those companies don't even use radioactive water and wastewater treatment methods. As a result, a vast amount of toxic and waste waste flows into the Sitalakhya River, either directly or indirectly, as a result of the illegal discharge operation. Domestic waste and industrial sludge from Narayanganj's urban areas are also dumped into this river without being treated. The people who live near the Sitalakhya River use the water for their everyday activities such as bathing, washing, and so on. As a result, pollution's impact is growing at a faster pace every day [3]. Industrial contaminants and effluents contain a variety of toxic elements, including heavy metals. Toxic elements coexist with germs and nitrogenous elements in agrochemical wastes [4,5]. Furthermore, the toilets constructed by residents of Narayanganj's slums pollute the river system by releasing harmful microorganisms, posing significant environmental and aquatic life risks, as well as causing numerous health issues (WARPO, n.d.). The people drink, cook, and bathe in this river water on a daily basis (Ahmed and Reazuddin, 2000). These harmful components have a major impact on the Sitalakhya River, which is forced to serve as their drain. In 1975 dissolved oxygen observed more than 6, in the current study it is observed below 2. In 1975 biochemical oxygen demand was found 1.72 ppm, in 2014 it is observed 6.64 ppm. pH is in within range during 40 years analysis [6-10].

As an environmental professional, we are very much concerned about the waste management of all kind of industries. In this study, we try to observe the effect of unplanned industrialization on the bank of river Sitalakkhya. In this purpose, we marge few water analysis report for 40 years. After analysis, it indicates a massive deviation in 40 years of water quality data. Day by day industrialization is growing up in entire Bangladesh. Especially garments, textile, fertilizer, food and power sector is rapidly rising. But maximum industries is buildup without consideration of any environmental impact [11-13]. They don't use proper waste management plan, effluent treatment or periodically effluent analysis. As a result, all hazardous waste directly goes into the environment, such as; river, canals, paddy field etc. Regarding this study, we try to understand the actual impact of the environment through the last 40 years of water analysis data. This study can prove the real impact in the Sitalakhya River water due to unplanned industrialization [14,15].

Quality of the Sitalakhya River water is polluted day by day by industrial effluents and household wastewater, lube oil and oil spillage around the operation of river ports. In this present review, we presented the Sitalakhya River water analysis report for the period of 1975 to 2018 depending on pH, dissolved oxygen, biochemical oxygen demand parameter. Our analysis shows day by day river water quality going far away from EQS value, which is significantly harmful to flora and fauna.

2. OBJECTIVE

The objective of the study is following target

- ✓ To find out 40 years trend of the Sitalakhya River water quality.
- ✓ Change of pH, DO and BOD
- ✓ Effect of effluent water in surface water body.

3. JUSTIFICATION OF THIS STUDY

Several studies have been carried out throughout the world using the concept of hydrodynamic analysis, water quality analysis, environmental flow assessment, flow augmentation and the combination of these concepts. Hydrodynamic analysis and water quality analysis have been done separately in Bangladesh for single or multiple rivers. The idea of hydrodynamic analysis and water quality analysis along with developing the flow scenario by doing the environmental flow assessment for Dhaka peripheral river network is novice. The flow scenario has been developed by determining the flow withdrawal at first and then the flow augmentation. As a result, this research focuses on water quality parameters such as pH, dissolved oxygen (DO), and biochemical oxygen demand (BOD) (BOD). BOD, DO, and TDS are the three most critical water quality parameters to consider when evaluating the coastal water's waste assimilation capability (Thomann and Mueller, 1987). The waste influx depletes DO, especially organic particulate matter in the process of organic degradation. BOD is used as a rough indicator of the effluent's oxygen-demanding capacity. Assimilative capacity varies in accordance with variations in hydrodynamic conditions and other ecological processes (Babu et al., 2006). So, these two parameters have been chosen due to their significant impacts on ecological balance. To perform this study, one-dimensional hydrodynamic model and water quality model have been developed using HEC-RAS (Hydrologic Engineering Center's River Analysis System). HEC-RAS is an integrated system of software, designed for interactive use for interactive use in a multi-tasking environment (Brunner, 2010).

Here mention some important point to justify this study.

- ✓ Industrial sector of Bangladesh is developing in last 40 years.
- ✓ The Sitalakhya River is a one of the important river in Bangladesh.
- ✓ Study area is surrounding of several textile, tannery, food, and fertilizer factory.
- ✓ River water is a vital water source in Bangladesh (Agriculture, house hold, industries).
- ✓ pH, DO and BOD is the important parameter of surface water body.
- ✓ Try to understand water quality trend during last 4 decades,

4. MATERIALS AND METHODS

The research was conducted with water quality of the Sitalakhya River, Ghorashal area (Fig. 1) The study area of the Sitalakhya River (Ghorashal Urea Fertilizer Aree) is located between 23° 59' 33" N to 23^0 45' 15" N latitudes and 90° 38' 11.76" E to 90° 37' 4.11" E longitudes. The study area is also connected with the river Brahmaputra, Lakhya, Balu, and Turag. Bangladesh.

In this review around 150 publication reviewed. All data is secondary data collected for several water related report, journal, and thesis.

Fig. 1. Location of study area
Source: (Majumder, 2005)

The Sitalakhya River herself and other connected rivers were likely to be important sites of chemical pollution. Based on this assessment, we review some research paper regarding water analysis of the Sitalakhya River in Ghorashal fertilizer area. In this study, data was collected through literature analysis and from many related organizations.

As a result, this research focuses on water quality parameters such as pH, dissolved oxygen (DO), and biochemical oxygen demand (BOD) are the three most critical water quality parameters to consider when evaluating the coastal water's waste assimilation capability (Thomann and Mueller, 1987). The waste influx depletes DO, especially organic particulate matter in the process of organic degradation. BOD is used as a rough indicator of the effluent's oxygen-demanding capacity. The interpreted data was then tabulated, with the most significant ones shown in graphs and figures.

5. CAUSES OF WATER POLLUTION

When appropriate regulatory measures are not implemented and stakeholders do not display sufficient concern, the major causes of inland water quality deterioration are related to land-based activities. Poverty, an unhealthy national economy, a lack of institutional strength, and a lack of knowledge and education are the fundamental driving forces. Pollutants enter the marine and coastal ecosystem through runoff from municipal, manufacturing, and agricultural wastes, as well as commercial seafaring activities.

6. INDUSTRIAL EFFLUENT

Industrial units are mainly found along the banks of rivers in Bangladesh. There are clear explanations for this, such as transportation of incoming raw materials and finished goods. Unfortunately, as a result of this, industrial units discharge effluents directly into rivers, with little regard for environmental degradation. Textiles, tanneries, pulp and paper mills, fertilizer, industrial chemical processing, and refineries are the most water-intensive industries. Both of these industries discharge a complex mixture of toxic chemicals, both organic and inorganic, into water bodies without treatment.

The North Central (NC) has the most industrial establishments in the world, and organic components degrade water quality by depleting dissolved oxygen during decomposition. Non-biodegradable organic components linger in the water system for a long time, eventually entering the food chain (Ahmed and Reazuddin, 2000). Metallic salts, as well as basic and acidic compounds, are the most common inorganic contaminants. In the river system, these inorganic components interact chemically and biochemically, causing water quality to deteriorate.

7. AGROCHEMICAL

Fertilizers and agrochemicals, such as herbicides and pesticides, are the most likely causes of agricultural runoff emissions. The main chemical fertilizers used in Bangladesh are urea, triple super phosphate (TSP), muriate of potash (MP), and gypsum. A total of around 2 million tons of fertilizers are used per year. In 1990, there was a 20% rise in fertilizer use due to the expansion of irrigated areas and the cultivation of HYV rice. However, the current rate of increase in usage has slowed and now ranges from minus 5% to 10%. Nitrogenous fertilizer accounted for about 88 percent of overall fertilizer use in 1995, which was about 67 percent in 1991. Domestic processing of urea, TSP, and gypsum currently accounts for around 90% of the demand (BBS, 1979, 1985, 1990, 1994, 1998).

In 1957, Bangladesh became the first country in the world to use pesticides. Although the patterns have been inconsistent, the area protected by plant protection measures has actually decreased since 1981. Insecticides are widely used for insect control, accounting for about 90% of all pesticides consumed (BBS, 1985, 1998). Fig. 3.1.1 in the Soil Degradation section depicts patterns in irrigated land and the use of chemical fertilizers and pesticides from 1991 to 1995.

8. OIL AND LUBE SPILLAGE

The country's two seaports, Chittagong and Mongla, handle 1500 to 1600 vessels and 12,000 to 13,000 cargoes annually on average (BBS, 1998). However, since these ports lack the necessary infrastructure to receive and treat bilge and ballast water, ships discharge wastewater into Bangladeshi territorial waters. Spills of oil and lube also occur during vessel refueling and cargo handling. In addition, the Bay of Bengal is home to a plethora of mechanized trawlers and vessels engaged in fishing. Since they are unaware of the negative impact on the environment, the owners of these vessels spill waste, including burned oil, into the sea.

As the seaports and the harbors of Bangladesh are located near shallow water, large oil tankers carrying crude and refined oil cannot enter them. Therefore, oil spills also take place in outer anchorage during the transfer of crude and refined oil from large oil tankers to small tankers. There have already been several environmental disasters due to heavy spillage from oil tankers in outer anchorage and along coastal areas. In late 1989, a Greek-owned Cypriot flagship charted to bring crude oil for the Bangladesh Petroleum Corporation caused about 3,000 tons of oil slicks along the Chittagong Cox's Bazar coast. The vessel developed a hole through which crude oil oozed out, but authorities only detected it as the vessel rose higher as it was unloaded at outer anchorage. A huge oil slick was also detected around the Khulna coast in 1992, which was dumped from a foreign ship. But the authorities concerned failed to identify the vessel responsible for this (Majumder, 1999).

Lube oil and heavy metals enter the coastal area water from the ship-breaking industries in Chittagong, and several accidents have occurred. However, there is no assessment available on the amount of lube oil discharged from ship-breaking industries. Concern over this pollution in the coastal area is emerging, and actions to prevent it are in the initial stage. Enforcement of ECA and ECR, with institutional strengthening, is essential to address this problem.

9. LOW FLOW IN DRY SEASON

A certain level of stream flow is required to maintain navigability, the wetland habitat and ecosystem, and equilibrium between freshwater and saline water mixing zones. Generally, reduction of water flow causes saline water intrusion into the river system. Saline water intrusion is aggravated in the coastal area of the country in dry season, when water flow from the river system becomes lean. Over the past two decades, the lowest water level data of the major rivers showed a declining tendency in the dry season (BBS, 1985, 1992, 1998). However, scientific research is required to establish whether decreasing water level has a direct linkage or not with salinity increase in the coastal area.

10. HISTORY OF INDUSTRIALIZATION IN BANGLADESH

In 1971s after the independence of Bangladesh, industrial development was so low; except Jute and Jute goods industries. After a few years of liberation, Ready Made Garments (RMG) sector start up. Day by day RMG sector grew up and in 2016, Bangladesh becomes the world's secondlargest apparel exporter of the western fast brand. In 1980s pharmaceuticals sector made expansion in Bangladesh. It is one of the most developed sectors which are contributing to Bangladesh economy. During this time, other sectors like tea manufacturing, leather factory, ship breaking, steel and cement etc, developed and gained momentum. From 2000 to 2012, many industries like electronics, glass, aluminum, plastic, cycle, and ceramic sector started their journey and contributed to the economy of Bangladesh. Most of the industrial development is carried out by the private sector. The contribution of the Industrial Sector to GDP is gradually increasing in Bangladesh. According to BBS, the role of the broad industry sector to GDP is 32.42 per cent in 2016-2017 financial year when 24 per cent was 2006-2007 and only 4 per cent in 1972.

Bangladesh has experienced significant industrial growth in the last 40-45 years, which has boosted the country's economy. As a result, Bangladesh's overall export in the 2016-2017 fiscal year was 34.8 billion dollars, compared to 14.11 billion dollars in the 2007-2008 fiscal year and 0.36 billion dollars in the 1972 fiscal year.

11. UNPLANNED INDUSTRIALIZATION EFFECT ON THE ENVIRONMENTAL SYSTEM

Industrialization is critical to a country's economic development. Simultaneously, many businesses contribute to environmental emissions and have a direct impact on the environment. Industries are to blame for pollution, which is caused by the discharge of contaminants and wastes created by industrial activities into natural environments such as water, air, and soil, resulting in environmental degradation. Industrial pollution has a variety of negative effects on the atmosphere, as well as serious implications for human health and life.

At the same period, industrial pollution can offensively kill animals, plants, degrade the quality of life and cause ecosystem imbalance. Leading industries such as textile mill, power stations, sewage treatment plants, steel mills, heating plants, glass smelting, and sugar mills among other processing, production and manufacturing companies are the main contributors to industrial pollution. These industries release effluents, smoke, material wastes, toxic byproducts, chemical consumer products that ultimately end up in the environmental system thereby producing pollution.

There are some major effects on the environmental system:

- Global Warming
- Water Pollution
- Air Pollution
- Soil Pollution
- Effect on human health
- Wildlife extinction
- Noise pollution

The severity of industrial pollution depends on the type of industries. Few industries are extremely harmful to our environmental system. Tannery industries effluent is responsible for high BOD and COD; contains highly suspended and dissolved solids, grease, oil and heavy metals like Chromium. Textile industries effluent is responsible for high BOD, dissolved and suspended solids, acids, phenolic substance, Chromium and choline dyes. The effluent of paint industries is contributing to high BOD, Solvents, and pigments, heavy metals like Pb, Cr, and Al. Effluents of beet sugar industries are responsible for high BOD. Industrial effluent water is partially responsible for decreasing dissolved oxygen in surface water.

12. THE INPUT OF UNPLANNED INDUSTRIALIZATION ON RIVER WATER QUALITY

Effluent water of various industries is responsible for water pollution. Water pollution is measured by analyzing the water samples. Chemical, physical, and biological test can show the present status of water quality. In this study, we have tried to analyze river water of the Sitalakhya River, Bangladesh by few measuring parameters likes Dissolved Oxygen (DO), Bio-Chemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD).

13. pH

The balance between hydrogen ions (H+) and hydroxide ions (OH-) in water is represented by pH, which describes the acidity or alkalinity of water. pH is measured on a scale of 0 to 14, with 0 being the lowest and 14 being the highest. Acidic solutions have a pH value less than 7 and contain more H+ than OH- ions. Basic, or alkaline, solutions have more OH- ions than H+ ions and have a pH greater than 7. When the pH of a solution is 7, it is said to be neutral, meaning it is neither acidic nor alkaline. The pH scale is logarithmic, which is crucial to note. Water with a pH of 5 has ten times the number of H+ ions and is ten times more acidic than water with a pH of 6. The recommended values found from different national and international sources that work on water quality are as follows:

Agriculture: The permissible limit of pH for irrigation 6.0 −8.4 (Ayers and Westcot, 1985), 6.5 −8.5 (FAO, 1992), 6.0–8.5 [16] or 6.0 – 9.0 [17].

Industrial Use: Low pH increases corrosion of concrete, pH 7.0 is required for most industries, pH 2.7- 7.2 advised for carbonated beverage industry (BIS, 1991).

Fisheries: Direct Impact for fisheries is below pH 6.5, species experience slow growth. When the value of pH is 4 or below and pH 11 or above, most species die. Low pH reduces the amount of dissolved inorganic phosphorous and carbon dioxide available for phytoplankton photosynthesis.

Drinking: Recommended standards for drinking water is 6.5 to 8.5 mg/l (BIS, India). The standard range of pH for drinking water is 6.5-8.5 (Beyond this range pH affects mucous membrane; bitter taste; corrosion and also affects aquatic life BIS, 1991). The other standards for pH are 6.5-8.5 (ICMR, 2012), <8 mg/l.

14. DISSOLVED OXYGEN (DO)

For most aquatic species, dissolved oxygen (DO) is the most essential gas; free oxygen, or DO, is needed for respiration. DO levels below 1 ppm are insufficient to sustain fish; most fish populations need levels of 5 to 6 ppm. The average DO level (6.5mg/l) indicates the river water's average consistency [18]. In our sample, DO levels ranged from 0.5 to 1.5 ppm in the dry season and 0.1 to 1.1 ppm in the wet season. In the dry season, the average value of DO is 1.01 ppm, and in the wet season, it is 0.45 ppm, while the normal value is about 6.5 ppm. As a result, the distinction between average and normal DO values is extremely skewed, indicating that river water is of poorer quality for fish and other aquatic life.

Agriculture: The permissible level of DO is 5 or more [17];

Industrial Use: Study reveals that clean water usually contains dissolved oxygen 4 to 6 mg/l which is suitable for most of the industrial uses to avoid metallic corrosion.

Fisheries: The permissible limit (mg/l) of DO for fisheries is 5-6 (www.fish-farming.net, 2015), 4> (FAO), 5-12 (articles.extension.org), 4-5 (www.thefishsite.com).

Drinking: 6 (GOB) [17], 5 (BIS), 5 (ICMR), 5 to 7 (Malaysia).

Oxygen is the most important gas for most aquatic organisms; free oxygen or DO is required for respiration. Oxygen softened in surface water due to the aerating act of winds. Oxygen is also present in the water as a consequence of aquatic plant photosynthesis. When dissolved oxygen turns into too low, fish and additional aquatic organisms cannot stay alive. The DO levels lower 1 ppm will not support fish, levels of 5-6 ppm are usually essential for most of the fish population. The regular value of DO levels (6.5 mg/l) shows the average quality of river water [19]. DO values in our study varied between 6 ppm in 1975 and 2.0 ppm in 2017 (Fig. 1, [20]. The lower value of DO is 2.0 ppm in 2017 whereas the standard value is around 6.5 ppm. So the comparison between existence value and the standard value of DO has greatly deviated (Fig. 2) so that it represents the poor quality of river water for fish life and other aquatic life cycles [21,22].

Table 1. Standards for pH as per different sources

Parameter	Organization	Standards
pH	Bureau of Indian Standard (BIS)	6.5 to 8.5
	Indian Council for Medical Research (ICMR)	6.5 to 8.5
	World Health Organization (WHO)	<8
	Malaysia	6.5 to 9
	Food and Agriculture Organization (FAO)	6.5 −8.5
	Asian Development Bank (ADB)	6.0–8.5
	(Ayers and Westcot, 1985)	6.0 −8.4

Recommended Standard: Recommended pHstandards for drinking, fisheries, irrigation or industrial cooling water is 6.5 to 8.5 mg/l.

Table 2. Standards for Dissolved Oxygen (DO) as per different sources

Parameter	Organization	Standards
Dissolved Oxygen	Environmental Conservation Rules, 1997	5 or more
	www.fish-farming.net, 2015	5-6
	www.thefishsite.com	4-5
	Bureau of Indian Standard, 1997	5
	Indian Council of Medical Research	5
	Malaysia 5-7	
Recommended Standard: Recommended Dissolved Oxygen (mg/l) for drinking 5-6, fisheries 4-6, and agriculture.		

15. BIOCHEMICAL OXYGEN DEMAND (BOD)

Biochemical Oxygen Demand (BOD) is a significant water quality parameter because it delivers an index to evaluate the effect of discharged wastewater on the receiving environment. The upper BOD value, indicates the greater amount of organic matter or food existing for oxygen-consuming bacteria. If the amount of DO consumption by bacteria exceeds the source of DO from aquatic plant photosynthesis or spreading from air, creates an unfavorable condition. Unpolluted, river waters will have a BOD of 5 mg/l whereas less BOD directly marks the amount of dissolved oxygen in rivers. Microbial growth will be boosted if the source water contains a lot of BOD, particularly at high temperatures. Oxygen would be absorbed as a result of this microbial growth and the resulting degradation of organic matter. This can result in a lack of oxygen in the river, which can have serious consequences for fish, including death. The amount of dissolved oxygen in rivers and streams is directly affected by BOD. The higher the BOD, the faster the oxygen in the stream is drained. Usually, unpolluted natural water has BOD of 5 mg/l or less. Higher forms of aquatic life will have less oxygen available as a result. Aquatic species become stressed, suffocate, and die as a result of high BOD. Leaves and woody debris, as well as dead plants and livestock, animal wastes, effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants, failed septic systems, and urban storm water runoff, are all sources of BOD. The more the BOD, the more rapidly oxygen is depleted in the river. This means a smaller amount of oxygen is available to higher forms of the aquatic lifecycle. The significance of the high BOD are the same as those for less dissolved oxygen; aquatic organisms become strained, quash, and die. Sources of BOD contain leaves and woody fragments; dead animals and plants; animal manure; effluents from paper mills and pulp, wastewater treatment plants, feedlots, food-processing plants, failing septic systems, and urban storm water overspill.

The recommended threshold values of BOD are 10 mgl−1 [23], 5 mgl-1 (ICMR) and 10 mgl−1 (ECR, 1997). The permissible value of BOD is suggested as 5-10 mgl−1 for fisheries and aquatic life.

16. INDUSTRIALIZATION IN STUDY AREA

In Bangladesh various industries developed during last 4 decade. Most of the industries are textile, food, tannery, paper, chemical, fertilizer etc. Due to communication facility and manpower availability, many of industries are located nearby Dhaka, which is the capital of Bangladesh. As the study area is 40 km distance from Dhaka city, there are many industries are growing up surrounding this location. Transportation system is very comfortable due to the Sitalakhya River and also road transportation is also upright. In our study, we find in the year 1991, there are cement industries, jute industries, power station, chemical industries, fertilizer industries.

Table 4 shows there are various industries developed in the bank of Sitalakhya river. DoE report shows, in 1991 there are fertilizer industries, cement industries, textile industries and power station is developed.

In Fig. 2, we can see in 1983 Bangladesh readymade garment export was very low. After 35 years, in 2017 garments exports is more than 30 billion dollars. So, we can see the change in our textile sector in between 1983 and 2017.

In Table 5, we can see several industries and related waste water characteristics. Here, it is showed that most of the industries are creating waste water which is polluting our environment.

Table 3. Standards for pH as per different sources

Parameter	Using Purpose	Standards
Biochemical Oxygen Demand	Drinking Water	2 or less
	Fisheries	6 of less
	Irrigation	10 of less
	Process Industries	10 of less
Recommended Standard: Recommended Biological Oxygen Demand (BOD) (mg/l) for drinking 2, fisheries 6, and agriculture 10		

Source: The Environmental Conservation Rules 1997, DoE

Table 4. List of industries around of the Shitalakshya River (DoE, 1991)

No.	Types of Industries	Quantity
01	Fertilizer Industries	2
02	Cement Industries	2
03	Oil Industries	4
04	Dock Industries	3
05	Jute Industries	12
06	Textile Industries	2
07	Tannery Industries	3
08	Iron Industries	2
09	Power Station	2
10	Chemical Industries	1

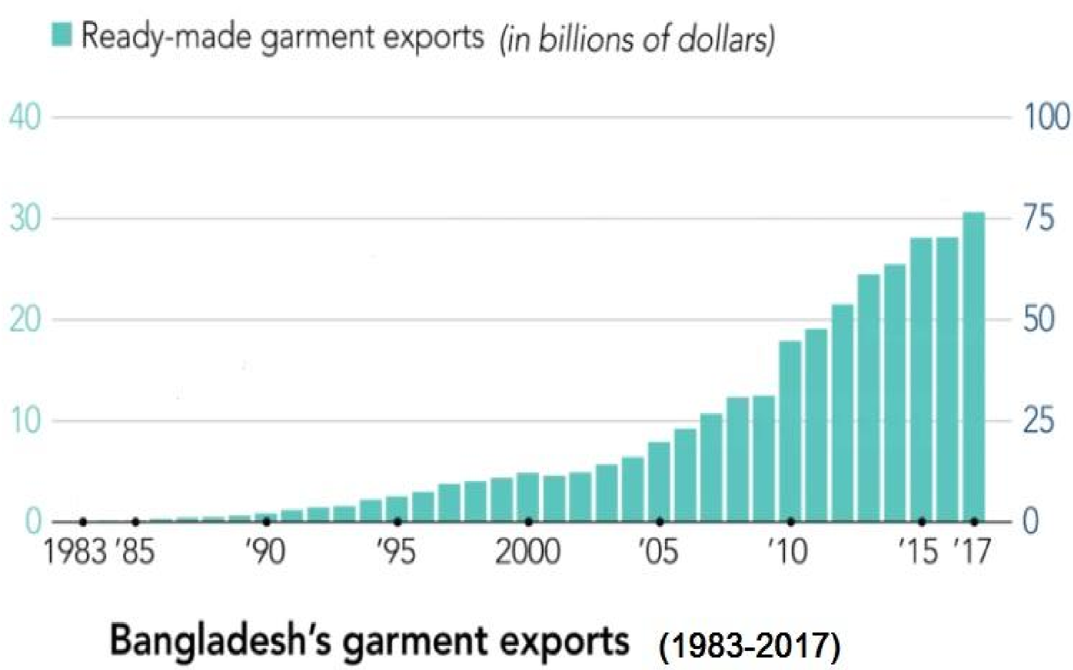

Fig. 2. Changes in Bangladesh garments export

Table 5. Important characteristics of waste water from major industries

Industries	Important characteristics
Acid manufacture	Low pH
Beet sugar	High BOD
Coal washery and $FeSO_4$ present	Low pH, high suspended solids, H_2SO_4
Coke manufacture phenol and oils	High suspended solids, NH_3, H_2S
Distillery	High BOD, with brown color and disagreeable odour, high dissolved and suspended solids.
Electroplating	Low pH, high COD; also contains heavy metals and toxic substances.
Paint manufacture	High BOD; contains synthetic resins, solvents, pigments and heavy metals such as Al, Cr and Pb.
Petroleum refining	High COD/BOD ratio; also contains hydrocarbons, alcohols, aldehydes, phenols, oils, metals etc.
Plastic manufacture	Acids, formaldehyde and phenols.
Pulp and paper industry	Intense brown colored with characteristic odor, board industry alkaline; highly dissolved and suspended solids.
Steel industry	Low pH, phenols suspended solids and metals present.
Tannery	High BOD and COD; contains highly dissolved and suspended solids, oil and grease and heavy metals like Cr.
Textile processing	High BOD; suspended and dissolved solids, phenolic substances, acids, chlorine dues and Cr present.

Source: Kumar & Kakrani [24]

Table 6. Category of pollutant sources and pollutants of Shitalakhya River

Categories of Pollutant Sources	Pollutants	Pollution source*
Urea Fertilizer Plant	NO_3^-, NH^{4+}	PS
Lime stone & stone grinding Plant & Cement industry	Fe, Ca^{+2}, HCO_3^-	NPS & PS
Agricultural Land	B, Na^+, PO_4^{+2}, SO_4^{-2}, NO_3^-+, NH_4^+, Fe	NPS
Oil Industry & Refinery	Pb, Cd, Cl^-, Fe	PS
Sewerage & Public Toilet	Pathogens & Other microbes	NPS & PS
Metal & Waste dumping place	Fe, Zn, Pb, Mn, Al^{+3}, Mg^{+2}	NPS & PS
Boat & Ship dock yard	Cl^-, Fe, Mn, Pb, Zn, Ca^{+2}	PS
Soap factory	Ca^{+2}, HCO_3^-, Pb	PS
Dye factory, Textile & Tannery	Ca^{+2}, Pb, Cr, Co, Zn, Cl^-	NPS & PS
Rice processing industry	Na^+, PO_4^{+2}, SO_4^{-2}, NO_3^-, NH_4^+, Fe	NPS
Power plant & station	Pb, Cr, Zn, Fe	PS
Jute mill & Store house	Na^+, PO_4^{+2}, SO_4^{-2}, NO_3^-, NH_4^+	NPS & PS
Electroplating Industry	Fe, Zn, Cd, Al^{+3}	PS
Market place (Meat & Vegetable)	Pathogens & Other microbes	NPS
High way & Rail station	Pb, Fe, Cr, Zn, Al^{+3}	NPS & PS

**NPS- Non Polluted Source, PS – Polluted Source*

Source: Alam (2006)

Table 7. Comparison of investigated data with standard values for fisheries

Parameters	Bangladesh Standard for Fisheries (EQS,1997)	Investigated Water Quality (average value in 2017)
pH	6.5-8.5	6.6
DO (mg/l)	4.0-6.0	2
BOD (mg/l)	(-) or below 2	15.6
TDS (mg/l)	500	238
EC (µs/cm)	800-1000	1685
Temperature (°C)	25	27.04
Transparency (cm)	40	24.6

In Table 6, we see categorized for pollutants and non-pollution source.

In Table 7, we can see standard value of pH, DO, BOD, TDS, Temperature, and Transparency for fisheries.

17. WATER QUALITY DATA ANALYSIS FOR 40 YEARS

Water is necessary for the survival of all living species, but it is becoming increasingly endangered as human populations expand and demand more high-quality water for domestic and economic purposes. In the natural world, water contains a variety of dissolved and non-dissolved particulate matter. Dissolved salts and minerals are essential components of good water because they support the health and vitality of the species that depend on this ecosystem service (Stark, 2000). Pesticides, organic pollutants, and nuclear contaminants can all be found in water, as can metals like mercury and cadmium, as well as pesticides, organic toxins, and radioactive contaminants. Living organisms are essential components of biogeochemical processes in marine environments, and water from natural sources almost always includes them [25-28]. Some of these, especially bacteria and viruses, can, however, be harmful to humans if present in drinking water. Water quality varies over time and space, necessitating regular monitoring to identify spatial patterns and changes. Once a monitoring station has been established, water quantity monitoring can be done to some extent with minimal human involvement. Water quality is normally calculated by analyzing samples of water obtained at regular intervals from selected monitoring stations. Since 1973, the Department of the Environment has been monitoring surface and ground water quality, and it is currently monitoring the water quality of 27 rivers across the country on a monthly basis. The majority of monitoring stations, on the other hand, were chosen long ago from which the emission scenario was modified. As a result, 59 strategic locations were chosen for this study based on existing stations along 13 of the country's most significant rivers. Pollution hotspots have been found in some of the strategic locations.

18. RESULTS

Here we try to analysis of the Sitalakhya River in respect of pH, BOD, DO.

19. pH

It has been observed that pH level of the river throughout the study period was within the standard limit for surface water (6.5-8.5 mg/l). Maximum pH was 7.6 in wet season, 2016and minimum pH was 6.5 in wet season, 2017 as shown in Table 7, Figs. 2 and 3. The pH was found to vary from 6.6to 7.6 during the period of 1975-2018 at Ghorashal fertilizer point.

20. DISSOLVED OXYGEN

Oxygen is the most important gas for most aquatic organisms; free oxygen or DO is required for respiration. Oxygen softened in surface water due to the aerating act of winds. Oxygen is also present in the water as a consequence of aquatic plant photosynthesis. When dissolved oxygen turns into too low, fish and additional aquatic organisms cannot stay alive. DO values in our study varied between 7.1 mg/l in 1975 and 0.66 mg/l in 2017 (Table 8, Fig. 4, and Fig. 5). The lower value of DO is 0.66 ppm in dry season, 2017 whereas the standard value is around 6.5 ppm. So the comparison between existence value and the standard value of DO has greatly deviated (Fig. 2) so that it represents the poor quality of river water for fish life and other aquatic life cycles [21,22].

Table 8. pH Value of Sitalakhya River During 1975 to 2018

Year	Dry Season	Wet Season
1975	6.9	7.35
1976	7.36	7.2
1977	7.1	6.93
1978	7.36	7.05
1979	7.02	6.83
2010	7.22	7.05
2011	7.14	7.22
2012	7.22	7.37
2013	7.7	7.11
2014	7.19	7.43
2016	7.5	7.6
2017	7.2	6.5
2018	7.1	6.7

Source: DoE, Yearly Report

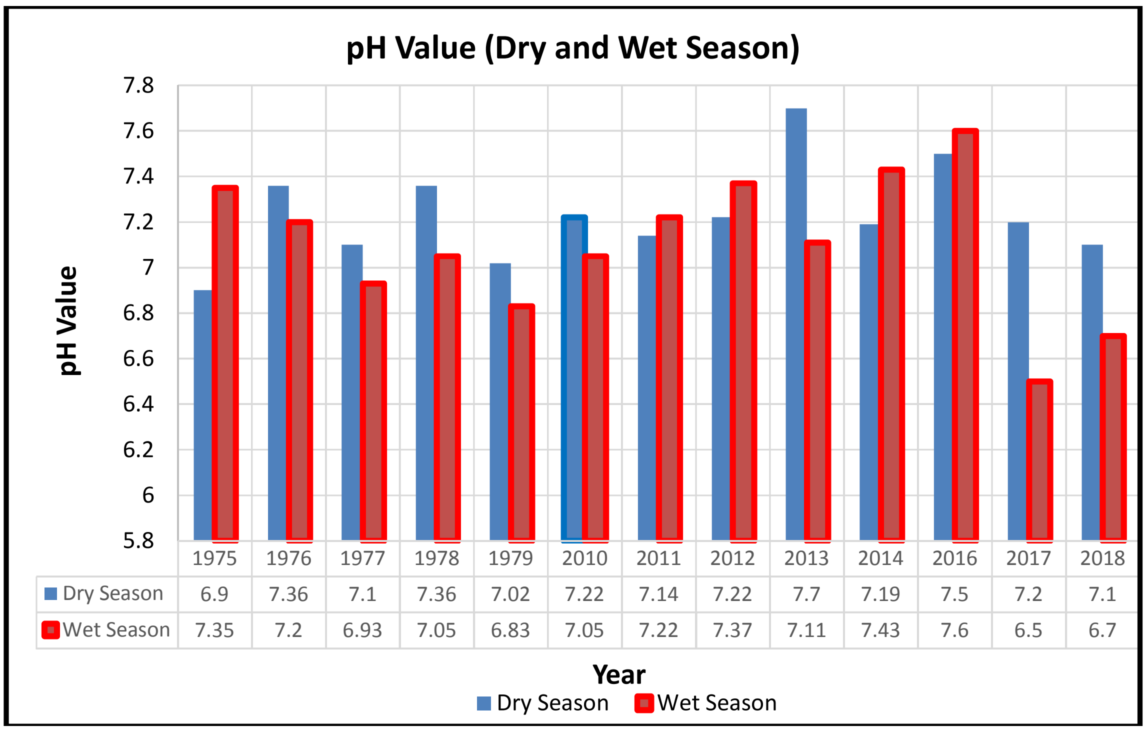

Fig. 3. pH Value of the Sitalakhya River during 1975-2018

21. BOD

Biochemical Oxygen Demand (BOD) is a significant water quality parameter because it delivers an index to evaluate the effect of discharged wastewater on the receiving environment. The upper BOD value, indicates the greater amount of organic matter or food existing for oxygen-consuming bacteria. If the amount of DO consumption by bacteria exceeds the source of DO from aquatic plant photosynthesis or spreading from air, creates an unfavorable condition. Unpolluted, river waters will have a BOD of 5 mg/l whereas less BOD directly marks the amount of dissolved oxygen in rivers. The more the BOD, the more rapidly oxygen is depleted in the river. This means a smaller amount of oxygen is available to higher forms of the aquatic lifecycle [29-31]. The significance of the high BOD are the same as those for less dissolved oxygen; aquatic organisms become strained, quash, and die.

Sources of BOD contain leaves and woody fragments; dead animals and plants; animal manure; effluents from paper mills and pulp, wastewater treatment plants, feedlots, food-processing plants, failing septic systems, and urban storm water overspill. In the present study, BOD values were 1.35 mg/l in 1973 and 35 in dry season 2016 (Table 9, Fig. 6 and Fig 7). In Comparison between 1975 and 2018 the BOD presented higher deviation, it mentions to the lower quality of the river water i.e. the greater rate of pollution of water, it mentions that the higher the deviancy the lower the quality of water for fish and another aquatic lifecycle. GOB [17] and ADB [16] proposed a BOD of 10 mg L^{-1} in irrigation water quality standards for Bangladesh. According to the Bangladesh Standard for Fisheries [32] minimum BOD level is 2 ppm.

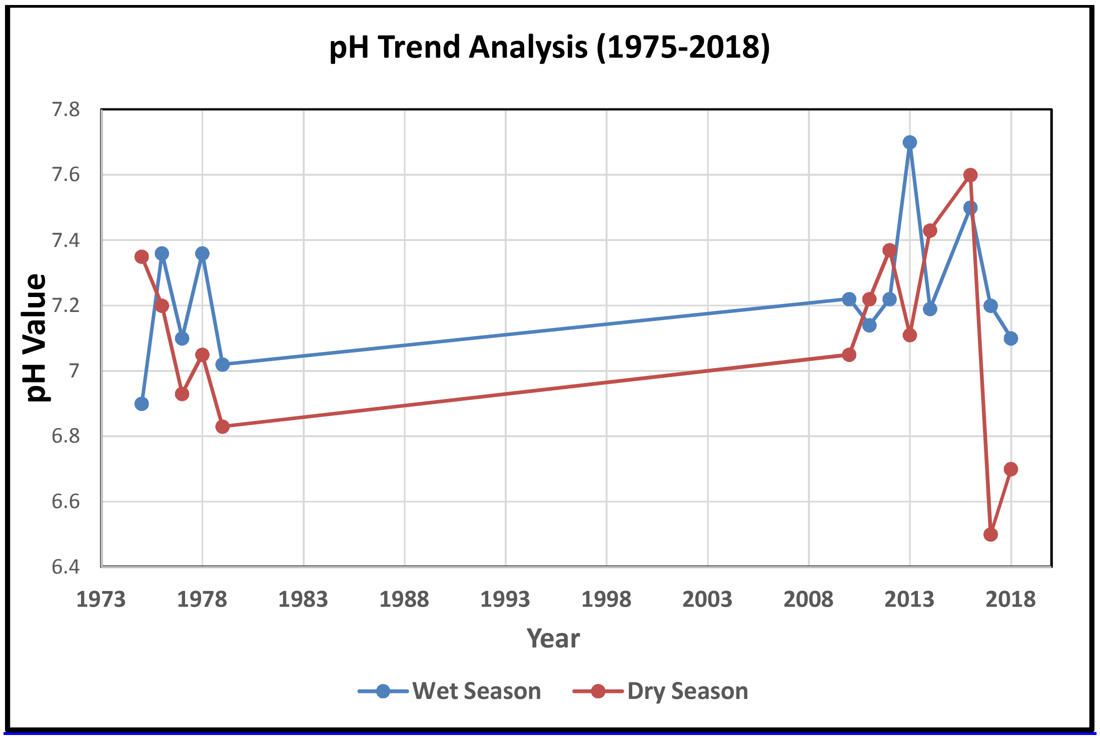

Fig. 4. pH trend analysis of the Sitalakhya River in 40 years

Table 9. Dissolved Oxygen on the Sitalakhya River During 1975 to 2016

Year	Dry Season	Wet Season
1975	7.1	6
1976	5.5	6.5
1977	3.8	5.2
1978	5.16	3.8
1979	6.1	3.5
2010	3.77	5.53
2011	3.8	5.63
2012	2.18	3.56
2013	2.69	4.1
2014	0.66	3.86
2016	2.5	6.3

Source: DoE, Yearly Report

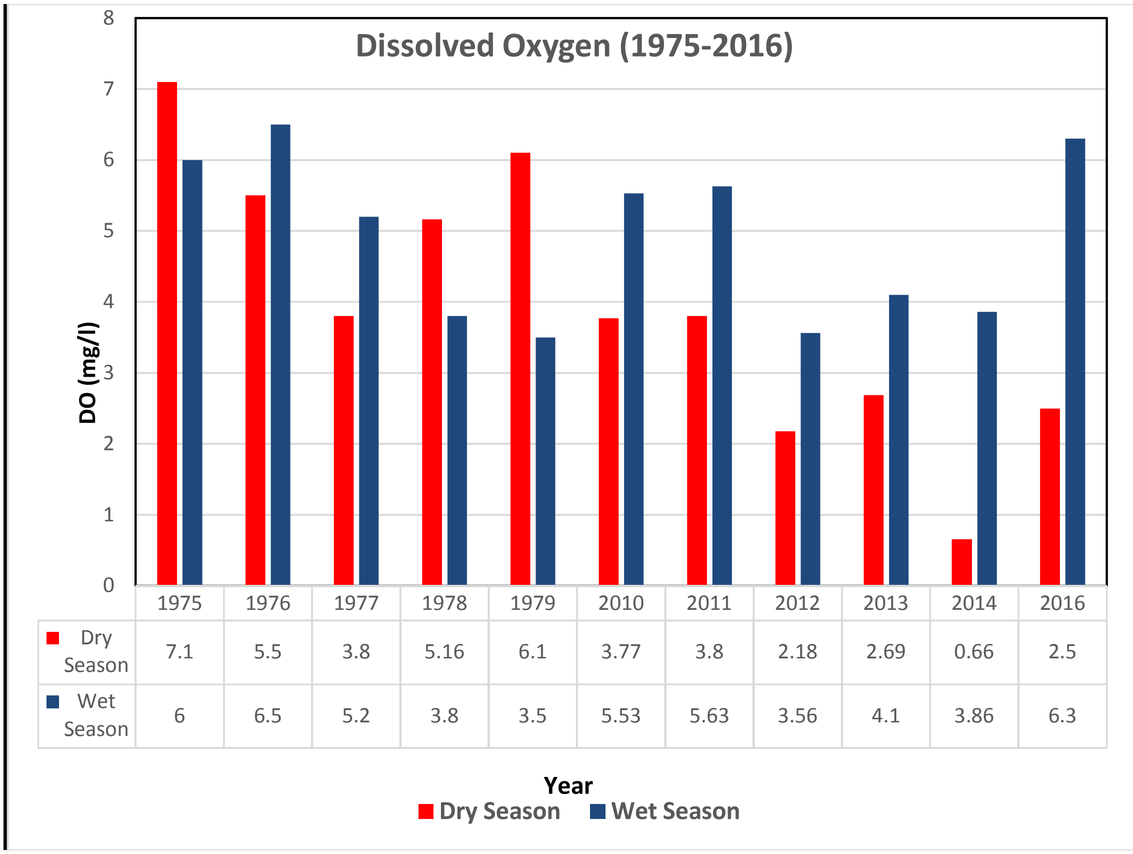

Fig. 5. Dissolved Oxygen (DO) Level in the Sitalakkhya River during 1975-2016

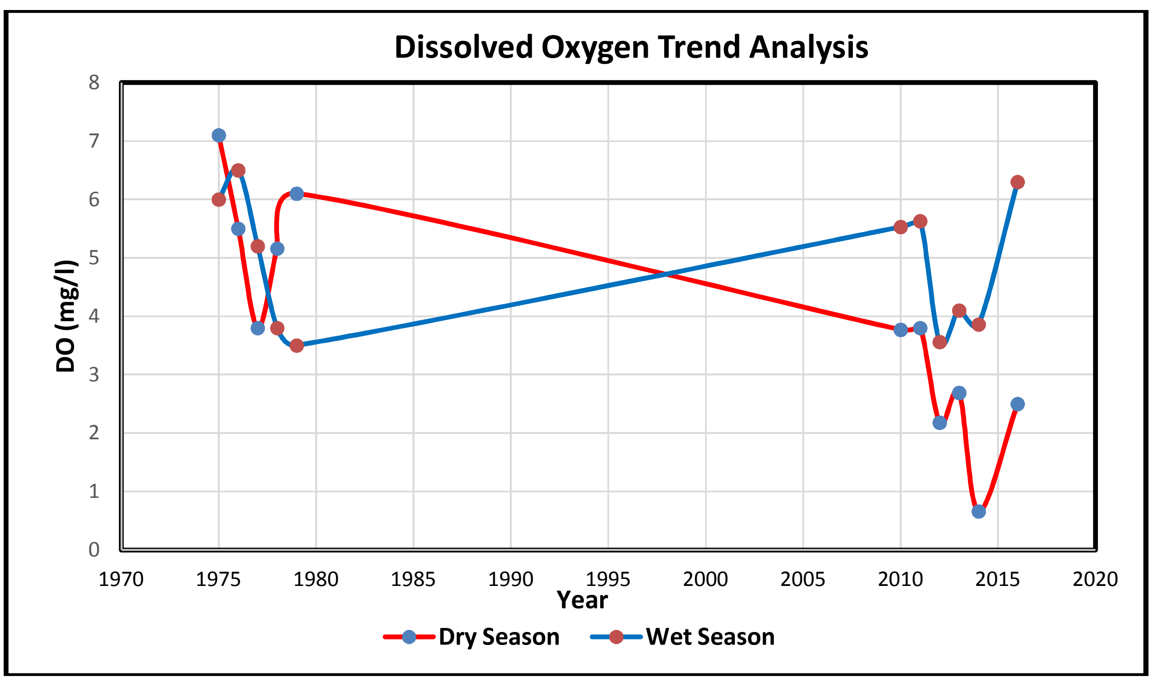

Fig. 6. Dissolved Oxygen (DO) Trend in the Sitalakhya River During 1975-2016

Table 10. BOD Level in the Sitalakhya River During 1975 to 2018

Year	Dry	Wet
1975	1.85	1.72
1976	2.23	2.2
1977	2.3	1.9
1978	2.8	1.35
1979	3.8	2.6
2010	9.58	4.67
2011	10.62	3.98
2012	11.17	5.21
2013	22.83	5.75
2014	16.8	6.64
2016	35	5
2017	7	12
2018	8	16

Source: DoE, Yearly Report, 2013-2018

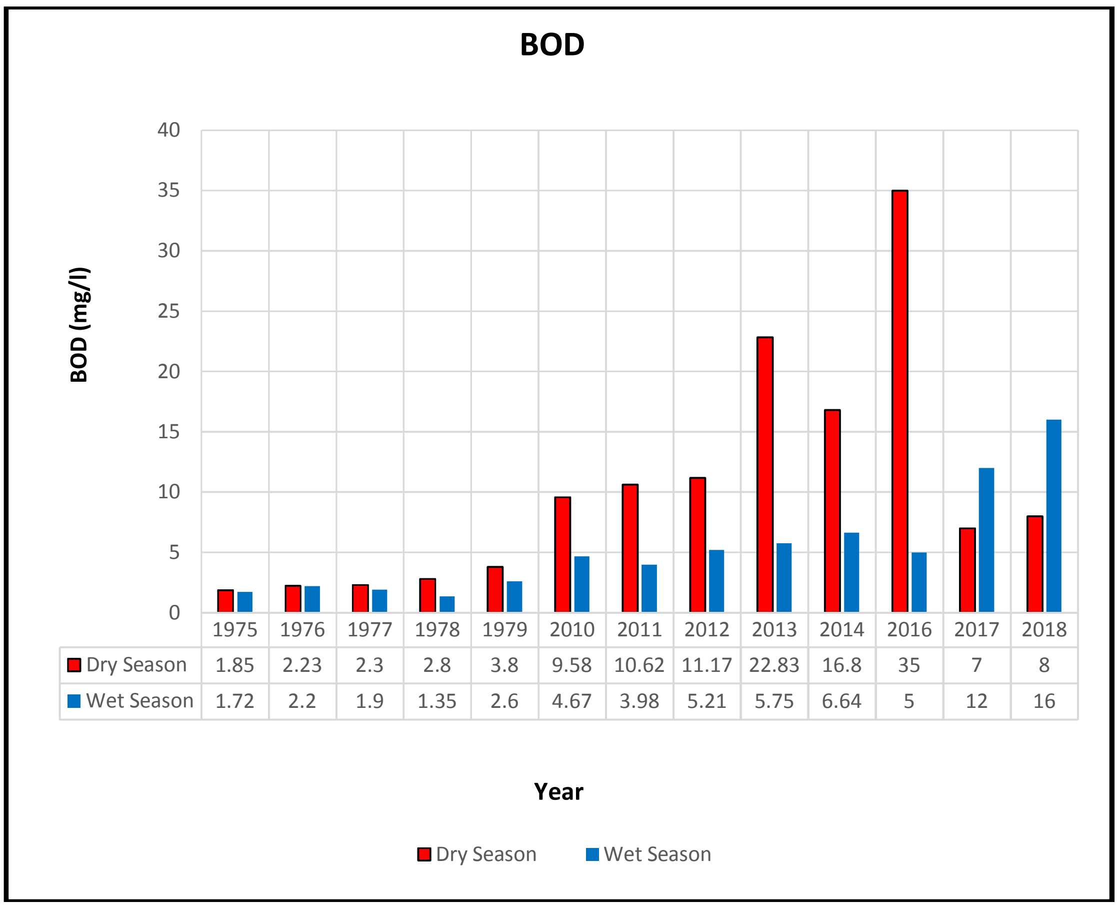

Fig. 7. BOD level of the Sitalakhya River in During 1975-2018

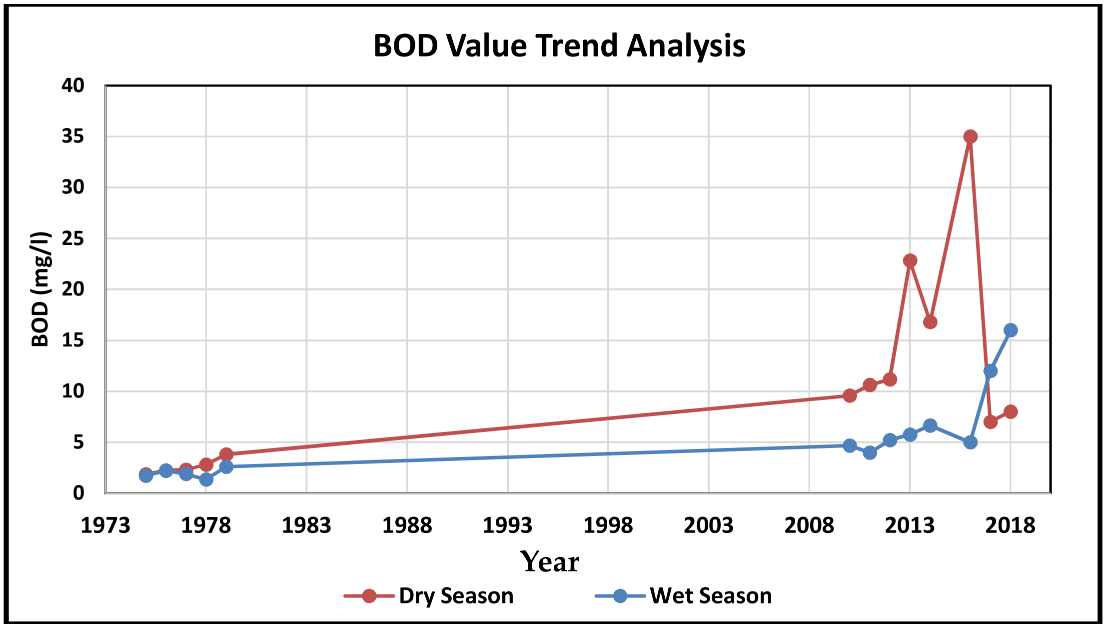

Fig. 8. BOD Trend of the Sitalakhya River During 1975-2018

22. DISCUSSION

Between all the tested physical parameters; DO, COD and BOD exceed standard level. During 1975 DO and BOD value was within the limit of DoE, but within 43 years during 2018, DO level goes to harmful condition. The overall test results reveal that the water of the Sitalakhya River is not suitable for flora and fauna. Government need to take proper initiative to control the effluent discharge to the river Sitalakhya. In this time of industrial development in Bangladesh, the government should take strict measures to maintain the suitability of water in the Sitalakhya River for fish and aquatic life.
In this review I find the following observation.

- ✓ In between 1975-2018, during 4 decades the Sitalakhya river water quality degraded.
- ✓ DO and BOD value is out of DoE limit.
- ✓ Unplanned Industrialization is the cause of water pollution.
- ✓ We have to stop water pollution by various industries and use proper waste treatment.

22. CONCLUSION AND RECOMMENDATIONS

Extensive disposal of industrial wastes is polluting the water of the Sitalakhya River. With the pollution of water bodies by organic wastes and chemical, the oxygen concentration in this water body comes to be very low at particular locations of the river. The water pollution leads to either death or migration of fishes to some safer areas. As a consequence, the fish population in this river has significantly decreased in recent times. The pollution problem cannot be solved in a short period, it needs constant efforts of government and industries.

According to this study I have following recommendation.

- ✓ Make sure all industries must use effluent treatment plant.
- ✓ No sewage water can dispose in river water.
- ✓ Regular monitoring of river water quality.

DECLARATION

This paper, or any part of it, has not been sent to any other institution for the award of any other degree, publication, or conference.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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