The Environment

THE ENVIRONMENT
Volume 1Issue 1 (2017) 13-25

Research Article

Impact Assessment of Temperature and Discharge Waste Materials on the Major Rivers of India: An overview

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ABSTRACT

A number of factories and tanneries are situated along the rivers which drains their effluents directly into them. The amount of wastewater and its temperature may influence the biochemical oxygen demand (BOD) of the river. During monsoon, drains flush out waste material in the river which decreases the water quality. It is observed that BOD of the river water is found to be positively correlated with the rainfall, the catchment size and the temperature of the surrounding area. Analysis of the water quality of the rivers has been carried out by experimental water quality data of five major rivers for the years 2002–2007. The study is an attempt to describe the variation in water quality of different Indian rivers that may be useful for better planning, monitoring and river basin management. At the same time, study illustrates the impact of pollutants on the river indicating health condition of the river through illustrating the relationship among temperature, BOD and others factors.

Keywords: Biochemical oxygen demand (BOD), Rainfall, Temperature, Wastewater, River

1. Introduction:

Rivers have been utilized by the mankind for thousands of years to the extent that only a few of them are now in their natural condition (Ngoye and Machiwa, 2004). Aquatic systems worldwide are majorly polluted due to untreated sewage and industrial effluents being disposed directly into the rivers. This study was undertaken to investigate the relationship between rainfall, temperature and biochemical oxygen demand (BOD) in major rivers of India. The BOD refers to the demand of oxygen by microorganism for oxidizing the organic compound in the water. The wastes usually contain a wide range of organic and inorganic pollutants including solvents, oils, grease, plastics, plasticizers, phenols, heavy metals, pesticides and suspended solids.

Pollutants entering in a river system normally result from many transport pathways including storm water runoff, discharge from ditches and creeks, vadose zone leaching, groundwater seepage and atmospheric deposition. These pathways are also seasondependent. Therefore, seasonal changes in surface water quality must be considered when establishing a water quality management program (Ouyang *et al*., 2006). The water quality has become a global concern (Mahananda *et al*., 2010) today. Because of the anthropogenic activities fresh water resources are deteriorating day-by-day at a very faster rate. A healthy aquatic ecosystem depends on the biological diversity and supportive physico-chemical characteristics of the ecosystem (Venkatesharaju *et al*., 2010).

Aquatic ecosystems are affected by several health stressors that significantly deplete biodiversity. In time to come, the loss of biodiversity and its effects are predicted to be greater for aquatic ecosystems than for terrestrial ecosystems (Sala *et al*., 2000). Serious ecological and sanitary problems are associated with pollutants discharged in river inflows (Vega et al., 1998; Singh *et al*., 2004 and Wang *et al*. 2007). Biological processes in surface waters appreciably depend on temperature of water (Pavla Pekarova *et al*., 2010).

The water pollution has significant effect on human health, balance of aquatic ecosystems, socio-economic development and prosperity (Milovanovic, 2007). High toxicity problems and eutrophication are associated with point and non-point sources of pollution (Sharma, 1996 and Jain, 2002). The water quality, which is influenced by various natural processes and anthropogenic activities is now a worldwide environmental issue (Ouyang, 2005;Shrestha and Kazama, 2007). The suspended and precipitated (non-floating) substances and organic substances in the water are capable of adhering to the pollutant particles (adsorption). The sediments, both suspended and precipitated stored on the water bottom, form a reservoir for many pollutants and trace substances of low solubility and low degree of degradability (Biney *et al*., 1994).

Increased temperature decreases the solubility of gases in water, such as O_2, CO_2, N_2, CH_4 and others (Chapman, D. *et al*., 1996). The dissolved oxygen (DO) of water decreases with increasing temperature. The temperatures of air and water have shown an increasing trend in the last few years (Pavla Pekarova *et al*., 2010). Due to climate change (temperature), hydrological and thermal regimes of rivers are expected to change which will have direct consequences on freshwater ecosystems, water quality and its use for humans. Many previous macro-scale hydrological modeling studies have been carried out to assess the impact of climate change (T) on water availability at continental (Arnell, 1999a; Lehner *et al*., 2006) and global scales (Arnell, 1999b; Do¨ ll and Zhang, 2010; Sperna Weiland *et al*., 2012; Vo¨ ro¨smarty et al., 2000). It has been observed that both river discharge and river catchment's temperature directly affect the water quality (Ducharne, 2008; Haag and West rich, 2002; Ozaki *et al*., 2003).

Human and ecological use of in-stream water requires to be considered in terms of the quantity and the quality of water (Chang, 2008). Without adequate quantity and quality of fresh water, sustainable development will not be possible (Kumar, 1997). The water quality gives important clue about the health of a watershed and necessary inputs for making decisions to control the current and future pollution of the receiving water bodies

(Khadam and Kaluarachchi, 2006). The information on water quality and pollution sources is important for implementation of sustainable water-use management strategies (Sarkar *et al*., 2007; Zhou *et al*., 2007 and Bu *et al*., 2009).

Anand–Vadodara belt, in western India is presently undergoing rapid industrial development and there have been reports of toxic pollution from industry into the river. Hence, characterization of the seasonal changes in the surface water quality is an important aspect for evaluating the temporal variations of river pollution due to natural or anthropogenic inputs of point and non-point sources. It includes urban, agricultural, industrial, and domestic wastewater, as well as sewage of metropolitan centers, small electroplating workshops, hospitals and scientific laboratories. The water quality measurements are important for minimizing industrial, mining or navigational accidents that cause short-term pollutant releases into or along the river. The monitoring will be beneficial to warn downstream users and to mitigate secondary damages (Srivastava *et al*., 2011).

The river plays a major role in absorption or carrying off municipal and industrial wastewater. The municipal and industrial wastewater discharge are regular polluting sources, whereas, the surface run-off is a cyclic phenomenon. Seasonal variations in rainfall, industrial and municipal wastewater, surface run-off have strong effects on river discharge and subsequently on the concentration of pollutants in the river water (Vega *et al*., 1998). Most of the Indian rivers are grossly polluted due to discharge of untreated sewage disposal and industrial effluents directly or indirectly into the rivers. These wastes usually contain a wide variety of organic and inorganic pollutants including solvents, oils, grease, plastics, plasticizers, phenols, heavy metals, pesticides and suspended solids. The organic matters may be present in the water in suspension or colloidal form (Chabbi, Rurpel 2000) and its determination method depends on their nature. The particulate organic load may comprise of a wide variety of life forms such as viruses, bacteria, amoebae, algae, spores and micro-plankton of vegetable and animal origin. The worst examples are the contamination of water with non-biodegradable products. The presence of lubricating oils, organic solvents, detergents, fertilizers and pesticides coming from industry and households may render the watercourse inappropriate for exploitation in irrigation as well as for drinking purpose as they have sanitary risks and known to have adsorption properties for other toxic substances as presented by Dontsova *et al*., 2009.

This level of pollution transforms the river water from oligosaprobic (low pollution) to polysaprobic (very high pollution). As for example, the River Ganges alone receives sewage of 29 class - I cities situated on its banks and the industrial effluents of about 300 small, medium, and big industrial units throughout its course of approximately 2525 kms. Likewise, Yamuna is another major river, threatened with the pollution in Delhi and Ghaziabad. Approximately 5,15,000 kiloliters of sewage wastewater is discharged in the river Yamuna daily. In addition, there are about 1,500 medium and small industrial units which also contribute huge amounts of untreated or partially treated effluent to the river Yamuna every day.

Similarly many other rivers were surveyed during past two decades to assess their pollution status. In addition to domestic and industrial discharge into the rivers, there are surface run off of agricultural areas, mines and even from cremation ground on the river banks. According to a report, over 32 thousand dead bodies were cremated at the major burning Ghats in the religious city Varanasi alone in the year 1984. The rivers constitute the main national water resources for domestic, industrial and irrigation purpose. For observation of the temporal variations in the BOD of rivers, regular monitoring programs are required for reliable estimates of the water quality. Murty and Prasad (1999) have used cross-section data for a sample of 100 factories belonging to 11 highly water polluting industries in 13 states, collected in a survey done in 1994/1995.

Most of the industries have inadequate effluent treatment facilities and dump their wastes directly into the river. The Indian government under the Ganga Action Plan (GAP) has implemented several schemes for the abatement of pollution of the Ganga by tanneries. However, there are violations of the pollution control measures, and the tannery effluents are still found in the River (Ganga basin Authority). According to National Green Tribunal (NGT), 402 tanneries were situated along Ganga River in Kanpur district. The State government may require to focus on installing wastewater treatment plant in Kanpur district for treating wastewater of tanneries.

Bertrand-Krajewski *et al.* (1995), presented flow and pollutant data for a combined sewer system with a catchment area of 61 hectares (ha) that discharges to an active sludge plant. During one storm, the flow to the treatment plant was approximately 3.08 times the dry weather flow (DWF). Influent mass loads to the waste water treatment Plant (WWTP) were 10, 7, and 1.2 times greater than the dry weather loads (DWL) for TSS, BOD, and NH_3 respectively. The effluent TSS mass load discharged to the river was 7 times greater than that discharged during DWF conditions. The authors indicated that the volatile suspended solids (VSS) concentration in the aeration basin was reduced causing the treatment efficiency to be affected for several days following a storm event.

Based on ten storm events to a small WWTP (Rouleau *et al.*, 1997), it was concluded that storm events contribute a significant increase in flow (up to 55%) and particulate matter consisting of TSS and chemical oxygen demand (COD), along with a delusional effect on dissolved pollutants such as ammonia. Effluent quality deteriorated during increased flows due to a rising sludge blanket in the secondary clarifiers resulting in suspended solids carryover.

A 3-year study by Giokas *et al.* (2002) investigated the effect of influent waste water flow variation on treatment plant performance. The authors' conclusion was that treatment plant performance decreased during increased inflows associated with rainfall. The decreased performance at high flows was primarily attributed to the decreased detention times in the treatment processes.

The conventional monitoring methods of sampling, laboratory testing and analysis of river water are very costly and time consuming. Therefore, it is very difficult to monitor the quality of river water over a long stretch at frequent intervals. This calls for a repetitive monitoring scheme so that the authorities may be in a position to implement remedial and control measures. The remote sensing techniques have the potential to repetitively monitor the river health. Several researchers (Moore, 1978; Lillesand and Kiefer, 1979; McKim et al., 1984; Khorram and Cheshire, 1985) have used satellite image interpretations for river and water bodies.

2. Data and Methodology:

2.1 River system of India: Table 1 illustrates the major rivers and there characteristics as follows:

Table 1: The major rivers of India (Source: Sharma & Paithankar, 2014, *modified by author)*

Name	Length (km)	Area (Sq. Km.)	Originates From	Ends in	Places Benefited
Ganga (Bhagirathi)	2480	8,61,452	Gangothri	Bay of Bengal	Uttar Pradesh, Uttarakhand, Bihar, West Bengal
Yamuna	1370	3,59,000	Yamunotri	Bay of Bengal	Delhi, Haryana and UP
Satlaj	622	56,560	Tibetan Plateau at Mansarover lake	Arabian sea	China and India
Narmada	1312	92,672	Amarkantak hill in Madhya Pradesh	Arabian sea	Madhya Pradesh and Maharashtra
Brahmaputra	725	580,000	Lake Manasarovar	Bay of Bengal	North Eastern state

2.2 Rainfall Data:

Rainfall data of India was acquired from the National Climatic Data Center (2005), a division of the National Oceanic and Atmospheric Administration (NOAA). Average annual rainfall of India is 715 mm. As mention in table-2 maximum rainfall are 919.5 mm in 2003 and minimum 737.30 mm in 2002.

2.3 Temperature Data:

Temperature data of India was acquired from the World Bank (climate variation). Average annual temperature of India varies in the range of 28-30 ^{0}c. As mention in **Table-3**, hottest year is 2006 with average temp 29.65 ^{0}c and normal year is 2003 with average temp 28.74 ^{0}c.

Table-2 Rainfall in India (in mm.)

(National Climatic Data Center, 2005)

Year	Jan – Sept
2002	737.3
2003	919.5
2004	774.2
2005	874.7
2006	889.3
2007	943.0

Table-3 Annual Temperature of India in ^{0}C (Source: World Bank-climate variation Report)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg Temp
2002	22.9	26.3	30.1	31.8	32.7	32.3	31.8	31.1	31	30.3	27.6	24.1	29.33
2003	21.1	24.4	28	32.3	33.1	32.3	31.2	31.3	30.9	29.1	27.3	23.9	28.74
2004	20.9	25.2	30.2	30.8	33	31.7	30.5	31.4	30.9	29.1	27.4	24.4	28.79
2005	22.3	25.3	29.1	32	32.5	34.2	30.9	30.9	31.9	29.3	27.5	24.9	29.23
2006	23.6	27.7	30.3	32.3	33	31.5	31.5	32.1	30.9	31.1	27.1	24.7	29.65
2007	23	23.8	28.8	31.6	33.6	32.1	30.6	31.5	30.8	30.5	28.2	24.4	29.08

2.4 BOD Data:

The BOD data of rivers are from the Central Pollution Control Board (CPCB). The maximum BOD of Ganga River was 27 mg/l in year 2003 and minimum 14mg/l in year 2007. Yamuna river's BOD was highest in 2006 (144 mg/l) and lowest in 2002 (36 mg/l). The maximum and minimum BOD of Satlaj river was recorded a 64 mg/l and min 24 mg/l respectively in 2004 and 2003 (Table-4).

Table 4: BOD of Major Indian River (mg/l) (Source: CPCB)

Ganga		Yamuna		Satlaj		Narmada		Bramaputra	
BOD	Year	BOD	Year	BOD	Year	BOD	Year	BOD	Year
16.8	2002	36	2002	45	2002	3.8	2002	3.9	2002
27	2003	58	2003	24	2003	3.3	2003	3.5	2003
14.4	2004	40	2004	64	2004	5.0	2004	3.5	2004
15.3	2005	59	2005	40	2005	4.5	2005	6.2	2005
16.4	2006	144	2006	32	2006	3.7	2006	5.7	2006
14	2007	59	2007	28	2007	5.0	2007	2.2	2007

3. Results and Discussions:

Based on the analysis of different parameters of rivers, the relation between temperature, rainfall, catchment size (pollutants load of catchment) and BOD of Indian river are established by the following formula:

$$BOD \propto C*IR*DR*T$$

Where,

-C stands for catchment area which clearly indicates the pollutants and effluents (domestic, industry, animal waste, etc.) load of that area.

-IR stands for Intensity of Rainfall which is helping in the runoff of debris from ground to the rivers.

-DR stands for Duration of Rainfall, which significantly affects the runoff of wastes and effluents into the river

-T stands for Temperature of river system

The above findings show that the temperature, rainfall (duration and intensity) and catchment area of the river positively affect the BOD of river water. The catchment area as well as the duration and intensity of the rainfall decides the runoff of the connecting drains/nalas in the river. Run off of the river/drains/nalas is constituted by the amount of waste materials that drains into the main river. It is observed that the temperature, rain fall and catchment area of some major Indian rivers show the negative result in the quality of river water.

The BOD of water decreases with the decrease in temperature of environment as higher temperature facilitates splitting of oxygen molecules from H_2O. The water quality monitoring results during 2002 to 2007 indicated that the status of BOD in the rivers continued to be critical. This was mainly due to discharge of domestic and industrial untreated wastewater from the cities situated along the rivers. The municipal corporations are not able to treat increasing load of municipal sewage flowing into the rivers. Furthermore, the rivers do not have adequate water flow for dilution. Therefore, the BOD is increasing year by year.

It was observed that in the case of Narmada river that when the environmental temperature increased, the BOD also increased. In 2002, average temperature was 29.33^{o}C and BOD was 3.8mg/l, while in 2003 the average temperature decreased by 0.59^{o}C with a reduction of 0.5 mg/l in BOD concentration. The same pattern of temperature and BOD was observed in 2004, 2005 and 2006, but in 2007 the average temperature was 29.08^{o}C with BOD value of 5 mg/l. The pattern of the temperature did not follow in above year as temperature fell and rainfall increased but the BOD of the river water increased slightly.

In fact the first rainfall of the monsoon season increases the BOD of the river and subsequently decreases because all the drains are flushed out through first rain. It means the rainfall alone does not affect the BOD. The catchment area of the river also plays a major role in increasing and decreasing the BOD in river. When the catchment area is small, the rainfall doesn’t affect BOD significantly.

The data of Bramaputra river shows that in the year 2002, the average annual temperature was 29.33 ^{o}C and BOD was 3.9 mg/l, and in 2003 the average temperature decreased from 29.33 ^{o}C to 28.74 ^{o}C, likewise BOD also decreased from 3.9 mg/l to 3.5 mg/l. For the years 2004, 2005 and 2006 the temperature and rainfall both increased with result that the BOD of river water also increased in 2004 and 2005. In 2007 the temperature was 29.08 ^{o}C and BOD was 2.2 mg/l because in this year rainfall was very high so the BOD decreased. First rainfall of the monsoon increased BOD and afterwards constantly decreased the BOD of river because all drains were flushed out through first rain. The catchment area of the river also played a major role in increasing and decreasing the value of BOD in river as the larger catchment area receives bigger volume of water through rainfall which impacts the value of BOD.

In Ganga River, average annual temperature in 2002 was 29.33 ^{o}C and BOD was 16.8 mg/l, while in 2003 the average temperature decreased from 29.33 ^{o}C to 28.74 ^{o}C and the average rainfall increased from 737.3 mm to 919.5 mm then BOD also increased from 16.8 mg/l to 27.0 mg/l. Since the catchment area of this river is extremely large so BOD remained almost constant in 2004, 2005, 2006 and 2007.

In Satlaj River, the average temperature was 29.33^{o}C and BOD was 45 mg/l in 2002 while in 2003 the average temperature decreased from 29.33 ^{o}C to 28.74 ^{o}C and average rainfall increased from 737.3mm to 919.5mm, as a result BOD decreased from 45 mg/l to 24 mg/l. The small catchment area of this river affected the runoff (velocity of water) of drains. In the years 2004, 2005, 2006 and 2007 the rainfall increased with minor variation in the temperature resulting in fall in BOD in the given years (Fig.7 & 8).

In Yamuna river in the year of 2002, average annual temperature was 29.33 ^{o}C and BOD was 36 mg/l, in 2003 average temperature decreased from 29.33 ^{o}C to 28.74 ^{o}C and average rainfall increased from 737.3 to 919.5; as a result BOD increased from 36 mg/l to 58 mg/l.

Figure-1 to 10 illustrates the relationship between affect of Temperature and Rainfall on BOD of different rivers of India. Temperature increases due to action of thermal effluents from industries which is directly poured into the river. Thus there is direct impact of pollutants on the temperature of rivers.

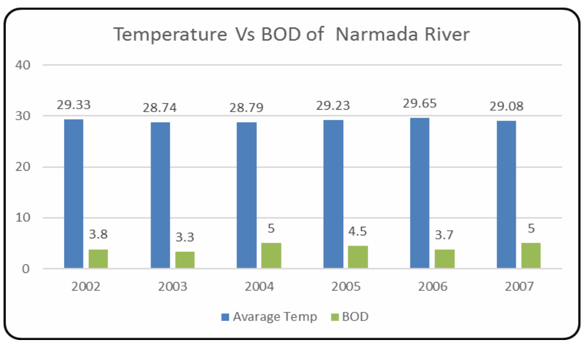

Fig: 1- Graph between Temperature (^{O}C) and BOD (mg/l) of Narmada River

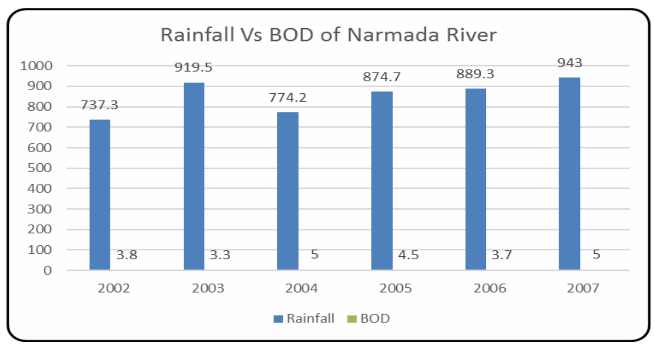

Fig: 2- Graph between Rainfall (mm) and BOD (mg/l) of Narmada River

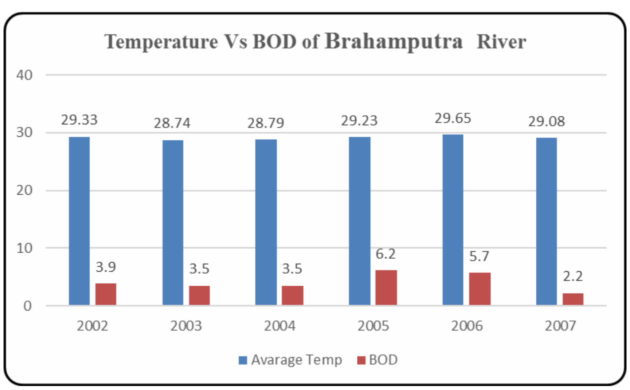

Fig: 3- Graph between Temperature (^{O}C) and BOD (mg/l) of Brahamputra River

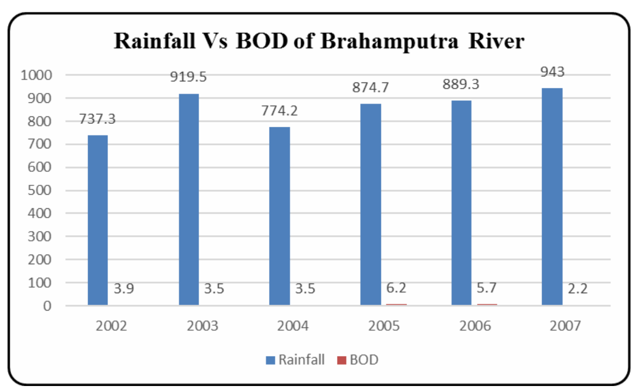

Fig: 4- Graph between Rainfall (mm) and BOD (mg/l) of Bramaputra River

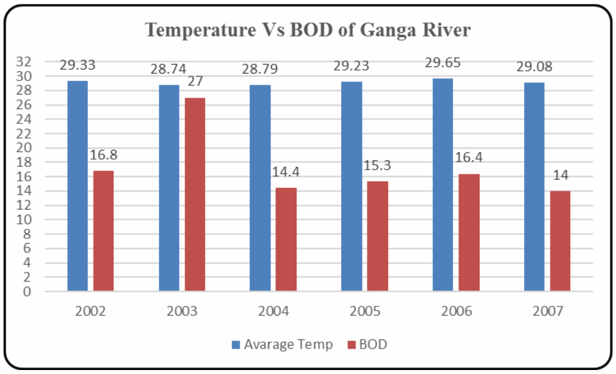

Fig: 5 Graphs between Temperature (^{O}C) and BOD (mg/l) of Ganga River

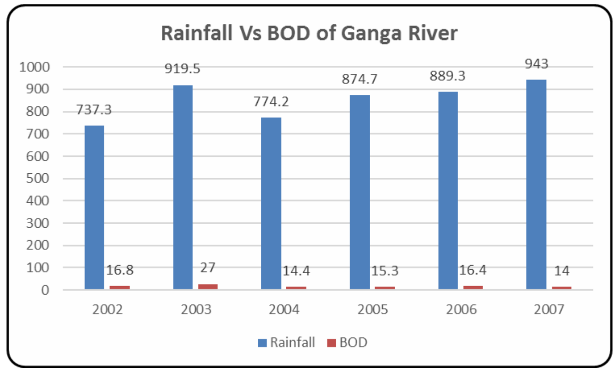

Fig: 6- Graph between Rainfall (mm) and BOD (mg/l) of Ganga River

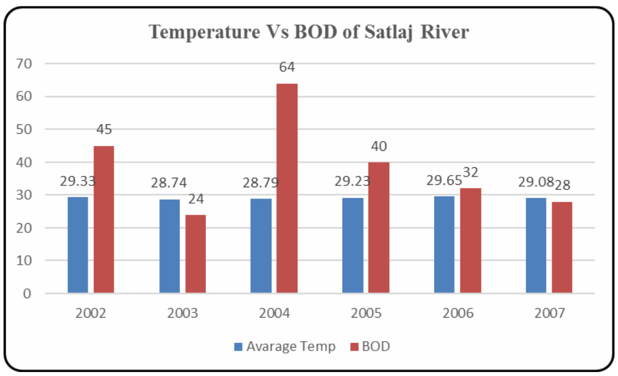

Fig: 7- Graph between Temperature (^{O}C) and BOD (mg/l) of Satlaj River

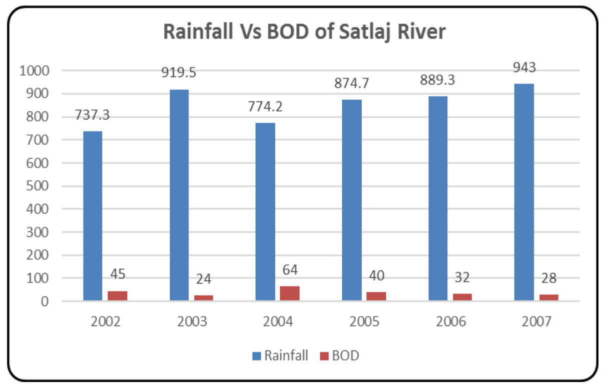

Fig: 8- Graph between Rainfall (mm) and BOD (mg/l) of Satlaj River

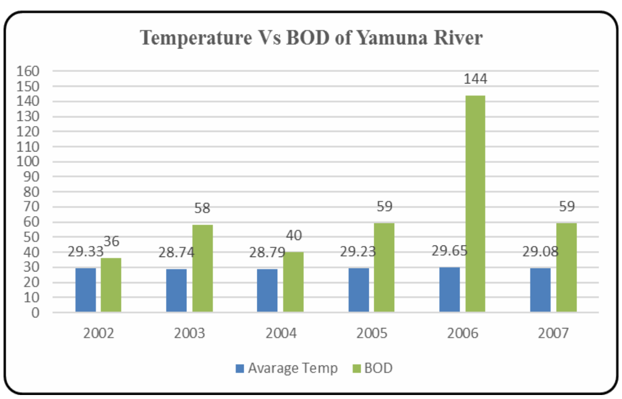

Fig: 9- Graph between Temperature (^{O}C) and BOD (mg/l) of Yamuna River

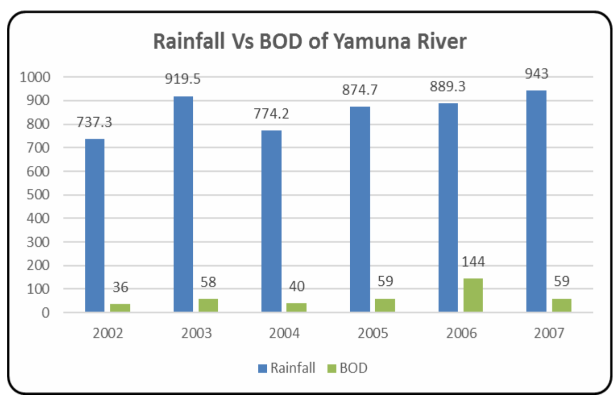

Fig: 10- Graph between Rainfall (mm) and BOD (mg/l) of Yamuna River

4. Suggestions:

For the prevention and management of water pollution and improving the quality of rivers, there are some remedial measures are as follows:

a) All Industries situated in the catchment of the river should be install Effluent Treatment Plant (ETP)to remove contaminants from their effluents and wastewater. Untreated water discharge into rivers should not be allowed.

b) All towns and cities situated in the catchment of river should have Sewage Treatment Plants to treat the sewage.

c) Proper maintenance of treatment plants.

d) Religious practices/activities which pollute river water should not be manages.

e) Promoting communities participation in the river cleaning up of the local rivers.

f) Organizing awareness programs and meetings on the river pollution and its threats.

g) Provide proper garbage collection system on both the banks of the river so that garbage is not dumped in the river. Improving the flow pattern of the river which will improve its carrying capacity.

h) Government agencies should impose some rules and penalties over polluting agency strictly.

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