ASSESSMENT OF WATER QUALITY OF NAJAFGARH DRAIN AND ITS IMPACT ON RIVER YAMUNA

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CANDIDATE's DECLARATION

I, VAISHALI NEHRA, 2K16/ENE/20, student of MTech (ENVIRONMENT ENGINEERING), hereby declare that the project Dissertation titled "ASSESSMENT OF WATER QUALITY OF NAJAFGARH DRAIN AND ITS IMPACT ON RIVER YAMUNA" which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "**ASSESSMENT OF WATER QUALITY OF NAJAFGARH DRAIN AND ITS IMPACT ON RIVER YAMUNA**" which is submitted by **VAISHALI NEHRA, 2K16/ENE/20**, Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

SUPERVISOR

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VAISHALI NEHRA

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ABSTRACT

Water is one of the basic amenities of life and Yamuna is a major source of water supply for Delhi and nearby states of Haryana, Uttar Pradesh, Rajasthan etc. Due to the rapid growth of industries and advanced agricultural activities in and around national capital territory Delhi, the deterioration of Yamuna river has become a major concern. The objective of this study is to assess the Water Quality Of Najafgarh drain and unveil the present deteriorated condition of Yamuna river in Delhi. A comparison has been made between the water quality of river Yamuna before and after the confluence of Najafgarh Drain into it. The present situation and contamination level of River has been analysed due to various drains present in the Delhi stretch. The effect of pollution load and waste water added to Yamuna in Delhi is studied by comparing the water quality in river Yamuna at palla(before entering in Delhi) and at Okhla barrage (the downstream point from where the river Yamuna meets Agra canal and leaves Delhi.). For the study, water samples were collected from six different locations in river and Najafgarh Drain. Experimental results indicated that the water quality of river was comparable with the Drain as most of the parameters were exceeding the prescribed standards for surface water. The WQI is calculated for the various locations of Yamuna river and it indicated that tremendous efforts are required to improve the water quality of river Yamuna. As Yamuna water is used for irrigation so the suitability of water for irrigation is analyssed using different irrigation parameters. Overall the study concluded that Yamuna river has been converted into a Drain in Delhi stretch and its water is not suitable for any other purposes without proper and highly efficient treatment system.

CHAPTER 1

INTRODUCTION

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INTRODUCTION

In the world the rivers are the most important source of water and india majorly depends on rivers for its water supply. The human civilization majorly originated and sustained in and around river basins in view of all the basic requirements from drinking water, food preparation, agricultural take up, fishing etc being met there. In ancient times civilizations develop along the banks of the rivers and in modern times too the development is at a fast pace in the cities and areas near the rivers. With the modernization, human activities and needs further lend to the industrialization. Water has become an essential requirement for industrial development and agriculture, thus resulted into excessive use of riverine system and hence damaging the rivers at a non-recovering rate, almost of all kinds of the wastes of industries containing pesticides, insecticides, fertilizers and chemicals is being discarded into the streams without any handling.

The river provides water for agriculture, commercial uses, aquaculture and domestic purposes. But humans pollute these rivers by immense disposal of sewage and manufacturing waste unfortunately. Now the situation is so worse that the river pollution has reached the alarming risk level and has acquired a serious dimension in India. In our country 55 small rivers, fourteen major and numerous hundred rivers are facing acute water pollution problem. The shifting physical and chemical characteristic of water and their interface alter the biological community of aquatic ecosystems of rivers. Anthropogenic activities in the river basin affect the physico-chemical properties of river which have indirect consequence on the biological resources interrelating with each other, apart from degrading the environment. According to CPCB, only 1.6% waste water get treated and towns and cities in India are getting 90% of polluted water through water supply lines. According to the Ministry of Environment and Forest (MoEF), most of rivers in India are contaminated, mainly because of straight arrival of unprocessed sewage consequential in intolerable levels in them of BOD, SS. Even high bacterial growth is noted with the marine systems that progressively upsurges eutrophication of water bodies[Pennington et al.,2001;Kistemann et al., 2002]

Heavy metals have been also discovered as an important constituent of pollution to riverine system [Anon,1971; Angino et al.,1970; Handa et al., 1975; Hiremoth and shetty, 1988] as they find their way through sewage and manufacturing sector wastes from mining mineral, processing industries including smelting and foundries, electroplating use of catalysts in industries, corrosion of pipes and joints , metal salts suits being used in pest and vector control and chemical accidents.

Minimata being disaster during the early 1950s concerned the mysterious neurologic illness in human who mainly subsided on fish. It also caused severe mortality in fishes since the disease also prevailed among local sea birds and house cats. Investigation led to the discovery that it was all due to the eating of fish which had collected great quantity of mercury. Through the food chain toxic effects were caused in men, cats, birds [Fujlta, 1975]. By this incident scientist all over the world became aware of the existence of toxic metals in the environment. Thus, they started working on accumulation of toxic metals in the ecosystem and the research is still going on.

In North India the main sources of water are Ganga, Yamuna, Gomti, Hindon, Ghaghara, Ken and Nainital Lake which are highly polluted by untreated industrial waste and sewage discharge from cities and town. The river Yamuna starts from Yamnotri and passes through a distance of 1376 km from Yamnotri to Allahabad. The Tars, Giri, Betwa, Ken and Chambal also join this river at different places.

The marine life of Yamuna polluted by continuous ejection of sewage and industrial wastes of about 30000 big and small industries through numerous drains from the cities on its Bank. The Yamuna river often refers to as lifeline of Delhi and nearby states is on the verge of dying. It won’t be exaggerated to say that it is difficult to differentiate whether it is a river or drain just because of the acute pollution the river is suffering in the capital. Staying in the capital always make us feel privileged from the people in the rest of the country but after monitoring the class of water of river Yamuna, opinion changes drastically, it made us wonder whether it is actually that holy river or a mere drain. Just because of the nearly 20 drains that pour sewage and untreated waste into the river, the 22 km stretch of Yamuna in Delhi has virtually no aquatic life. Before entering Delhi the river has significant dissolved oxygen and aquatic life and is home to various aquatic species like turtles, crocodiles, fishes and various species of phytoplankton and zooplankton but as soon as it enters the Delhi after Wazirabad the river starts puffing for life. Between its 22 km stretch from

Wazirabad barrage to Okhla barrage the river is referred to as "ecologically dead" by various ecologists because of nearly negligible dissolved oxygen, very high pollution. The waste water from the drains in Delhi is discarded straight into the river, polluting it to a level that is non-recoverable and thereby killing all the essential components required for the sustenance of life in a river. Phytoplankton creates carbon-based complexes from carbon dioxide in water and hence help in supporting aquatic life in rivers but these phytoplankton and zooplanktons have vanish from the urban stretch of Yamuna and therefore there is not at all marine life left in the river in Delhi.

1.1 WASTE WATER GENERATION

Around 850 MGD of waste is being discarded in the river by the 21 drains in Delhi. The Najafgarh drain alone is responsible for around 67% pollution as per experts. Anyone can become queasy by the stink originating from these drains. Vijay Panswani , CPCB counsel said "there is no fresh water flow in river Yamuna except during monsoon season. For fulfilling the water requirements of residents of Delhi, the entire fresh water of the river is harnesses at Wazirabad, therefore Yamuna is no more a river in Delhi. It is a drain."[Dhananjay Mahapatra, 2012].

Around 2000 MLD of waste water has been discharged alone by Najafgarh drain into Yamuna. The treatment plants installed over Najafgarh drain basin are not effective enough to treat this entire amount of waste, they could treat only about 30% (around 600 MLD) and the rest 70% is derelict into the river Yamuna without any treatment. Then after treatment the treated waste is also discharged into the river and there it get mixed with untreated waste hence clearly failing the purpose of waste water treatment. [CPCB, 2012]. These facts are the major eminent factors that makes the Najafgarh drain stretch and area around it a concern from health and environmental aspects.

Najafgarh Drain has its origin from Alwar-Rewari region of Rajasthan and enters Delhi on the south western side thereby traversing around 40 kms before it merges with river Yamuna in the north. The drain has around 400 square kilometers catchment area. There are many severe constraints in the sewerage system, therefore large amount of raw sewage flows in the drain and reaches Yamuna through it. The Najafgarh basin flow has been divided into three stages. About 150 MLD is the background flow in the drain before entering into Delhi. Nearly 40% is untreated and the remaining 60% has been discharged in the river from conventional treatment plant. This flow in the drain has around 100 mg/l of BOD[CPCB,2001-02]. As the sewerage systems are not that efficient therefore untreated sewage in large amount is discharged into the Najafgarh drain from various other secondary drains.

The waste water loads in Najafgarh drain consists of water from all the three sectors that is domestic, agricultural and industrial. As area around the drain is extremely polluted so the majority of discharge into the drain is due to domestic wastes. The domestic units discharge waste water around 1340 MLD in the drain followed by 150 MLD from the industrial sector and the contribution from agriculture in that region is nearly negligible. BOD contribution from the domestic sector is about 78%. Various harmful substances, suspended solids, toxins, sewage , organics and inorganics along with harmful pathogenic substances have been added into the drain from all these sources. Now in the last stage in Najafgarh drain falls out in river Yamuna and fresh water is added into the drain hence polluting the water of river Yamuna to a great extent.

1.2 OBJECTIVES OF THE STUDY

The aim of the study is:

(1) To Assess the water quality of Najafgarh drain and to unveil the present deteriorated condition of pollution level of the water of Yamuna river in Delhi.

(2) To compare the water quality in river Yamuna before and after the confluence of Najafgarh drain in it and describe the effect of pollution load and waste water added to Yamuna in Delhi by comparing the water quality in river Yamuna at Palla (before entering in Delhi) and at Okhla barrage (the downstream point from where the river Yamuna meets agra canal and leaves Delhi.

(3) To determine the WQI of Yamuna river so as to indicate the extent of treatment required for cleaning the river and make its water useful for various purposes.

(4) To analyse the suitability of river water for irrigation purposes through various irrigation parameters

By these results a basis for further planning and studies can be provided that will be beneficial in preventing the damage caused to natural resources and environment from the water pollution in the river.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Water pollution levels in many developing countries remain significantly higher than in the developed world. While such pollution is often a byproduct of economic activity, it also imparts a health burden on the population. The limnology implies a complete knowledge of fresh water area including its physical, chemical and biological aspects [knight, 1970]. While pollution deteriorates and changes the environment [Prakash and Rawat, 1979] and it acts as the most important limiting factor. [odum,1971].

Its study can be evaluated by worth noting additions of Arora et al., [1965]; Basu [1965,1966]; Ghosh et al., [1973]; Jhingran [1974]; Verma et al., [1977,1978]; Prakash and Rawat [1978;1979]; Prasad and Saxena [1980]; pang et al., [1984]; Chattopadhay et al., [1984]; Kuldesia and Singh [1988]; Kuldesia and Verma [1989]; Kuldesia [1992]; Sharma [1993]; Sharma[1994]; Dixit[1995]; Pandey[1996]; Singh[1997]; Verma[1999]; of India while the work done in foreign countries is also quite significant, the landmark of which has been provided by Burdick [1957]; Belba[1987]; Glaze[1987].

Ellis [1931] specified the role of some industrial effluents on the life of fishes in the Missourie river in USA and later in pollution of river Coeurd' Alene and in 1937 he detected the pollution of a stream and methods for its detection. The effects of many workers cannot be forgotten with regard to the industrial pollution. Seth and Bhaskaran [1950] found that the effect of industrial effluents of the sanitary conditions of river hooghly in and around Calcutta.

The development of drains with the advent of urbanization and their discharge in the rivers causes pollution of rivers. The credit in this field goes to Verma et al., [1978] who studied the physico-chemical and biological characteristics of khadrabad drain in western U.P. Dakshini and Soni [1979] studied the physico-chemical and biological characteristics of Rajghat and Najafgarh drains at Delhi. Sharma et al., concluded the study of some drains at Agra.

Due to increase in pollution of river Ganga day by day a Ganga Action Plan was set up and commencing with investigation at almost all the major cities situated along the bank of river Ganga. In this aspect noticeable work has been done by Sazena and Chandra [1966]; pahwa [1979,1985]; Sinha et al., [1989]; Shankar [1989]; Shukla [1989]; Rao et al., [1990].

The studies on pollution of river Ganga then draw the attention towards Yamuna which is highly polluted even more than Ganga and is a major tributary of Ganges. The Yamuna action plan was set up in year 1993 to overcome the increasing pollution in river Yamuna. A study of river yamuna was done three decades ago when Chakraborty et al., [1959] worked out the pollution status of river Yamuna at the point of confluence of Ganga and Yamuna in Allahabad. Lateron Mathur [1978] studied on the pollution of river Yamuna at Delhi where there is a fats rate of occurrence of industrialization and urbanization. Mohan and Sarkar [1965] made some observations on the status of pollution of the river Yamuna at Okhla, the downstream location of Yamuna in Delhi. Arora et al., [1965] worked on the water quality of river Yamuna at Agra. Bhargava [1977,1982,1985] studied the pollution of river Yamuna, its fate for Delhi and worked on the methods for reducing the pollution level and prevention of the same. Dakshini and Soni [1979]; Sharma et al., [1981]; Vashishtha and Kapoor [1981] studied and monitored the pollution status of major drains of Delhi. Agra and Yamunanagar. Singh and Misra [1985,1989] studied the aspects of pollution of river Yamuna from Delhi to Allahabad. Nigam [1989] conducted experiments on the pollution and self-purification of Agra canal originating at Okhla from the river Yamuna. Certain investigation centershave been developed by the committee of Yamuna action plan at major industrial towns.

The National Environmental Engineering Research Institute Nagpur worked on the latest treatment practices and methods for rendering the polluted water caused by industrialization and urbanization less harmful. Without inclusion of NEERI the knowledge would have remain incomplete and in addition to it the efforts made by Central Board for Prevention and Control of Water pollution cannot be neglected. [Bhoota,1971]

Water pollution has turned India’s beautiful lakes into dirty ponds. The crystal clear appearance of most of the rivers has been changed into blackish filthy appearance due to the effluents from industries. According to Kudesia [1992] the untreated human wastes dumped into the rivers is also a major cause of it and not the effluents from industries is the major culprit. In Delhi itself Yamuna takes in everyday about two hundred million litres of untreated human wastes while the industries accounts for only twenty million litres of effluents.

The water pollution will be India’s major problem in the coming 25 years unless sewage and sanitation facilities are improved as per the warning given by The International Institute of Applied System Analysis in Australia.

The domestic and industrial wastes are dumped without treatment into water bodies and waste water treatment is not considered a priority in most of the developing countries. (Dan’azumi et al., 2010). Water quality studies of rivers Ganga (Srivastava et al., 1996), Kali (Bharti and Krishna Murti, 1990), St.Lawerence river (Vis et al., 1998) and river Nile (Wahaab and Badawy, 2004) have indicated that their water is not fit for human consumption and other domestic purposes as it is highly toxic.In India, most of the developmental activities and for other purposes we are dependent on the 14 rivers majorly.(Sharma, 2007; Kaushik et al., 2009). The river Yamuna has been given the status of most polluted river in India.

2.2 EXTENT OF POLLUTION IN YAMUNA RIVER

The River Yamuna originates 6387 m above msl from the Yamnotri glacier at banderpoonch peak of Himalayas in Uttarkashi district of Uttarakhand and is the largest tributary of river Ganga, in its entire stretch the river covers states of Haryana, Rajasthan, Uttar Pradesh, Madhya Pradesh, and Himachal Pradesh and the entire National Capital territory of Delhi. From its origin at Himalayas it has total catchment area of 366,220 square kilometers and length is 1,376 km Its source is at Yamunotri, in the Uttarakhand Himalaya, in the Himalayan Mountains. Chambal, Ken, Betwa, Sind and Hindon are the major tributaries of the River Yamuna.(Jain et al.,2004). The annual flow and usage of the river is around 10000 and 4400 cumecs respectively and irrigation accounts for about 96% of its usage (MoEF, 1994). Unlike others it is not just a river but it is attached to various religious and cultural beliefs of the people and is quite significant. along with a source of livelihood for the population surviving on its banks it also has a eminent supporting factor to various agricultural and industrial practices. The river is the main source of supply of drinking water for the population settled along its banks. The Delhi abstracts around 70% and even more of its water supplies from the river Yamuna (CPCB, 1996., Upadhyay et al., 2010).from all this we can clearly estimate the importance of the river for the towns near its stretch. The number of people estimated to be dependent on Yamuna river water can be estimated to be 57 million as per a study. The quality of river water has been deteriorating at a alarming rate due to rapid growth of industrialization, urbanization and inadequacy of infrastructure. A significant quantity of wastes has been discharged into the river from the various industrial activities occurring along its stretch. The Yamuna has hence become a drain in its lower segment because of the various industrial, domestic and agricultural effluents discharged into the river. (Ali et al., 2001)

According to CPCB (2000) around 22 industrial units from Haryana, 17 units from uttar Pradesh and 42 units from Delhi and around 359 industrial units in its total stretch discharges their toxic effluents directly into the river. various industries like chemical, paper and pulp, textiles, leather, tannery, power, distillery and pharmaceuticals etc can be counted among these.the various industrial cities on the bank of river in which these industries flourish areYamunanagar, Sonepat, Agra, Panipat, Mathura and Delhi. The categories of industries discharging wastewater into Yamuna river includes Pulp & paper, Sugar, tannery, steel plants Distilleries, Textiles, Leather, Chemical, Pharmaceuticals, rubber, glass, Oil Refineries, Thermal Power Plants, food etc. (CPCB, 2006).

As per different geological and ecological characteristics, the river Yamuna can be characterized into five major segments. These are Himalayan stretch (around 172 kms), upper stretch (224 ikms), Delhi stretch 922 kms), mixed stretch(490kms), diluted stretch (468kms). As shown in table (CWC,2009). In all these five stretches Delhi stretch is the most polluted among all and this stretch is the responsible of around 79% of total pollution load on the river.(CPCB,2007). The Himalayan stretch which is up to Tejawala barrage is not at all contaminated and the water quality is fit for bathing here as per desired standards for bathing. (YAP II; Bhargava, 1983; 1985; 2006)

Table.2.1 . VARIOUS SEGMENTS OF YAMUNA RIVER (YAP II)

S.NO.	REACH	SEGMENT	LENGTH	DESCRIPTION
I	From origin of Yamuna uptoTejawala barrage	Himalayan stretch	172 km	The water quality is quite pristine up to Tejawala barrage and the stream is turbulent .
II	Tejawala barrage to wazirabad barrage (upstream of Delhi)	Upper stretch	224 km	The flow constitutes of both fresh water as well as waste water from various settlements in dry weather conditions.
III	Wazirabad to Okhla barrage(Delhi)	Delhi stretch (most polluted)	22 km	The water is the plooution load from delhi majorly and after okhla barrage the water is diverted to states of U.P. and Haryana for irrigation purposes through agra canal.
IV	From Okhla barrage to its confluence with river Chambal	Mixed stretch: eutrophicated and highly polluted)	490 km	The waste water from various rural and urban settlements constitutes the DWF.
V	From Chambal confluence upto its confluence at allahabad with river ganga.	Diluted stretch	468 km	After dilution with Chambal the river gets fresh life.

(Source: YAP II, 2007)

For Indian Rivers the water quality has been characterized into five classes (Hindu, 2002)

Class A – The river after proper disinfection by adding chlorine and bleaching powder is fit for drinking.

Class B – The river water is fit for bathing only and not drinking.

Class C- only after proper treatment tye river water can be used for drinking .

Class D- the river water can be considered fit only for wildlife and fishes.

Class E- the water of the river is suitable only for irrigation works and industrial cooling.

The river Yamuna belongs to category E (Hindu,2002)

The Yamuna river has changed into as sewage drain because of extensive anthropogenic pressure .the various small and large drains in Delhi are the reason behind acute pollution in the Delhi stretch of river Yamuna. Delhi alone discharges its treated and untreated domestic and industrial wastes through small or large drains. The seven major drains viz; Najafgarh, Yamunapur, Sen Nursing Home, Barathpula, Maharanibag, Kalkaji and Tuglakabad has resulted into around 95% pollution in the river Yamuna. Due to the pollution by drains in Delhi the Yamuna river becomes so polluted that it hardly supports any life beyond Okhla the contamination of the river is not only due to organic matter alone but various toxins and heavy metals have been increasing the river at alarming rate. (Aggrawal, 1993).

2.3 POLLUTION LOAD DUE TO NAJAFGARH DRAIN

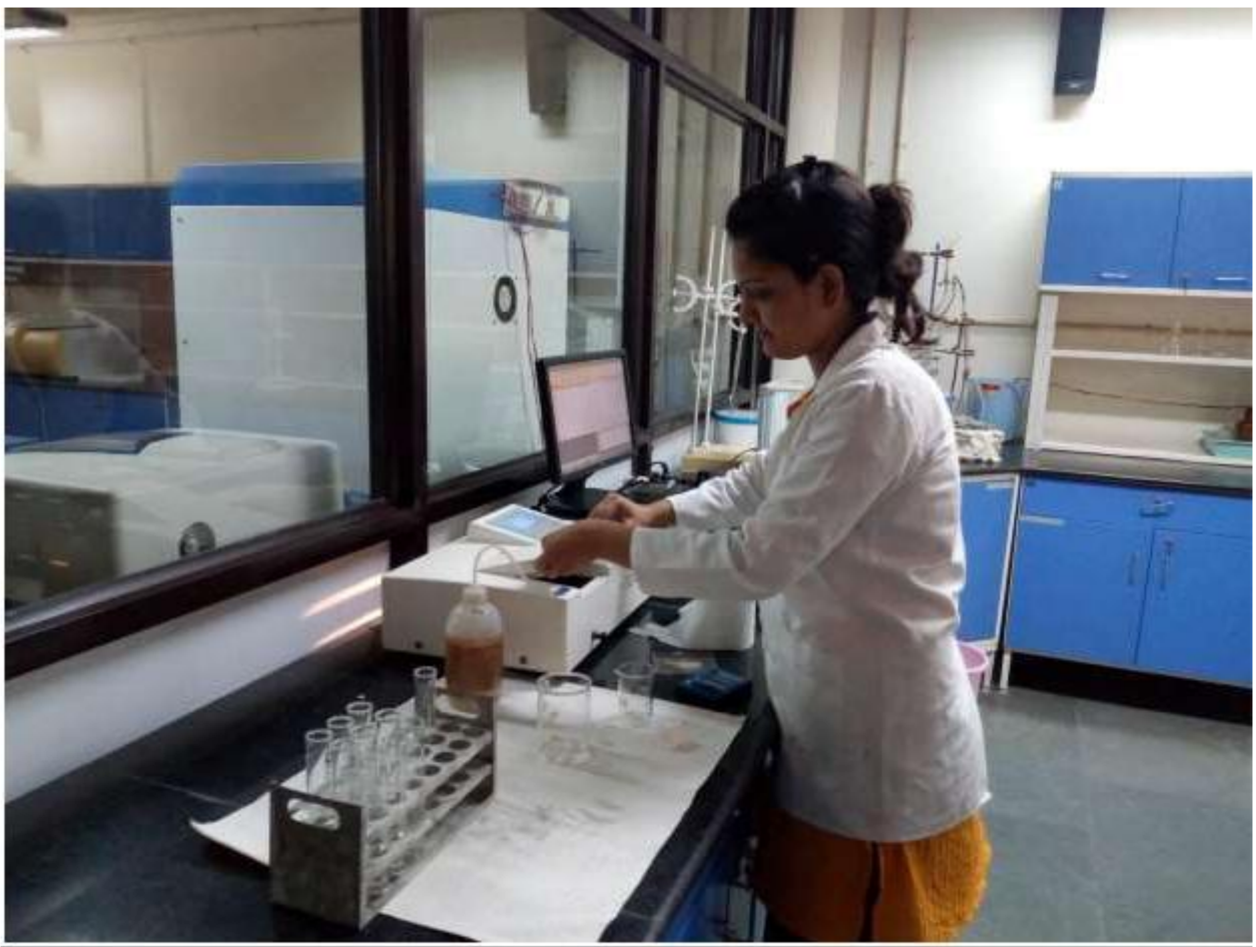
Najafgarh Drain has its origin from Alwar-Rewari region of Rajasthan and enters Delhi on the south western side thereby traversing around 40 kms before it merges with river Yamuna in the north. The drain has around 400 square kilometers catchment area. There are many severe constraints in the sewerage system, therefore large amount of raw sewage flows in the drain and reaches Yamuna through it.the Najafgarh basin flow has been divided into three stages. About 150 MLD is the background flow in the drain before entering into Delhi. Nearly 40% is untreated and the remaining 60% has been discharged in the river from conventional treatment plant. This flow in the drain has around 100 mg/l of BOD[CPCB,2001-02]. Next stage is the water that originates from Delhi itself. As the sewerage systems are not that efficient therefore untreated sewage in large amount is discharged into the Najafgarh drain from various other secondary drains.

The waste water loads in Najafgarh drain consists of water from all the three sectors that is domestic, agricultural and industrial. As area around the drain is extremely polluted so the majority of discharge into the drain is due to domestic wastes. The domestic units discharge waste water around 1340 MLD in the drain followed by 150 MLD from the industrial sector and the contribution from agriculture in that region is nearly negligible. BOD contribution from the domestic sector is about 78%. Various harmful substances, suspended solids, toxins, sewage , organics and inorganics along with harmful pathogenic substances have been added into the drain from all these sources. Now in the last stage in Najafgarh drain falls out in river Yamuna and fresh water is added into the drain hence polluting the water of river Yamuna to a great extent.

The presence of heavy metals in the Yamuna River due to their toxicity and accumulating nature is assumed to be of serious concern.(Jain, 2004). As per the works of some researchers there is an exchangeable fraction of around 30-50% of lead at some the sites of River Yamuna and around 30-50% of cadmium is either carbonate bound or exchangeable at almost all the sites of river Yamuna. This is therefore a great risk as they can easily enter the food chain and can cause serious health issues in living beings.

CHAPTER 3

METHODOLOGY



CHAPTER 3

METHODOLOGY

The water samples were collected from total six locations in the drain and river Yamuna as per the requirement of the study.

3.1 SAMPLING PROTOCOL

The sampling protocol was adopted from CPCB's " Guide Manual: Water And Wastewater Analysis, 2011". As per the guidelines given by CPCB, the main objective of Sampling is to collect representative sample. Representative Sample can be defined as a sample in which relative proportions or concentration of all pertinent components should resemble the water body being sampled to a great extent. The sample was prepared by combining portions of multiple "Grab Samples". The representative samples at all locations in the river were prepared by collecting the Grab Samples at various points of equal distances across the river and in the middle of the main channel of the river and at various depths. The sampling is done in the summer season in the month of June and the samples are collected at various durations of the day. A representative sample was then prepared by mixing same proportions of all the samples collected at a location over the day.

As per the CPCB's guidelines 1 litre sample is collected and analysed for various physical and chemical parameters.The storage, handling and analysis of the samples was done as per the guide manual issued by CPCB.

3.2 SAMPLING LOCATIONS

The sampling locations were chosen depending upon the accessibility and reach to the water. The sampling is done from nearby bridges in the mid of the river Yamuna and drain. The sampling locations were as follows:

Location 1: PALLA

This location is about 15 kms upstream from Wazirabad Barrage. At this location sampling reflects quality of raw water from Delhi's water supply and quality or river water before the waste water from Delhi is discharged into it.

The impact of industrial and domestic discharge from Haryana's Sonepat District is also reflected by the water samples collected from this location

Location 2: Wazirabad Bridge

This sample reflects the water quality of the river Yamuna before the addition of Najafgarh Drain in it. This is further used to compare the effect of discharge from Najafgarh Drain into the River.

FIGURE 3.1 SAMPLING LOCATION AT WAZIRABAD BRIDGE

Location 3: Najafgarh Drain

The sample is collected from the drain over a bridge just before the drain outfall into the river Yamuna.

FIGURE 3.2 SAMPLING LOCATION AT NAJAFAGRH DRAIN

Location 4: Pontoon Bridge

The sample was taken around 0.5 km downstream the confluence of Najafgarh Drain into the river Yamuna.

Location 5: Gurudwara Majnu ka Teela

The sample was taken around 3 kms from the downstream from the confluence of Najafgarh Drain into the river.

Location 6: Okhla Barrage

This location is around 24 kms downstream from wazirabad barrage and east of Delhi. The water quality at this location reflects the effect of various drains that discharges waste water into river Yamuna at Delhi and also the pollution load added to the river in Delhi.

These samples are further analysed for various physico-chemical parameters. The estimation of water temperature ,ph, DO. was done right at field spot every time.

3.3 SAMPLE TESTING

The sample testing is done as per CPCB's " Guide Manual: Water and Waste Water Analysis" . The samples collected were analysed for various physical and chemical parameters like Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) by open reflux method. The Nitrates were analysed by UV spectrophotometer at 400 nm. The other parameters which were tested includes Total Hardness, Total alkalinity, Dissolved Oxygen (DO), Ph, Conductivity, Total Suspended Solids(TSS) , Total Dissolved Solids(TDS).

Physical parameters of the waste water samples collected were analysed according to the following methods:

3.3.1. Temperature

Water sample was collected in a bucket and the temperature noted immediately by using Multi Parameter

3.3.2 Colour

Colour of the water bucket was visually examined.

3.3.3 Water current

Water current was observed by visual examination

3.3.4 Conductivity

Conductivity was observed fin the laboratory by conductivity meter in µS/cm.

3.3.5 Hydrogen Ion Concentration(Ph)

It was estimated by calculating pH by pH meter by using the formula:

pH = -log[H]+

3.3.6. Dissolved Oxygen

Dissolved oxygen was estimated by D.O. meter immediately after the sample is collected.

The Dilution equation for DO

This dilution equation computes the Dissolved Oxygen in the river after mixing of the Drain in the river.

$$DO_{MIX} = \frac{(DO_{DRAIN} * Q_{DRAIN} + DO_{RIVER} * Q_{RIVER})}{Q_{DRAIN} + Q_{RIVER}}$$

3.3.7 Biological Oxygen Demand

For biological oxygen demand (BOD) firstly DO was estimated at the time of sample collection and then the rest of the samples were kept in BOD incubator at 20ºC for 5 Days . Dilution Technique has also been applied at times for assessing the BOD of samples..the dilution was done as 1% and 5% for all the samples.

3.3.8 Chemical Oxygen Demand

Chemical oxygen demand was estimated using potassium dichromate by open reflux method.

3.3.9 Hardness

Hardness was estimated by standard EDTA titration method using EDTA and EBT as an indicator.

3.3.10 Total Alkalinity

Total alkalinity was estimated by usual titration method using methyl orange indicator.

3.3.11 Suspended solids

Total Suspended Solids were estimated by filtering the samples through a filter paper and weighing the residue left on the filter paper after keeping it in oven at 105 degree Celsius.

3.3.12 Dissolved solids

Total Dissolved Solids were measured by evaporating the filtrate obtained from the Suspended Solids analysis and then weighing the residue left in the evaporating dish.

3.3.13 Chlorides

Chlorine as chlorides was estimated according to Mohr's method (using silver nitrate as titrant and potassium chromate as an indicator).

3.3.14 Nitrate

Nitrate was estimated by spectrophotometer. UV spectrophotometer is used for the estimation of concentration of Nitrates in various samples at 400 nm

3.4. WQI INDEX CALCULATION

The analysis of various physical and chemical methods is done as given by the Guide Manual for Water and Waste Water Analysis given by CPCB. A set of most commonly used water quality parameters namely pH, ,total dissolved solid (TDS), total suspended solid (TSS), chloride, total alkalinity (TA), total hardness (TH), dissolved oxygen (DO), biochemical oxygen demand (BOD), Chemical Oxygen Demand (COD) and Nitrates which are used for WQI calculations at various sampling locations. The equation used for calculation is:

$$WQI = \Sigma Q_n W_n / \Sigma W_n$$

Where Q_n is the quality rating of nth quality parameter and W_n is the unit weight of nth quality parameter.

The quality rating Q_n is calculated using equation

$$Q_n = 100[(V_n - V_i)/(V_s - V_i)]$$

where V_n is the actual amount of nth parameter present, V_i is the ideal value of the parameter [$V_i = 0$, except for pH ($V_i = 7$) and DO ($V_i = 14.6$ mg/l)], V_s is the standard permissible value for the nth water quality parameter. Unit weight (W_n) is calculated using the formula

$W_n = k/V_s$

where k is the constant of proportionality and it is calculated using the equation

$k = [\ 1/\ \Sigma 1/V_s = 1,2,\ldots\ldots\ldots\ldots,n]$

Table 3.1 Water Quality Status and possible usage of the water samples(Brown et al. 1972)

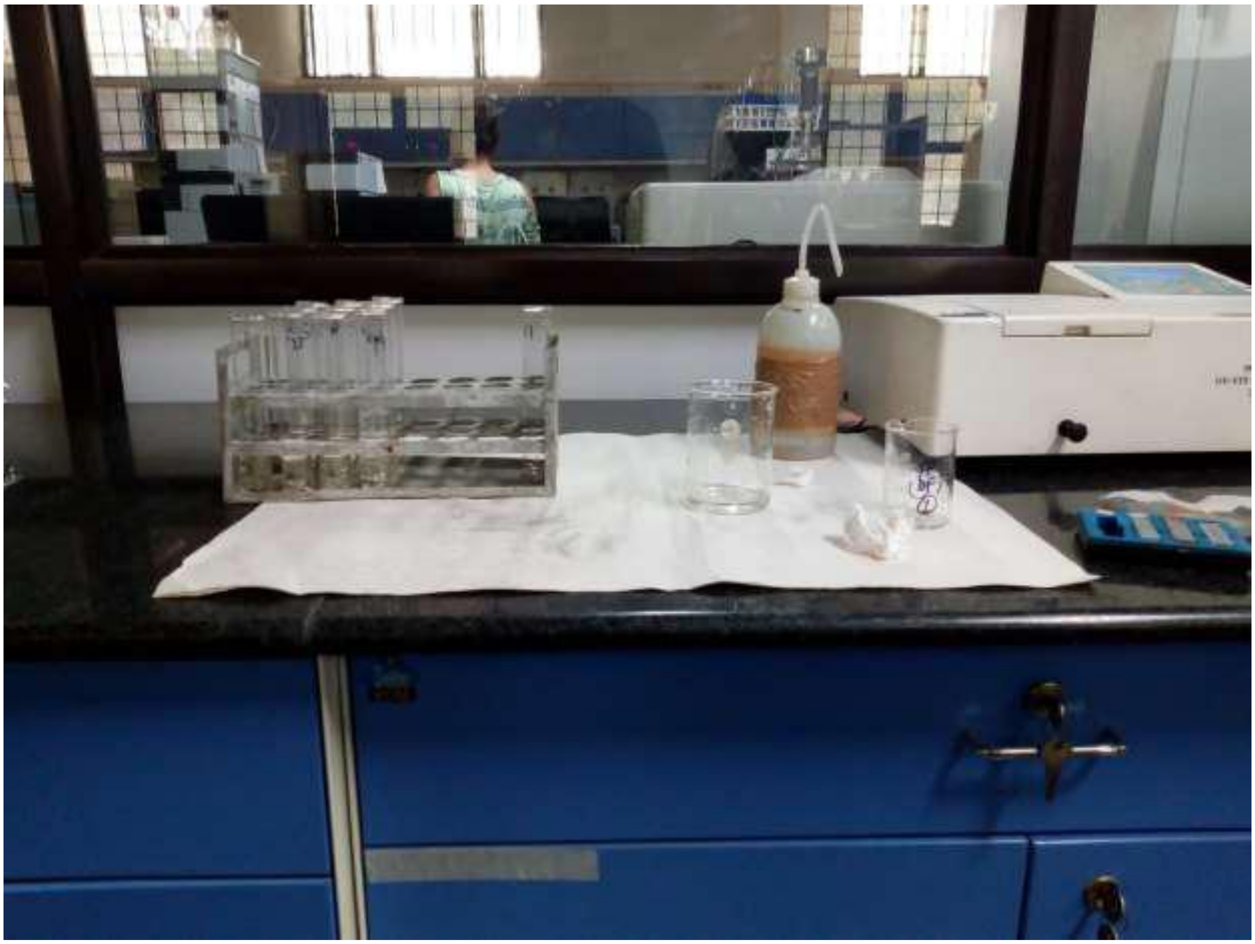
WQI	**WATERQUALITY STATUS**	**POSSIBLE USAGE**
0-25	Excellent	Drinking, irrigation and industrial
26-50	Good	Drinking, irrigation and industrial
51-75	Poor	Irrigation and industrial
76-100	Very Poor	Irrigation
>100	Unsuitable for Drinking and Fish Culture	Proper treatment required before use

Table 3.2.: Summary of Special Sampling and Handling Requirements

DETERMINATION	MIN. SAMPLE SIZE, ml	PRESERVATION	MAXIMUM STORAGE	
			RECOMMENDED	REGULATORY
Alkalinity	100	Refrigerate	24h	14d
BOD	1000	Refrigerate	6h	48h
COD	100	Analyse as soon as possible	7d	28d
Chloride	50	None required	N.S.	28d
Hardness	100	Add HNO3 and H2SO4 at Ph<2	6 months	6 months
Nitrate	100	Analyze as soon as possible, Refrigerate	48h	48h(28d for chlorinated samples)
Dissolved Oxygen	300	Analyze immediately	0.25h	0.25h
Temperature		Analyze immediately	0.25h	0.25h
Conductance	500	Refrigerate	28d	28d
Ph	50	Analyze Immediately	0.25h	0.25h

CHAPTER 4

RESULTS AND DISCUSSIONS



CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 SURVEY OF THE MAJOR POLLUTION SOURCES

During survey of the Major Pollution Sources in the river Yamuna the main problem was found to be due to direct discharge of domestic and industrial wastes from various industries situated on the bank of river into the river from Delhi's drains. The River Yamuna is relatively clean till it enters Delhi at Palla . By the time it leaves the city it is a sewer, carrying the wastes to downstream users. During most of its journey in the polluted stretches, the Yamuna has little flow to maintain its assimilative capacity- the ability to dilute waste. This is because:

Firstly, cities take clean water from the river and return only waste.

Secondly, the wastewater flow into the river has increased phenomenally, widening the gap between waste generated and waste treated.

As Yamuna enters Haryana, its water gets contaminated by various fertilizers and pesticides.the majority of the pollution load to the river is added from Delhi. Currently around 16.8 Million people lives in Delhi but the sewage disposal is not efficient enough to handle enormous amount of waste generated from the residents of Delhi. The major Nineteen drains which once used to carry rain water are now carrying the untreated sewage to the Yamuna when they open into the river.

Industrial wastes from around 22 units in Haryana and 42 units in Delhi are also responsible for various toxic chemicals and high level of deterioration of river Yamuna. The Delhi stretch is just 2% of the catchment area and the pollution load added from Delhi is about 80% of the total pollution of the river. These statistics prove that National Capital Territory is the major deteriorator of Holy River Yamuna.

The main sources of Pollution of River Yamuna in National Capital Territory of Delhi are:

- The population density on the banks of Yamuna river in Delhi is increasing at an alarming rate and the residents does not follow good sanitation practices.
- Domestic waste water and industrial effluents are discharged untreated in large proportions into the river Yamuna through various drains.
- The industries discharge their effluents into the river without any treatment
- Agricultural runoff carries various pesticides and fertilizers that enters food chain and causes various disorders in humans.
- Cremation activities across the banks of river and dumping of dead bodies into the river.
- Various religious activities and immersion of idols into the river.
- Storm water also carries a large amount of pollution load with the very first rain to the river.

The current scenario of pollution in River Yamuna is that the pollutants are increasing at an alarming rate in the river and Delhi homes will have much polluted water than ever before. Delhi produces 1900 million litres per day (MLD) of sewage but the sewage collected and treated by Delhi Jal Board (DJB) is only 54 percent of the sewage generated in the city. It has been found by the comptroller and auditor general of india that there are 32 sewage treatment plants but out of these 15 are working below their capacities. The River Yamuna has been polluted by these at a much faster rate than ever before and every step taken to clean the river has failed. A river which used to have ‘clear Blue’ water but now it is one of the most polluted rivers in the world especially in the Delhi stretch. In various reports and research works now the river has been declared as “sewage drain”.

4.2 SAMPLING RESULTS

The various samples analyzed indicates the level of deterioration of the Yamuna river due to Najafgarh drain. The sample taken at Palla represents the water quality of river Yamuna before it enters national capital territory Delhi. This water is full of life and can sustain various aquatic forms and last location at Okhla is representative of the deterioration of in water quality of river Yamuna due to the various drains falling out in the river. Sample 2 is taken to analyze the various physiochemical parameters of Najafgarh drain while the sample 3 and 4 represent the water quality of river Yamuna before and after the confluence of Najafgarh drain in it respectively.

Physical factors at various sampling locations

4.2.1. Water Flow

The sampling was done in month of May (i.e. summer season) that is why the flow was slow in the various locations in rivers although the flow was recordable fast in the Najafgarh. The flow value in the pre-monsoon period has been estimated as 10.5 m^3/sec. [India-WRIS, CWC] and the value for Najafgarh drain has been found as 50m^3/sec. [Kartikeya et.al, 2014]. The dilution is observed in the river by these flow values.

4.2.2. Color

The colour of the river is usually light yellowish to greenish but it becomes dark black at the drain points and also muddy at location 5. The black colour of water in the drain at at river is due to the presence of H_2S and NH_3.

4.2.3. Water Temperature

As the sampling is done during summer season the temperature recorded at all the sampling points is above 30ºC. There was not much variation in the temperature at different locations.

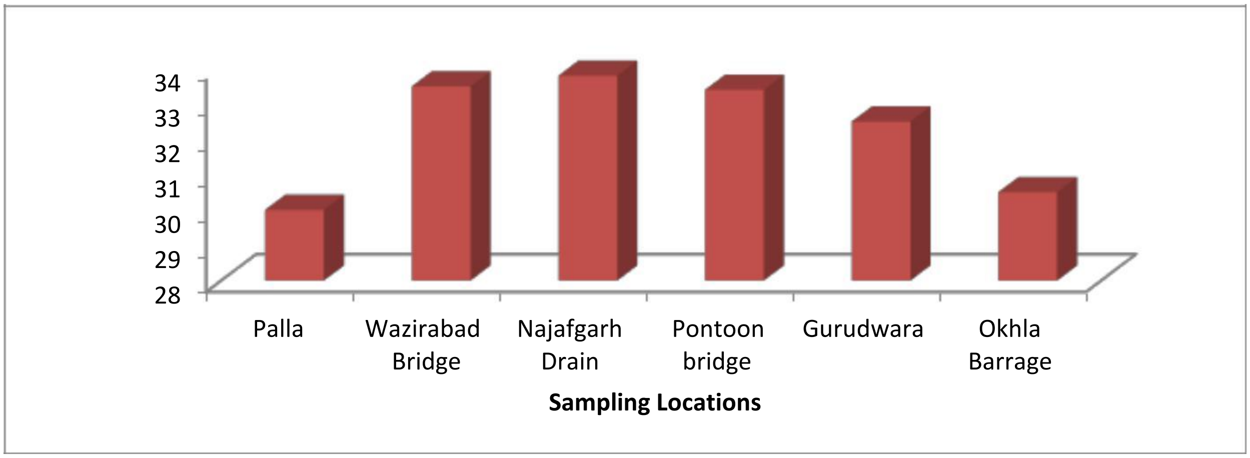


Figure.4.1. Temperature of Water at different Sampling Locations

4.2.4 Electrical Conductivity

Electrical conductivity gives the concentration of ions in the water. The EC value at different locations is related to amount of TDS i.e. various ions in the water body. In the najafgarh drain sample the conductivity was exceptionally high and the value recorded was 3750 µS/cm. the reason behind this high value of conductivity is presence of high dissolved solids and also a large quantity of continuous release of chemicals from various industries in Sonepat district of Haryana through the supplementary drain. The conductivity value recorded at Palla(upstream of Delhi) is 1693.33µS/cm whereas the value is 2680µS/cm at okhla (downstream of Delhi). The conductivity recorded at upstream of wazirabad bridge is 2066.66µS/cm whereas it is 3157.17 µS/cm and 2770µS/cm after the mixing of Najafgarh Drain in it. High conductivity is recorded at these locations due to mixing of highly conductive flow of Drains into the river.

EC of water samples at locations SIII, SIV, SV, SVI was much higher than that of the prescribed standard limits and the main reason behind this is high amount of Dissolved Solids.

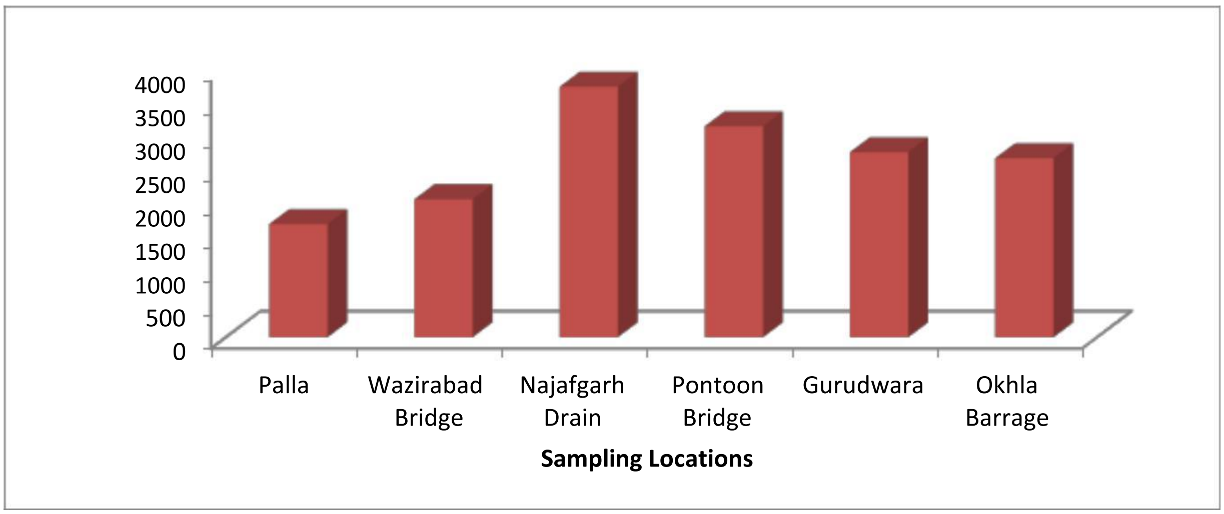


Figure 4.2. Electrical Conductivity of Samples from Various Locations

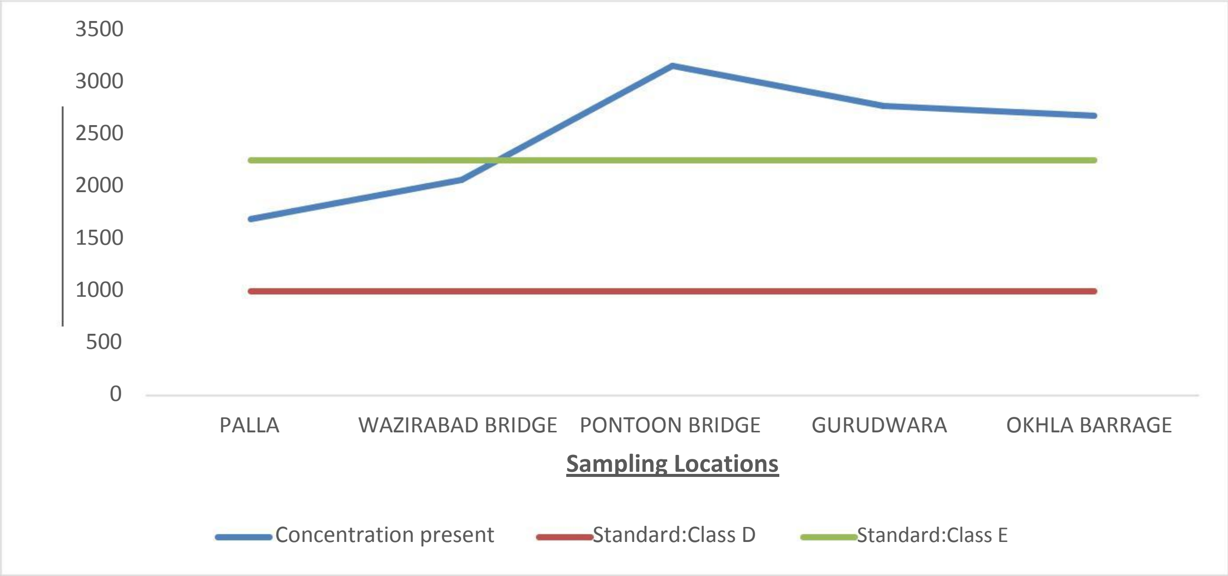


Figure 4.3 Comparison of Electrical Conductivity with Surface Water Quality Criteria

The conductivity standards for Class D and E are 1000 and 2250 µmho/cms AT 25ºC for surface water. The results shows that water at palla an wazirabad bridge have conductivity values as 1693.33 mho/cms and 2066.66 mho/cms. So the water at these locations falls under Class E as per conductivity consideration. While the conductivity at pontoon bridge and okhla barrage even exceeds the Class E standards.

Table 4.1: Physical factors at various Sampling locations

Parameters	Palla	Wazirabad bridge	Najafgarh drain	Pontoon bridge	Gurudwara	Okhla
Temperature	30.00	33.50	33.80	33.40	32.50	30.50
Water current	slow	Slow	Fast	slow	slow	Fast
Colour	muddy	black	Dark black	black	muddy	Black

4.2.5 pH (Hydrogen Ion Concentration):

Najafgarh Drain shows highest Ph value of 8.50 while in river Yamuna the lowest value was observed at palla which is 7.80. Although there was not much difference in the pH value at various locations. Higher Ph value at various locations could be due to the presence of bicarbonates and carbonates of calcium and magnesium in wastewater. Urban runoff and industrial effluent could be the main source of such pollutants. As there is high level of hardness in the river which makes the pH of the river inclined towards alkaline level. As ph rises the toxic chemicals become more soluble thereby causing harm to aquatic fauna. On the other hand low ph levels (below optimal) also stress the aquatic life in the rivers and fishes dies because of it.

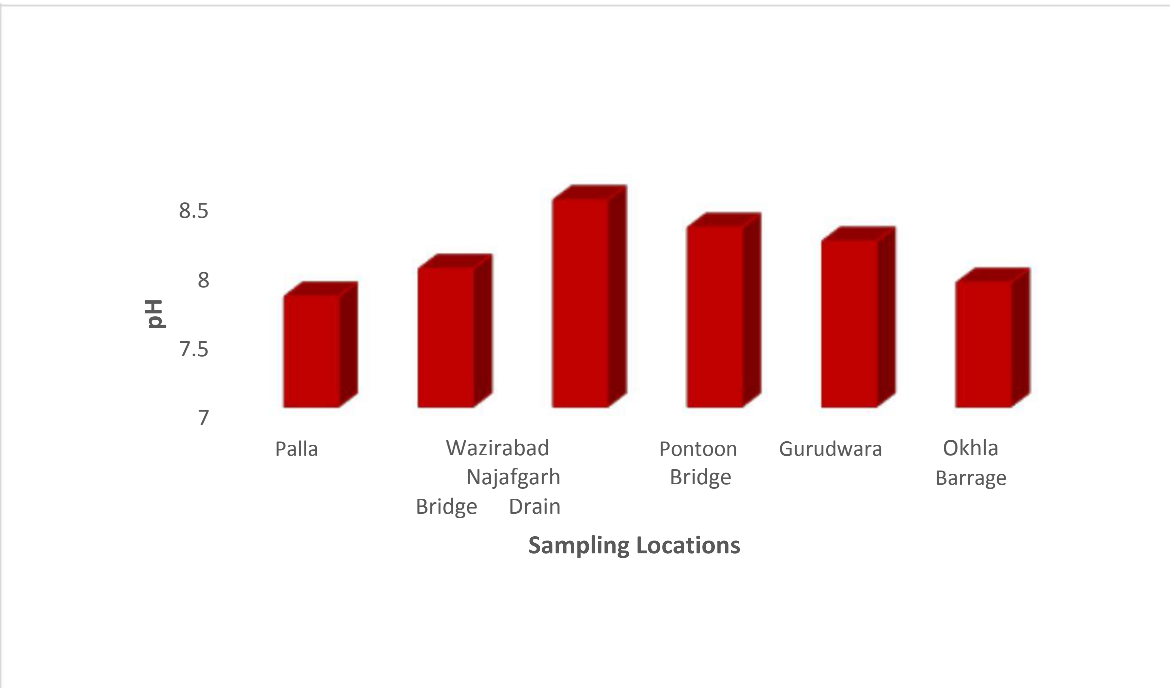


Figure 4.4: pH at various sampling locations

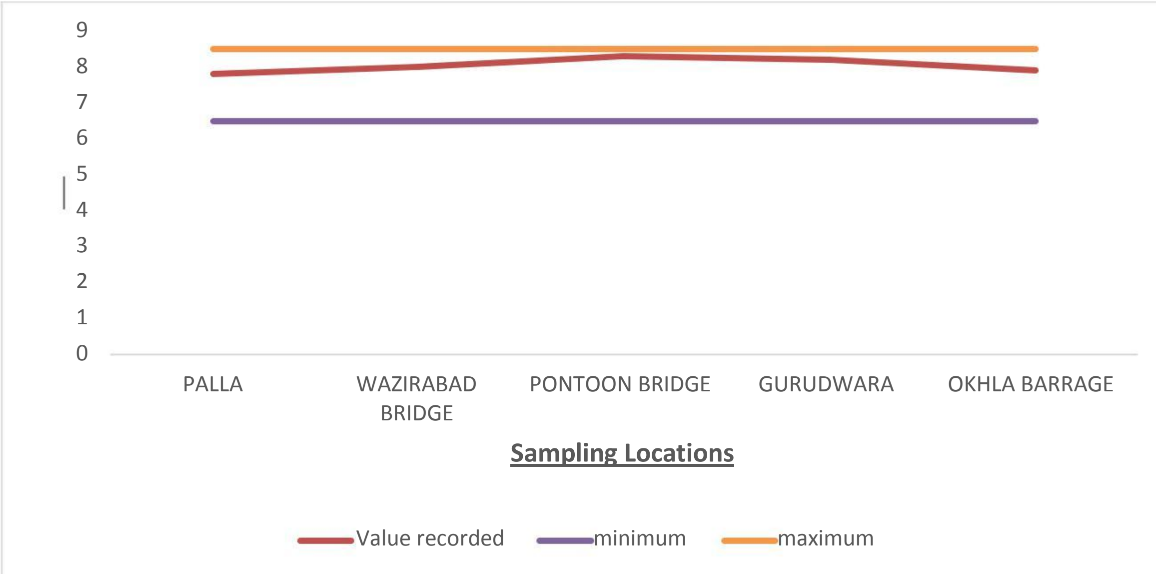


Figure 4.5 Comparison of pH with prescribed minimum and maximum value for surface water

The maximum and minimum value of pH is 6.5 and 8.5 respectively as per surface water quality criteria specified by CPCB and BIS. The pH recorded at all the sampling locations was meeting the standards.

4.2.6 Total Alkalinity

Najafgarh Drain Sample shows maximum value of Total alkalinity and the value was 720 mg/l . the value of total alkalinity at palla was lowest among the Yamuna river samples and it was found to be 200 mg/l . after the confluence of Najafagrh drain into river Yamuna the alkalinity changes from 350 mg/l (at Wazirabad Bridge) to 680 mg/l (pontoon bridge). At Gurudwara the alkalinity recorded was 580 mg/l and the final downstream location of Okhla barrage shows the alkalinity as 710 mg/l.

As per the surface water quality criteria the alkalinity should be 200 mg/l(maximum value for discharge of effluents). The value of alkalinity found was above this limit at all the locations in the river Yamuna. . The experimental results are clear indication of high concentration of Carbonates, Bicarbonates and hydroxyl ion are present at all the locations in the river Yamuna in its Delhi's stretch.

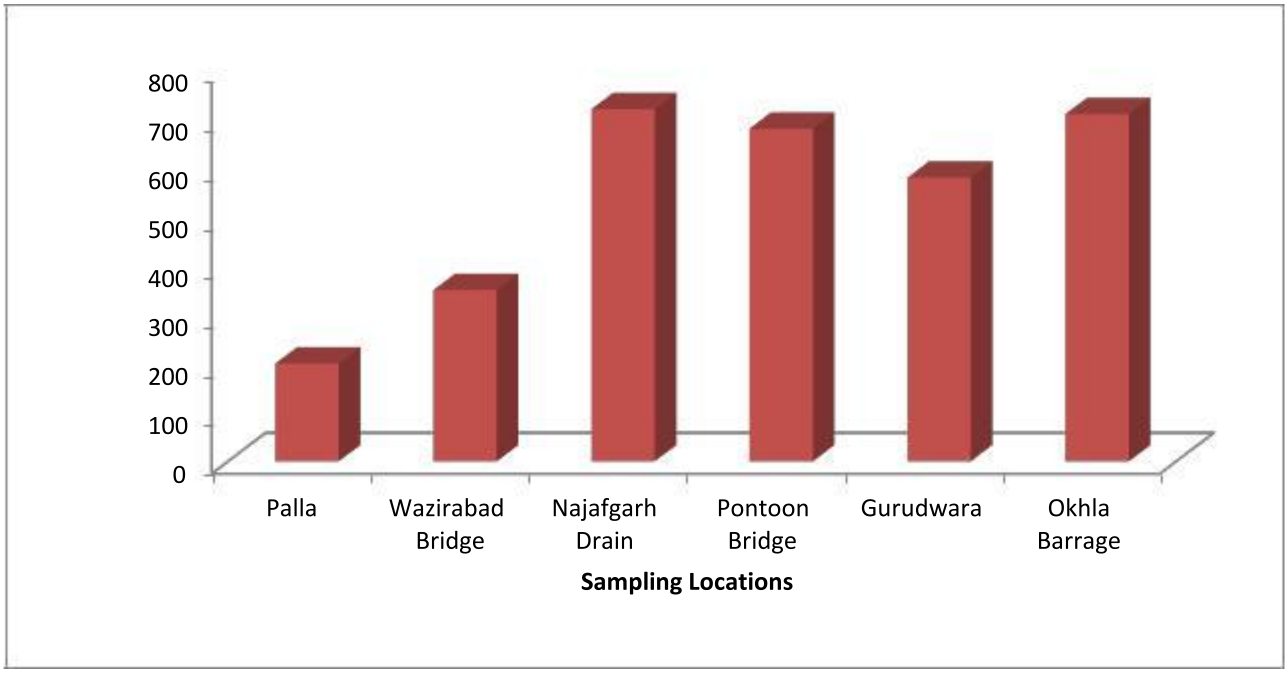


Figure 4.6 Total Alkalinity of Water at various Sampling Locations

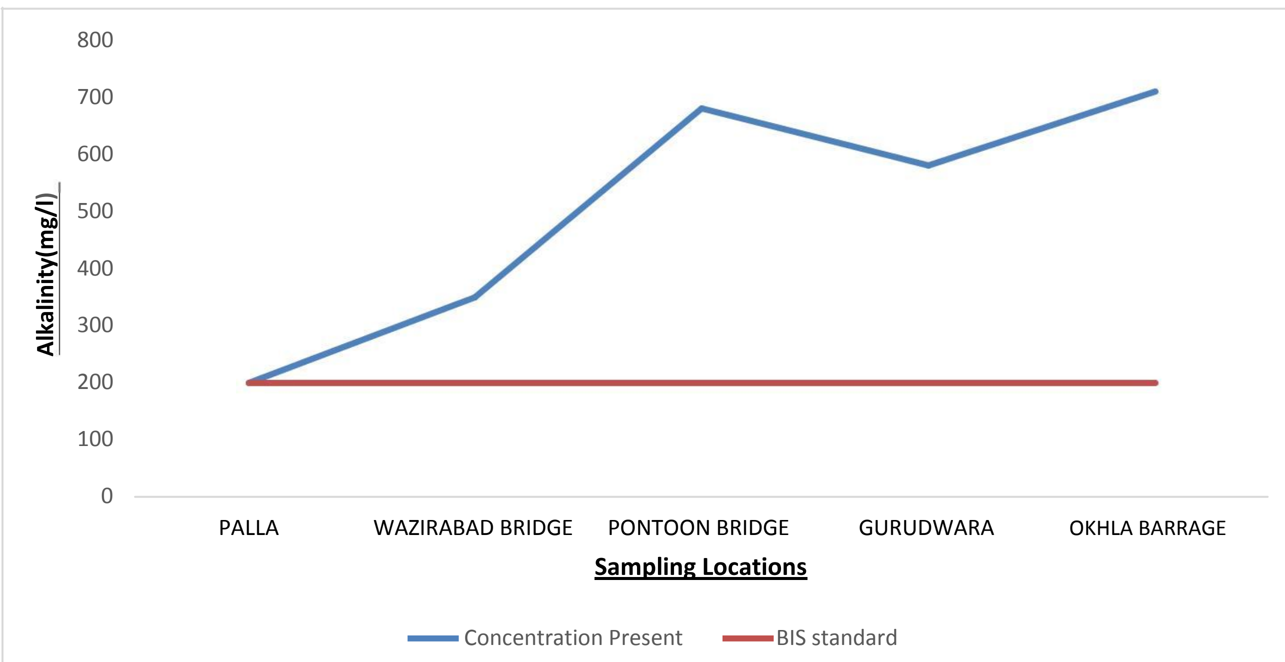


FIGURE 4.7 Comparison of Alkalinity present with standard value for surface water

4.2.7 Total Dissolved Solids

The TDS value for the drain sample was recorded as 2750 mg/l and after the mixing of drain water into the river the TDS of the river changes from 1550 mg/l(Wazirabad bridge) to 2210 mg/l (pontoon Bridge). The TDS value was found to be 2160 mg/l at Gurudwara sample. The value at the downstream point of Delhi was found to be 2100 mg/l whereas at the entry point of river in Delhi at Palla the value of TDS is 1080 mg/l. The salinity nature of water in the river is represented by the TDS. The TDS value for all the locations has been represented in Graph 4. The value of TDS was quite high in all the studied samples thus showing that a large amount of chemical pollutants has been mixed and completely dissolved in the river. As the TDS level in river increases it automatically increase the Biochemical oxygen demand (BOD) and Chemical Oxygen Demand (COD) and then reduce the Dissolved Oxygen in the river.

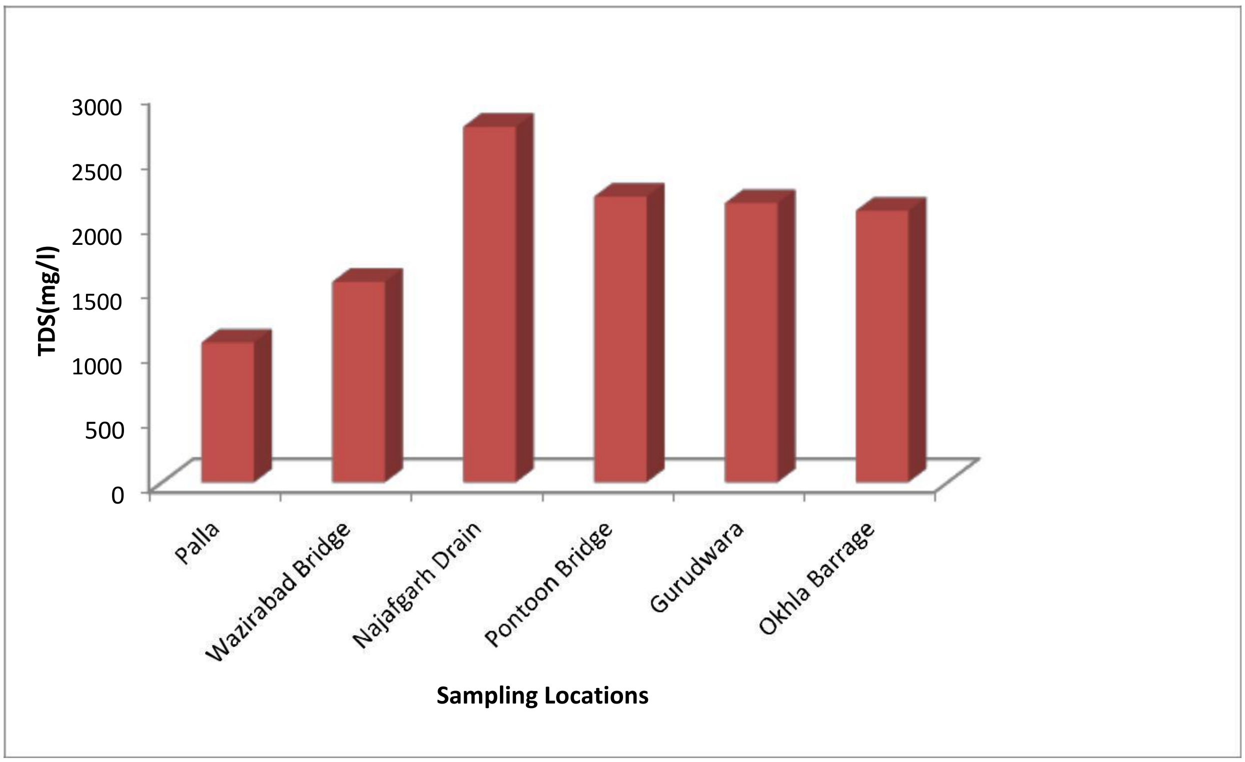


Figure 4.8 TDS in water at various sampling locations

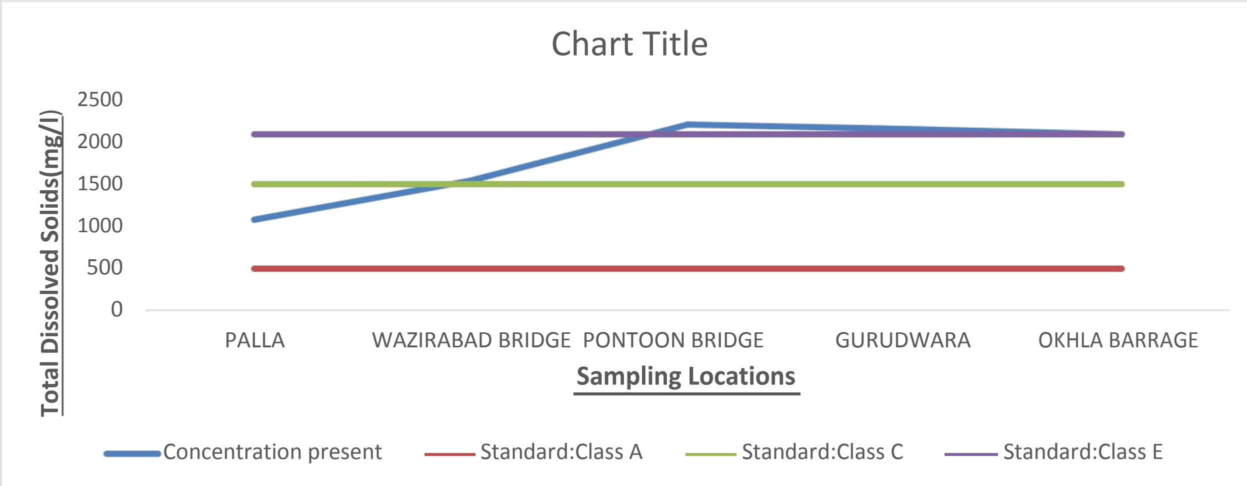


Figure 4.9 Comparison of TDS with Surface water Quality Criteria

4.2.8 Dissolved Oxygen

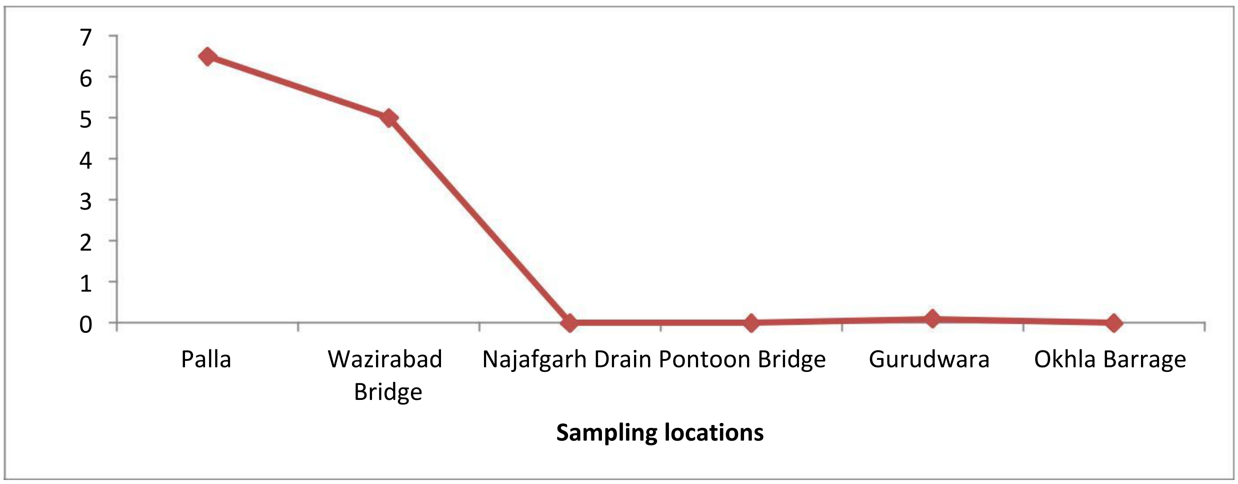


Figure 4.10 DO in water at various Sampling Locations

The Dissolved Oxygen was measured with the help of D.O. Meter. The value of D.O recorded at Palla was 6.5 mg/l . the value of D.O. decreases to 5 mg/l at Wazirabad Bridge. The D.O. value in the drain was recorded as 0 mg/l. Infact after mixing of the Drain water into the River the Dissolved oxygen in the river becomes negligible. A mere 0.1 mg/l is recorded at gurudwara. The river becomes nearly devoid of any oxygen in its entire Delhi stretch. The D.O. recorded at Okhla Barrage is also 0 mg/l. As the BOD levels are high in the Najafgarh Drain and the in the river at locations examined , the level of dissolved oxygen (DO) decreases as the oxygen available in the water is consumed by the bacteria to satisfy the Chemical and Biochemical Oxygen demand. As there is nearly negligible oxygen dissolved in water so, the experimental results clearly indicate the DO is zero. The water in the Delhi stretch of river Yamuna is thereby declared as 'Dead Water Quality'. DO is an important water quality parameter for rivers because the DO is required for aerobic oxidation of the organic matters that is being discharged as waste into the river. DO levels is also an eminent factor in the process of self-purification in rivers

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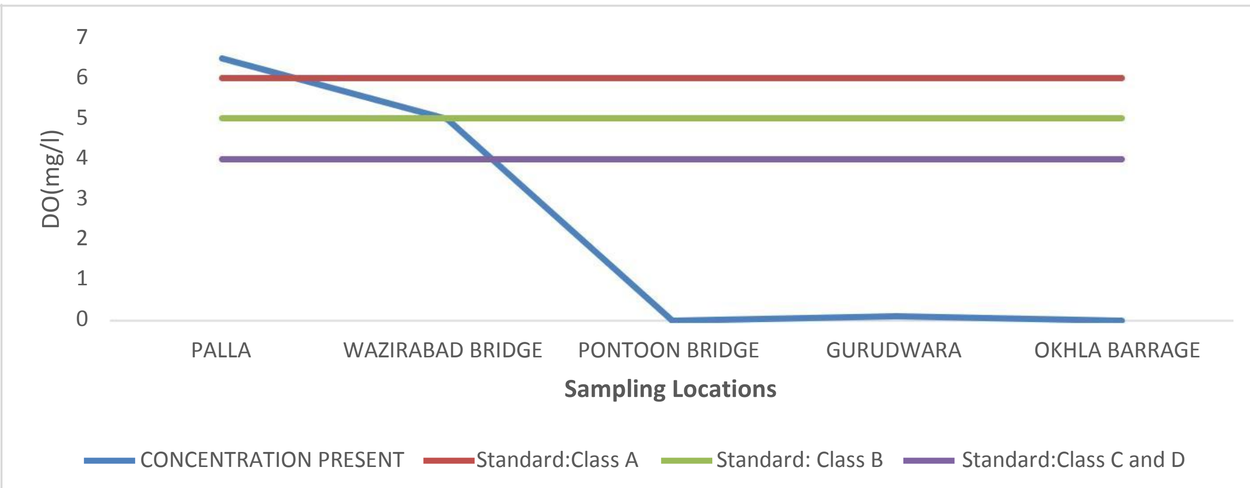

Figure 4.11 Comparison of DO with Surface Water Quality Criteria (CPCB and BIS)

4.2.9. Total Suspended Solids

TSS was measured as the residue left on the filter paper after drying in the oven at 105 degree Celsius. The maximum TSS was observed in drain which is as obvious and the value recorded is 2150 mg/l. The suspended solids changes drastically in the river from Palla to Okhla and the values recorded are 120 mg/l at Palla and 1800 mg/l at Okhla. The Najafgarh Drain added a considerable amount of TSS to the river Yamuna as due to the mixing of drain the TSS values observed before and after confluence were 500 , 1890 and 1700 mg/l respectively.

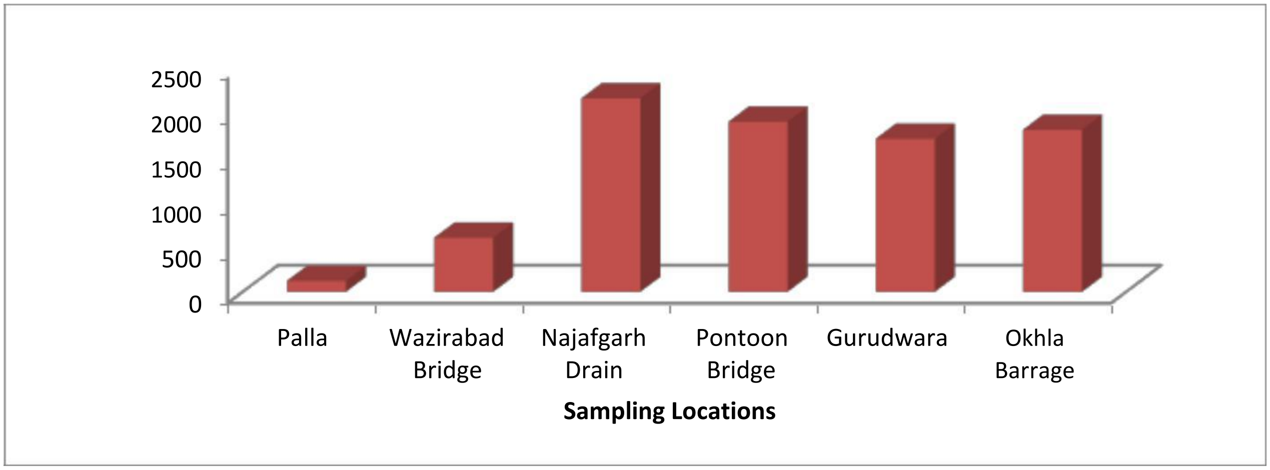

Figure 4.12 TSS at various Sampling Locations

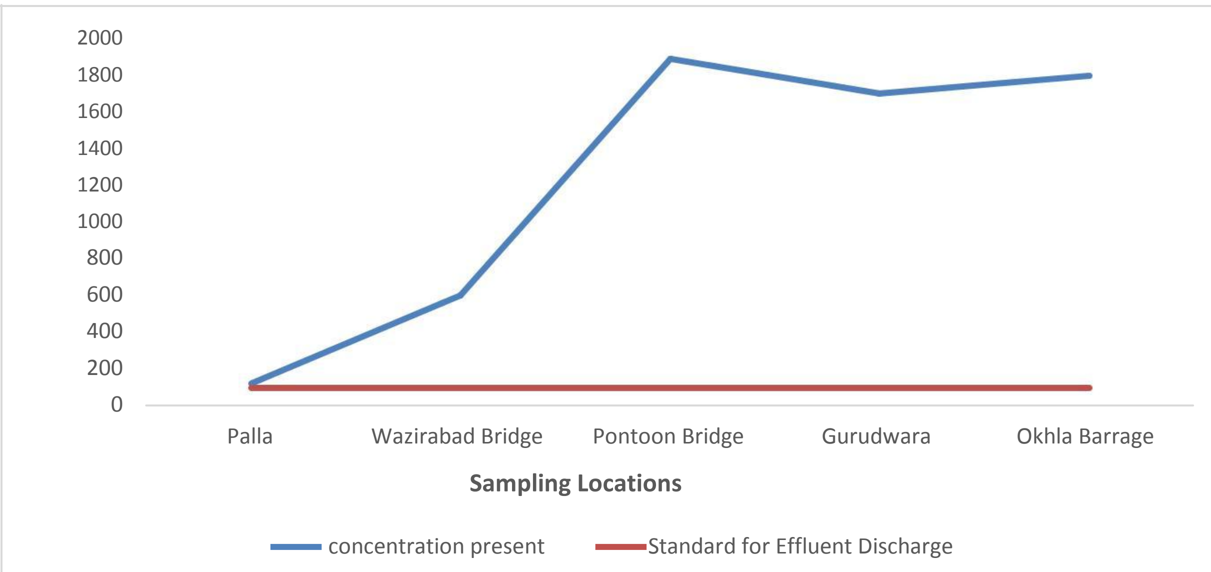

Figure 4.13 Comparison of TSS with Surface Water Quality Criteria

4.2.10 Hardness

The experimental value observed for Palla sample was 120 mg/l and on the other hand it was 556 mg/l at Okhla barrage. For Najafgarh Drain the hardness was calculated as 550 mg/l. The hardness in the Delhi stretch of the river was almost equivalent in all the samples showing average value of nearly 530 mg/l.

Hardness is added to the water by various dissolved multivalent cations in water. These cations are being discharged by industries through their effluents into the river. The hardness value in Yamuna river is comparable with the value of hardness in Najafgarh Drain. This clearly indicates that water quality of river is same as that of drain. The results shows that urban runoff and industrial effluents are the major contributor in polluting the quality of water in Yamuna river.

As per CPCB Guide Manual for Waste Water Analysis, the water can be characterized into following categories based on hardness value:

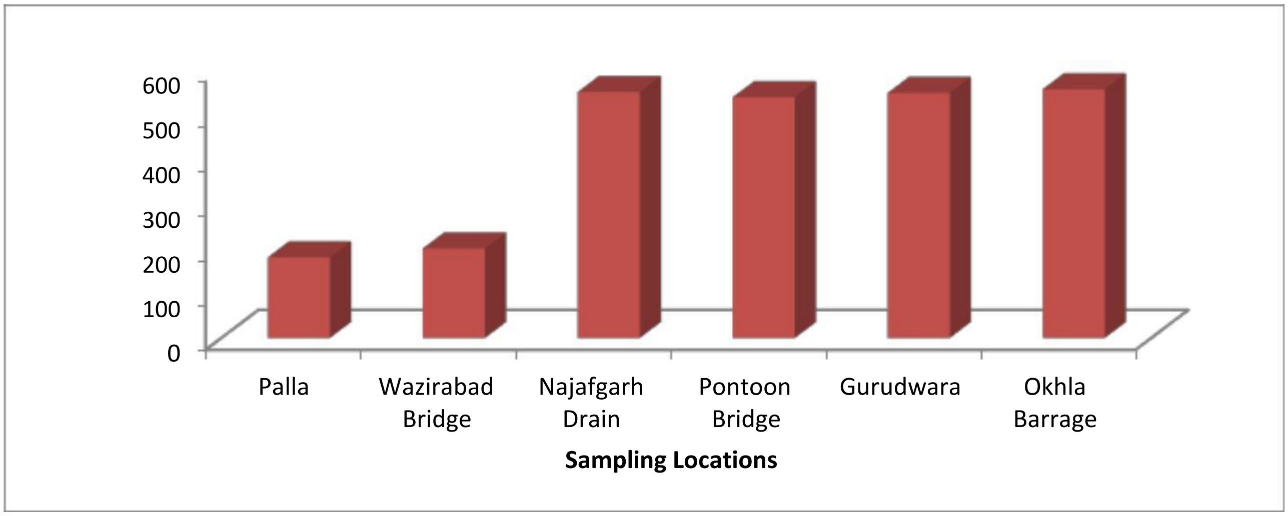

Figure 4.14: Hardness in water at various Sampling Locations

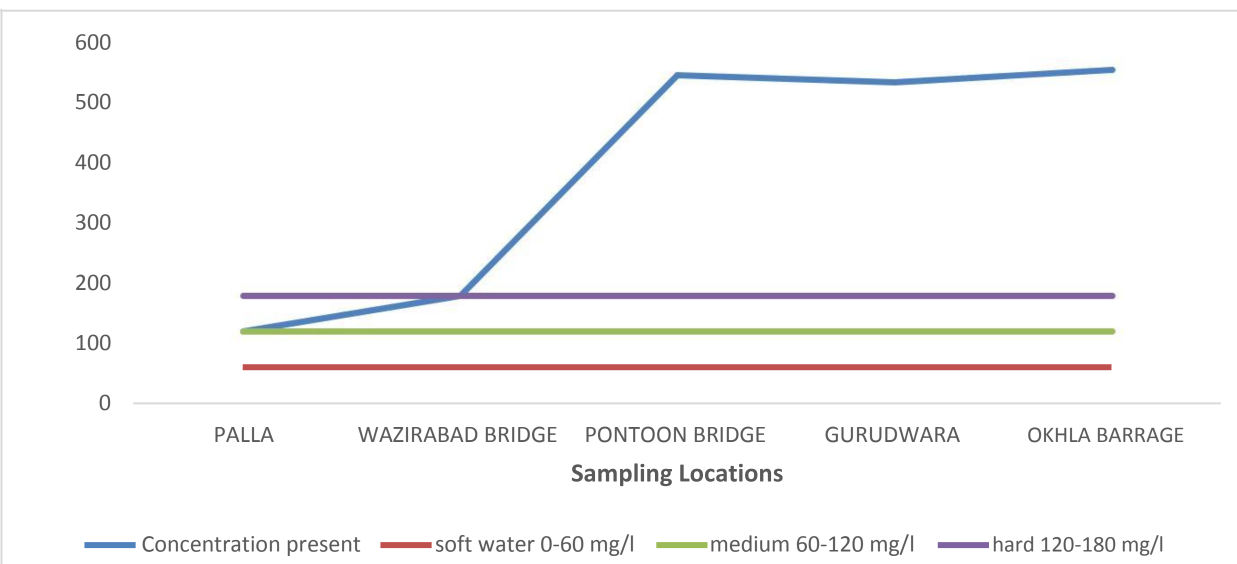

Figure 4.15 Comparison of Hardness with CPCB Standards

4.2.11 Chlorides

The value estimated after lab tests was 600 mg/l for Najafgarh Drain. The chloride concentration in Yamuna river sample changes from 240 mg/l to 540 mg/l after the confluence of Najafgarh drain in it. The Palla sample gives chloride Value of 90 mg/l whereas at Okhla Barrage the concentration increases to upto 550 mg/l.

As per surface water quality criteria specified by CPCB and BIS, the chlorides(max) beyond 250 mg/l for Class A and 600 mg/l for Class C and E are undesirable. The water quality at Palla and Wazirabad Bridge satisfies the criteria for Class A , C and E while the water present at other sampling locations is fit for Class C and E.

The chloride in limited amount is useful for water but the concentration of chlorides was quite high at the sampling locations making the water fit for only irrigation purposes. This high amount of chlorides also indicated that urban runoff has been directly dumped into the river without any treatment.

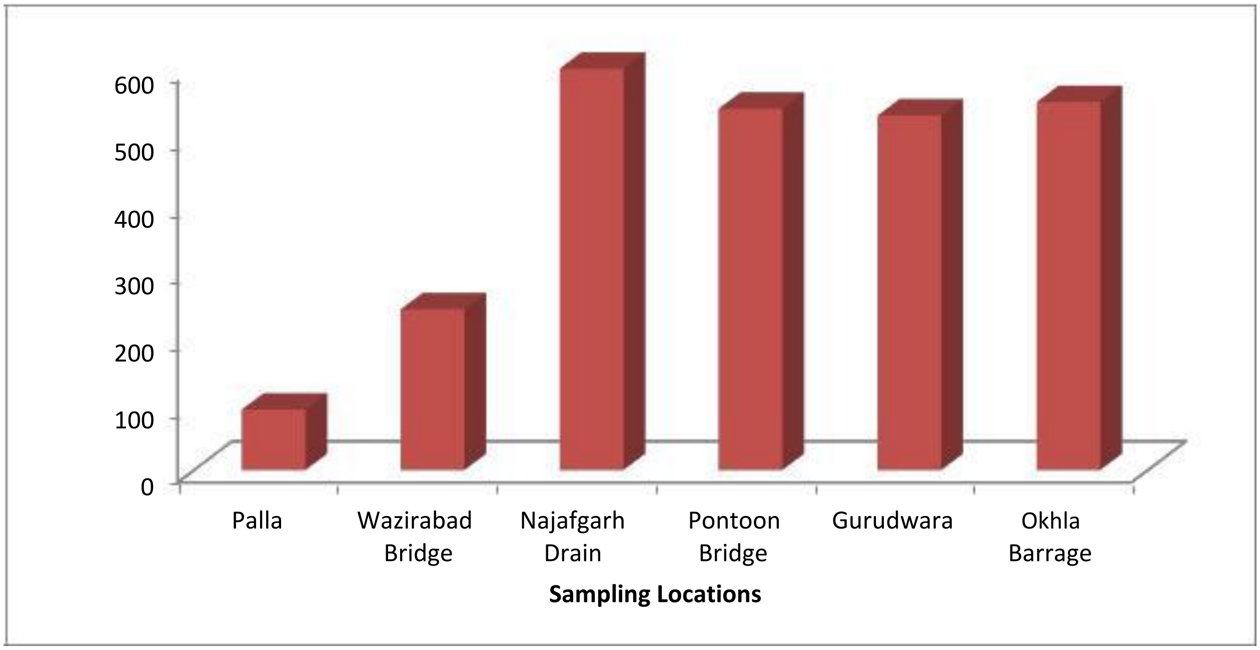

Figure 4.16: Chlorides at various Sampling Locations

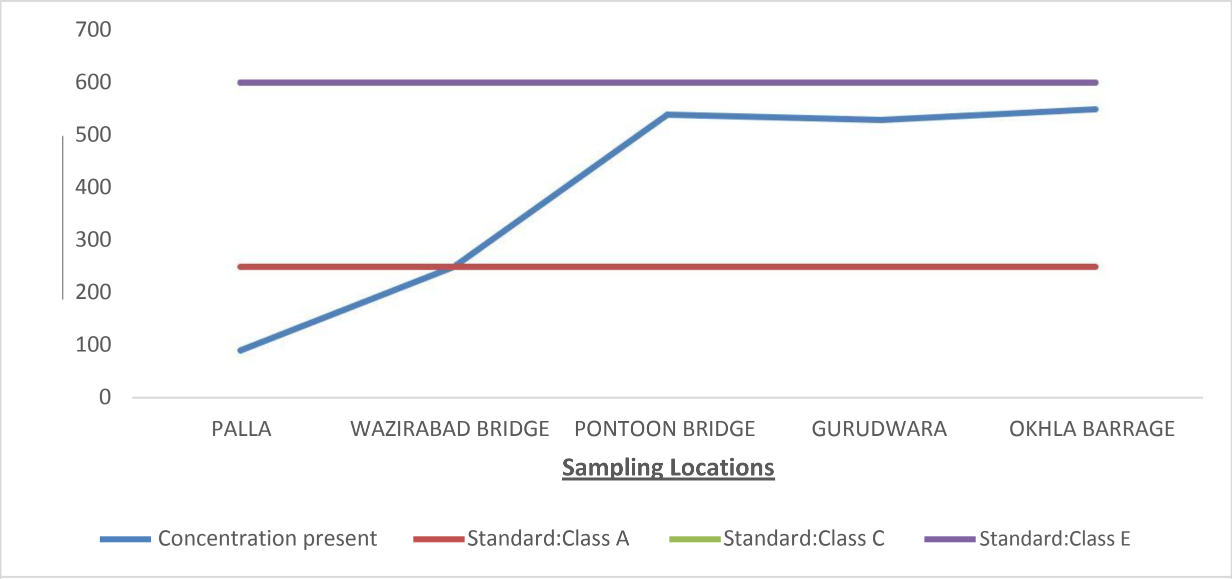

Figure 4.17: Comparison of Chlorides results with standards.

4.2.12 BIOCHEMICAL OXYGEN DEMAND (BOD)

The 5 day BOD value for all the samples was measured. The test results for river at various locations vary strongly ranging from a value of 6 mg/l to a maximum of 68 mg/l. the biochemical oxygen demand (BOD) value experimentally calculated for drain was 75 mg/l. The high value of BOD in the drain indicates that the pollution level is significantly high. This high level of contamination leads to more consumption of oxygen in the river which is clearly shown by BOD and DO results. The BOD at palla was found 6 mg/l while at Okhla(downstream of Delhi), the value has increased to 45 mg/l because of the effluents from various drains which carry industrial and municipal wastes to the river. The pollution load added from various drains , industries and other practices has deteriorated the water quality in the drain considerably. The value for the samples tested was above the prescribed standards. The BOD at upstream of Wazirabad Bridge was 10 mg/l whereas after the Najafgarh Drain discharges into the river, the BOD increases to 68 mg/l at Pontoon Bridge and a value of 66 mg/l was found for Gurudwara sample. BOD was found well above the limit of 3 mg/l in the river Yamuna due to this reason the D.O. has depleted significantly after Wazirabad Barrage and the value remain critical in the remaining part of the studied river stretch.

As per surface water quality criteria specified by CPCB and BIS the BOD(max) above 2 mg/l for Class A and 3 mg/l for Class B and C is undesirable. The results indicated that BOD is higher than prescribed standards for all the sampling locations and the water quality does not falls in any of the Classes from A, B or C .so this water can not be used for any other purpose except irrigation and industrial cooling.

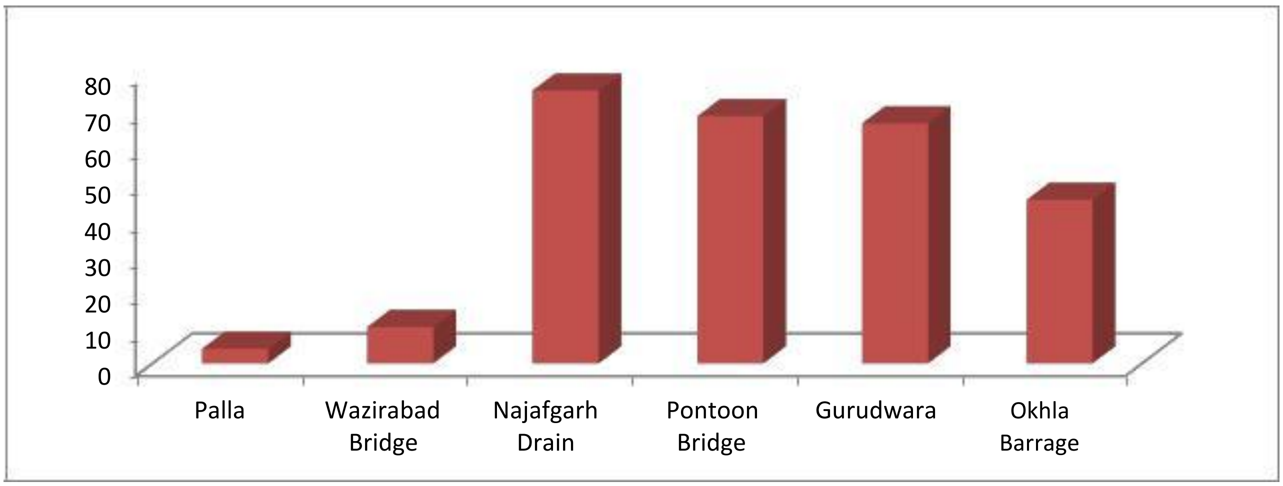

Figure 4.18 BOD at various Sampling Locations

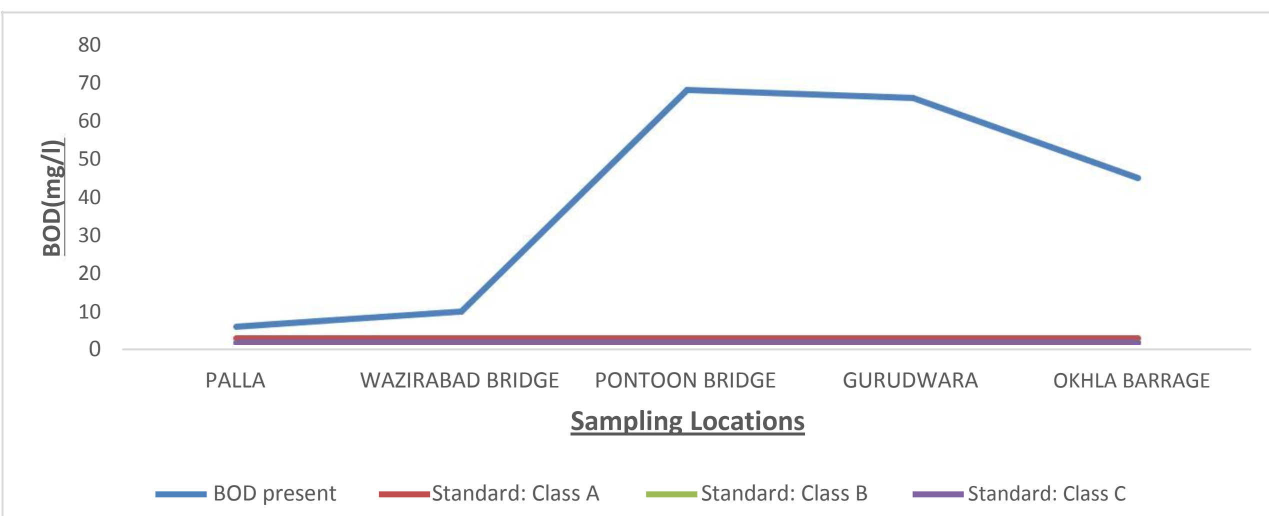

Figure 4.19 Comparison of BOD with Surface Water Quality Criteria

4.2.13 CHEMICAL OXYGEN DEMAND

COD is also an important parameter for surface water quality and it indicates the health of water bodies. It is indicative of total oxygen required for degradation of organic matter whether biodegradable or non biodegradable. COD increases drastically after the Najafgarh drain mixes with the river and then the COD was found to be higher than the desired concentration in the entire stretch of river. there exists an inverse relationship between COD and DO. As the COD is high in the river therefore it makes the DO negligible. The high value of COD indicates the water is polluted by various toxins.

As per the standards specified for surface water effluent discharged in the river the COD specified is 100 mg/l. The value of COD in Najafgarh Drain is 550 mg/l. As per COD criteria the water at Palla is of desired quality only and at the other locations the values are far beyond the standards. After confluence of Najafgarh Drain the COD changes from 150 mg/l to 470 mg/l. The pollution load from Delhi changes the COD from 70 mg/l at Palla to 430 mg/l at Okhla Barrage.

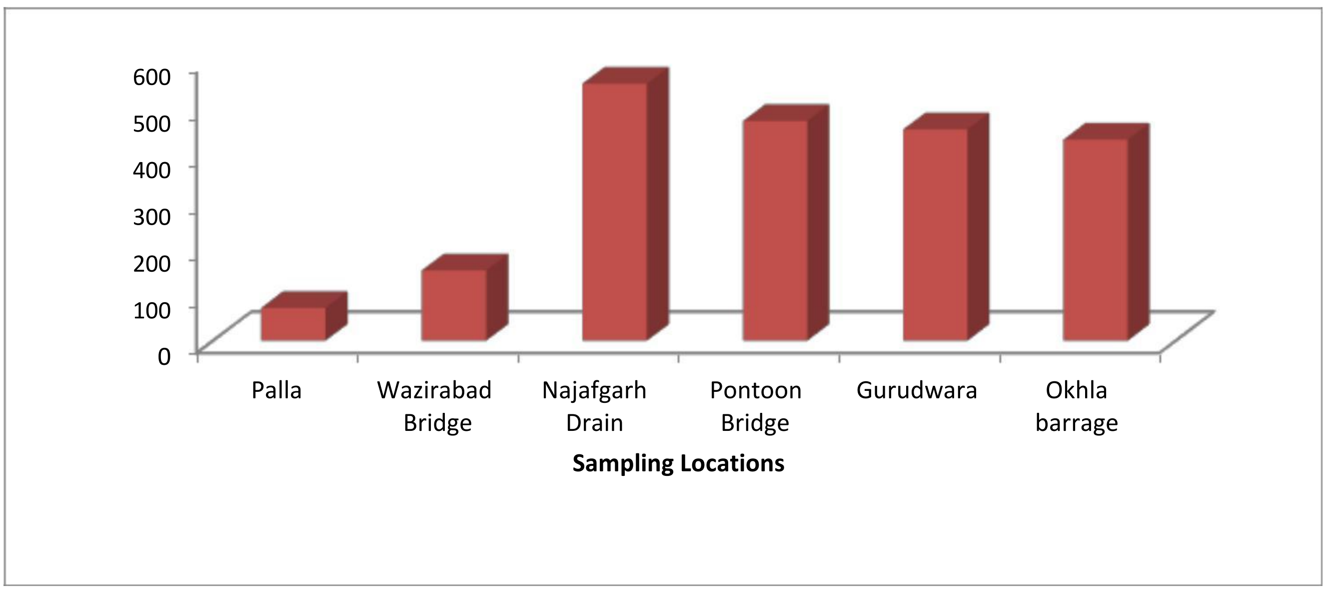

Figure 4.20: COD value at various Sampling Locations

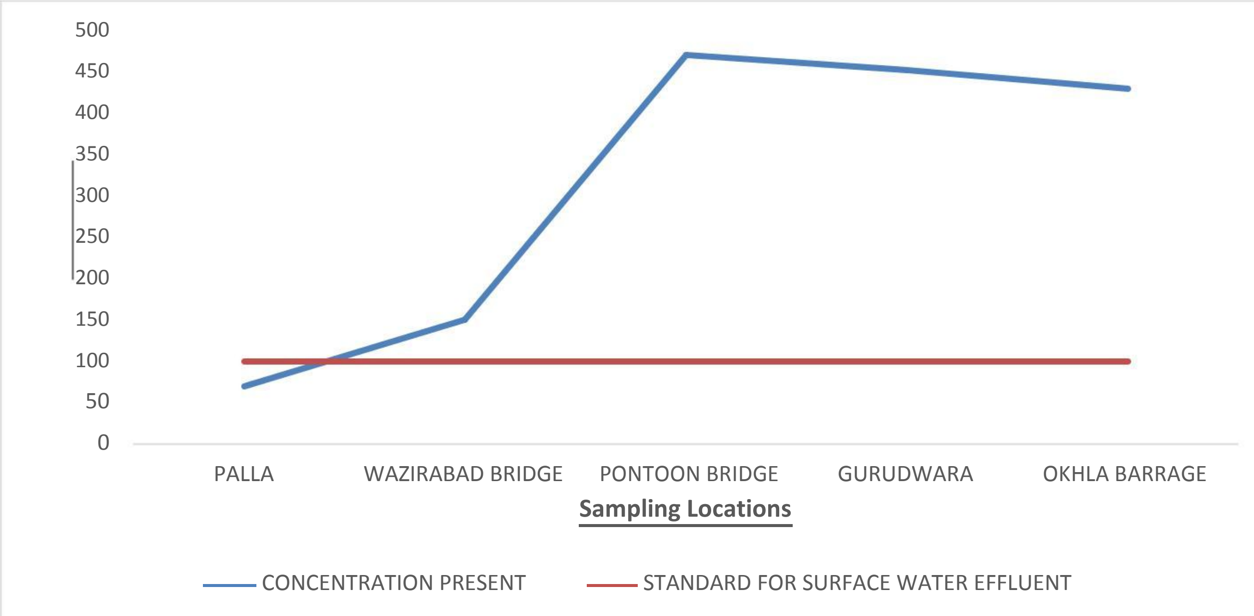

Figure 4.21 Comparison of COD value with Surface Water Quality Criteria

4.2.14 NITRATE

Nitrates if present at normal level in water does not have direct effect on aquatic insects or fishes unlike temperature and dissolved oxygen. But if nitrates are present in excess , then it creates difficult conditions and makes survival of aquatic insects and fishes difficult. The nitrate value recorded for Palla sample is 13.5 mg/l which is normal and thereby aquatic life sustains there, but in Delhi stretch of river because of addition of water from various drains the nitrate level recorded is beyond permissible limits. For Najafgarh drain the value of nitrate recorded is 234.56 mg/l. this high value is because the drain carries waste water discharge from various agricultural activities undergoing in its way from Alwar to Delhi. As various fertilizers used in agricultural operations contain nitrates and this nitrate is being discharged along with rain water to the nearby drains and streams and ultimately to the river Yamuna. The discharge from Najafgarh increases the Nitrate levels in the river Yamuna to quite high levels as before the confluence of drain into the river the nitrate level recorded is 38.5 mg/l whereas after confluence the value increases to 186.43 mg/l (pontoon Bridge) and 105.87 mg/l (Gurudwara). As in its entire Delhi stretch, river Yamuna receives discharge from various drains so the ultimate value of nitrate recorded at Okhla barrage is 105.87 mg/l which is also beyond permissible limits. As the nitrate contamination level is quite high in the river, therefore accumulation of organic matter has occurred. The excess growth of nitrates has lead to high growth of algae on the surface of river and thereby blocking the sunlight to penetrate the water and ultimately destroys the aquatic flaura and fauna. The dead organic matter must have settled at the bottom and that is why DO level in the river has been recorded as zero as the oxygen dissolved in water has been consumed by bacteria in decaying the organic matter. Due to absence of oxygen aquatic life in the river could not survive.

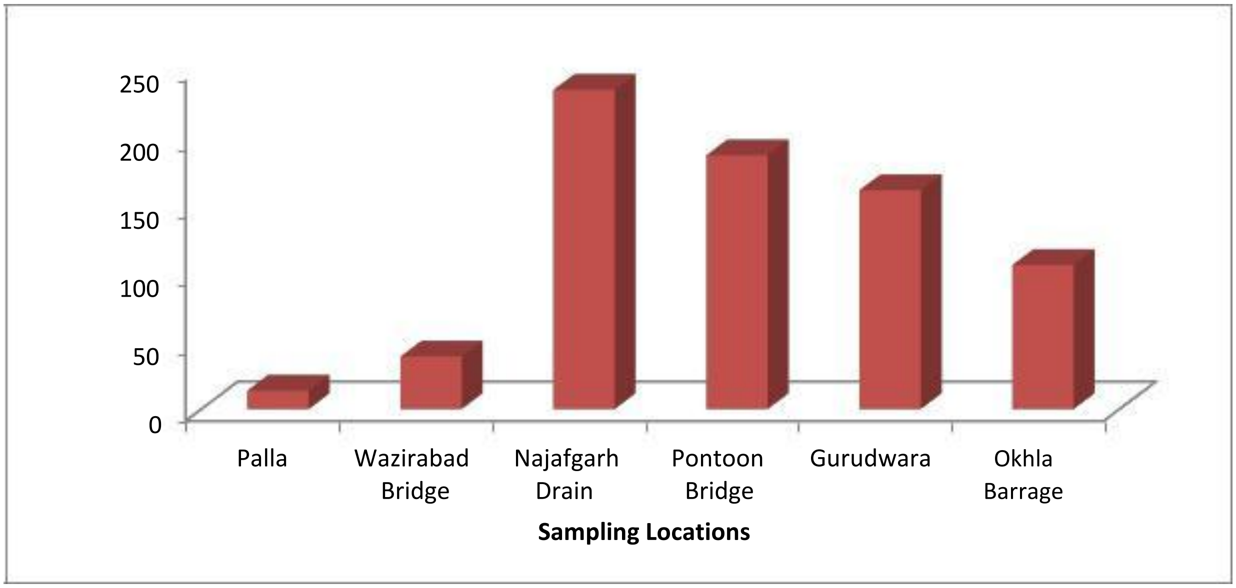

Figure 4.22 Nitrates at various Sampling Locations

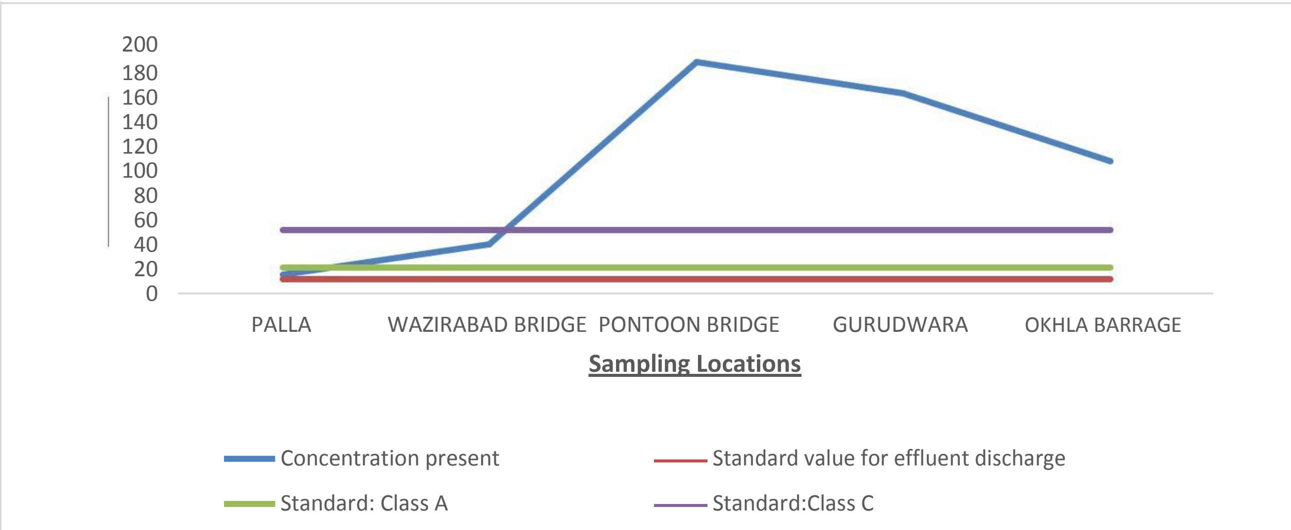

Figure 4.23 Comparison of Nitrate Concentration with Surface Water Quality Criteria

Table 4.2 Chemical Analysis Result at various Sampling Locations

Parameters	Palla	Wazirabad Bridge	Najafgarh Drain	Pontoon Bridge	Gurudwara	Okhla Barrage
Ph	7.8	8.0	8.5	8.3	8.2	7.9
TA	200	350	720	680	580	710
TDS	1080	1550	2750	2210	2160	2100
TSS	120	600	2150	1890	1700	1800
D.O.	6.5	5.0	0.0	0.0	0.1	0.0
Hardness	120	180	550	548	535	556
Chlorides	90	250	600	540	530	550
B.O.D.	6	10	75	68	66	45
Conductivity	1693.33	2066.66	3750	3157.15	2770	2680
C.O.D.	70	150	550	470	452	430
Nitrates	13.5	38.5	234.56	186.43	160.75	105.87

4.3 WQI ANALYSIS

The first step in calculation of WQI following ‘weighted arithmetic index’ method involves the estimation of ‘unit weight’ assigned to each physico-chemical parameter considered for the calculation. By assigning unit-weights, all the concerned parameters of different units and dimensions are transformed to a common scale. Maximum weight, i.e. 0.3032436 is assigned to both DO and BOD, thus suggesting the key significance of these two parameters in water quality assessment and their considerable impact on the index.

TABLE 4.3 CALCULATION OF WQI AT PALLA

Parameter		Vn	Vs	1/Vn	Wn	Qn	QnWn
TDS		1080	500	0.002	0.003	216.000	0.655
pH		7.8	8.5	0.117	0.178	53.333	9.513
Cl		90	250	0.004	0.006	36.000	0.218
TA		200	120	0.008	0.012	166.666	2.105
Hardness		120	300	0.003	0.005	40.000	0.202
Nitrate		13.5	45	0.022	0.033	30.000	1.010
TSS		120	500	0.002	0.003	24.000	0.072
DO		6.5	5	0.2	0.303	84.370	25.586
BOD		6	5	0.2	0.303	120.00	36.389
COD		70	10	0.1	0.151	700.00	106.135
				0.659536	1.000		181.889
			K=	1.516218		WQI=	181.8891

Table 4.4 CALCULATION OF WQI AT WAZIARABAD BRIDGE

Parameter		V	Si	1/Si	Wi	Qi	WiQi
TDS		1550.000	500.000	0.002	0.003	310.000	0.877
pH		8.000	8.500	0.118	0.166	66.667	11.091
Cl		250.000	250.000	0.004	0.006	100.000	0.566
TA		350.000	120.000	0.008	0.012	291.667	3.437
Hardness		180.000	300.000	0.003	0.005	60.000	0.283
NO3		38.500	45.000	0.022	0.031	85.556	2.689
TSS		600.000	500.000	0.002	0.003	120.000	0.339
DO		5.000	5.000	0.200	0.283	100.000	28.283
BOD		10.000	6.000	0.167	0.236	166.667	39.281
COD		150.000	10.000	0.100	0.141	1500.000	212.120
				0.626	0.886		298.966
			K=	1.597		WQI=	337.611

Table 4.5 CALCULATION OF WQI AT PONTOON BRIDGE

Parameter		V	Si	1/Si	Wi	Qi	WiQi
TDS		2210.000	500.000	0.002	0.003	442.000	1.250
pH		8.300	8.500	0.118	0.166	86.667	14.419
Cl		540.000	250.000	0.004	0.006	216.000	1.222
TA		680.000	120.000	0.008	0.012	566.667	6.678
Hardness		548.000	300.000	0.003	0.005	182.667	0.861
NO3		186.430	45.000	0.022	0.031	414.289	13.019
TSS		1890.000	500.000	0.002	0.003	378.000	1.069
DO		0.000	5.000	0.200	0.283	152.083	43.013
BOD		68.000	5.000	0.200	0.283	1360.000	384.644
COD		470.000	10.000	0.100	0.141	4700.000	664.643
				0.660	0.933		1130.818
			K=	1.516		WQI=	1212.450

Table 4.6 CALCULATION OF WQI AT GURUDWARA

Parameter		Vn	Vs	1/Vs	Wn	Qn	WiQn
TDS		2160.000	500.000	0.002	0.003	432.000	1.222
pH		8.200	8.500	0.118	0.166	80.000	13.309
Cl		530.000	250.000	0.004	0.006	212.000	1.199
TA		580.000	120.000	0.008	0.012	483.333	5.696
Hardness		535.000	300.000	0.003	0.005	178.333	0.841
NO3		160.750	45.000	0.022	0.031	357.222	11.226
TSS		1700.000	500.000	0.002	0.003	340.000	0.962
DO		0.100	5.000	0.200	0.283	151.042	42.719
BOD		66.000	5.000	0.200	0.283	1320.000	373.331
COD		452.000	10.000	0.100	0.141	4520.000	639.188
				0.660	0.933		1089.692
			K=	1.516		WQI=	1168.356

Table4.7 CALCULATION OF WQI AT OKHLA BARRAGE

Parameter		V	Si	1/Si	Wi	Qi	WiQi
TDS		2100.000	500.000	0.002	0.003	420.000	1.274
pH		7.900	8.500	0.118	0.178	60.000	10.703
Cl		550.000	250.000	0.004	0.006	220.000	1.334
TA		710.000	120.000	0.008	0.013	591.667	7.476
Hardness		556.000	300.000	0.003	0.005	185.333	0.937
NO3		105.870	45.000	0.022	0.034	235.267	7.927
TSS		1800.000	500.000	0.002	0.003	360.000	1.092
DO		0.000	5.000	0.200	0.303	152.083	46.118
BOD		45.000	5.000	0.200	0.303	900.000	272.919
COD		430.000	10.000	0.100	0.152	4300.000	651.974
				0.660	1.000		1001.753
			K=	1.516		WQI=	1001.753

TABLE 4.8 SUMMARY OF WQI AT VARIOUS SAMPLING LOCATIONS

Sampling location	WQI	WQS
Palla	181.8891	Unsuitable for any purpose without proper treatment
Wazirabad Bridge	339.0792	Unsuitable for any purpose without proper treatment
Pontoon Bridge	1212.45	Unsuitable for any purpose without proper treatment
Gurudwara	1168.356	Unsuitable for any purpose without proper treatment
Okhla Barrage	1001.753	Unsuitable for any purpose without proper treatment

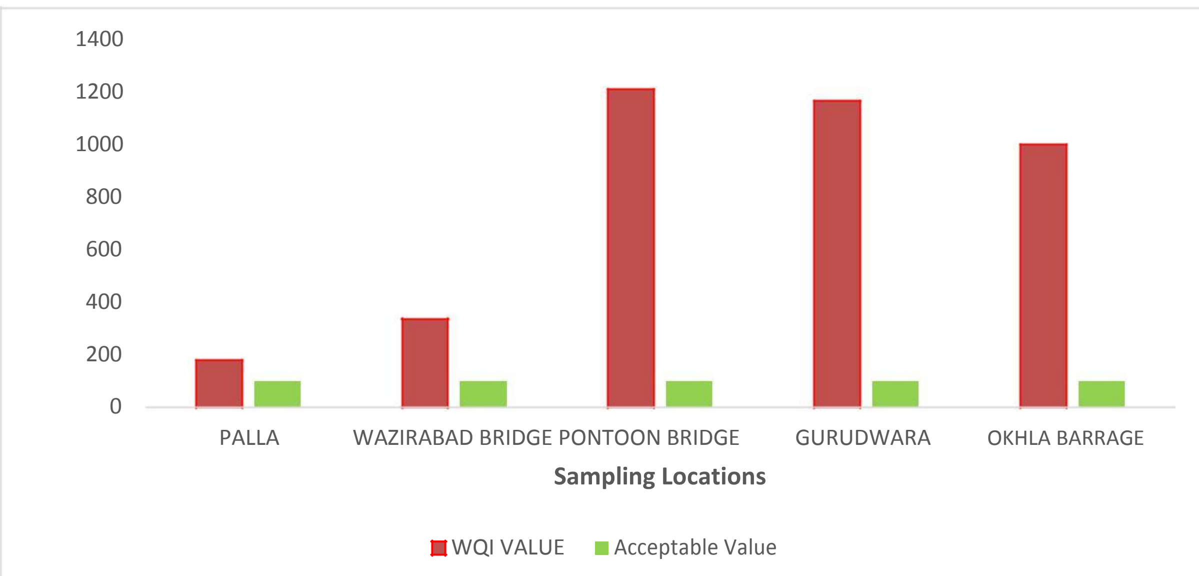

Figure 4.24 Comparison of WQI with acceptable limit

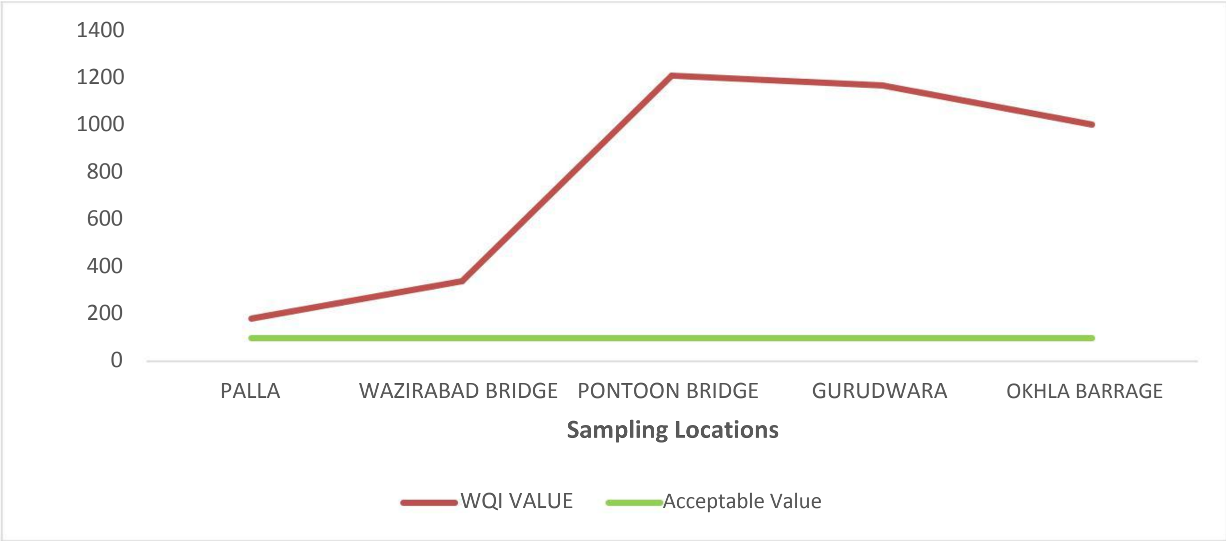

Figure 4.25 Comparison of WQI value with acceptable limit

The WQI is above the prescribed standards at all the locations of river Yamuna. As per WQI criteria this water is therefore unsuitable for any purposes without proper treatment. The contamination level of Yamuna has increases to very high levels so to take the water quality upto prescribed standards needs highly efficient treatment system.

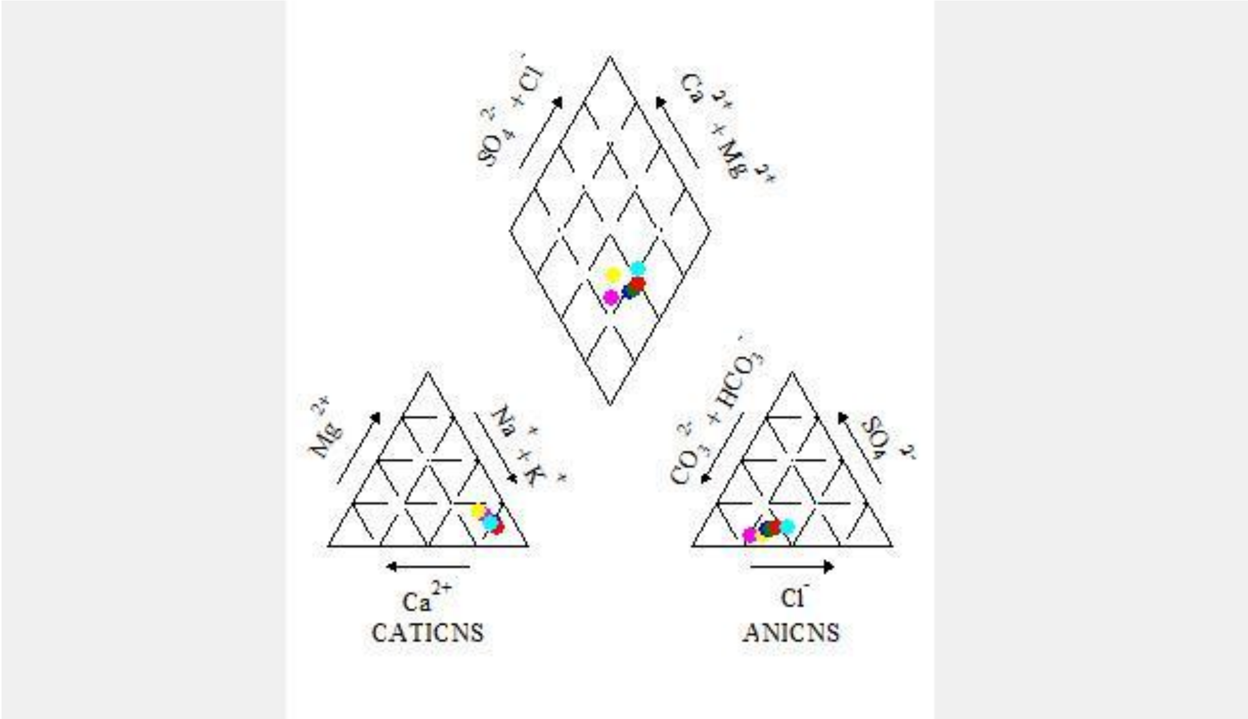

Figure 4.26 Piper Diagram

4.4 SUITABILITY FOR IRRIGATION

Various parameters which are required for the suitability analysis for irrigation were analysed. The parameters used for the purpose are; electrical conductivity, sodium adsorption ratio, sodium percent, residual sodium carbonate, magnesium ratio and Kelly's ratio. U.S. Salinity Laboratory Diagram and Wilcox Diagrams were also prepared.

4.4.1 Electrical Conductivity

Electrical conductivity is very important for the estimation of salinity hazards to the crops. EC is also studied as a reflection of TDS in the water. The quality of irrigation water based on EC has been shown in Table 4.9 **(Raghunath 1987)**

Table 4.9 Quality of irrigation water based on Electrical Conductivity

Quality of Water	Electrical conductivity (micromhos/cm)
Excellent (C1)	<250
Good (C2)	250-750
Doubtful (C3)	750-2250
Unsuitable (C4)	>2250

4.4.2 Sodium Absorption Ratio (SAR)

SAR is defined by U.S. Salinity Laboratory (1954) where the ion concentrations are expressed in milliequivalents per liter. SAR value gives an idea about the extent to which the irrigation water is going to enter into cation-exchange reaction in the soil. High SAR value is indication of sodium hazard and replacement of adsorbed calcium and magnesium.This causes high damage to soil structure. SAR is expressed as

$SAR = Na^{+} / [(Ca^{2+}Mg^{2+})/2)]^{1/2}$.

All the concentrations are in meq/l.

The water at Palla can be used for irrigation and is is suitable for all kinds of crops. (S1) and also at Wazirabad the SAR value is within acceptable limits for irrigation. After the confluence of Najafgarh Drain the sodium content has increased drastically and the SAR value has increased to 21.4(S3), 19.4(S3), 18.5(S3) at Pontoon Bridge, Gurudwara and Okhla Barrage making the water harmful for almost all types of soil. This type of water is characterized as high Sodium water. The US Salinity Lab Diagram has been prepared for more detailed analysis as shown in Figure 4.27. The US salinity lab's diagram (US Salinity Lab Staff, 1954) is widely used for rating irrigation waters, where SAR is plotted against EC. The analytical data plot is shown in Figure 4.27.

Table 4.10 Classification of Irrigation water based on SAR

S.No.	Types of Water	SAR Value	Quality	Suitability for irrigation
1.	Low Sodium Water(S1)	0-10	Excellent	Suitable for all types of crops and all types of soils, except for those crops which are sensitive to sodium.
2.	Medium Sodium Water(S2)	10-18	Good	Suitable for all types of crops and all types of soils, except for those crops which are sensitive to Sodium.
3.	High Sodium Water(S3)	18-26	Fair	Harmful for almost all types of soil, requires good drainage, high leaching gypsum addition
4.	VeryHigh Sodium Water(S4)	>26	Poor	Unsuitable for irrigation

As per USSL Diagram, The water quality of Yamuna river at palla falls under C3S1 category i.e. low sodium hazard and high salinity hazard, at Wazirabad it is C3S2 i.e. medium Sodium and high Salinity Hazard whereas after the Yamuna receives discharge from various drains in Delhi the water quality deteriorates and comes under C4S4 i.e. High Sodium and very High Salinity Hazard.

Table 4.11 Sodium Percent Water Class(Wilcox, 1995)

Sodium Percentage	Water Class
<20	Excellent
20-40	Good
40-60	Permissible
60-80	Doubtful
>80	Unsuitable

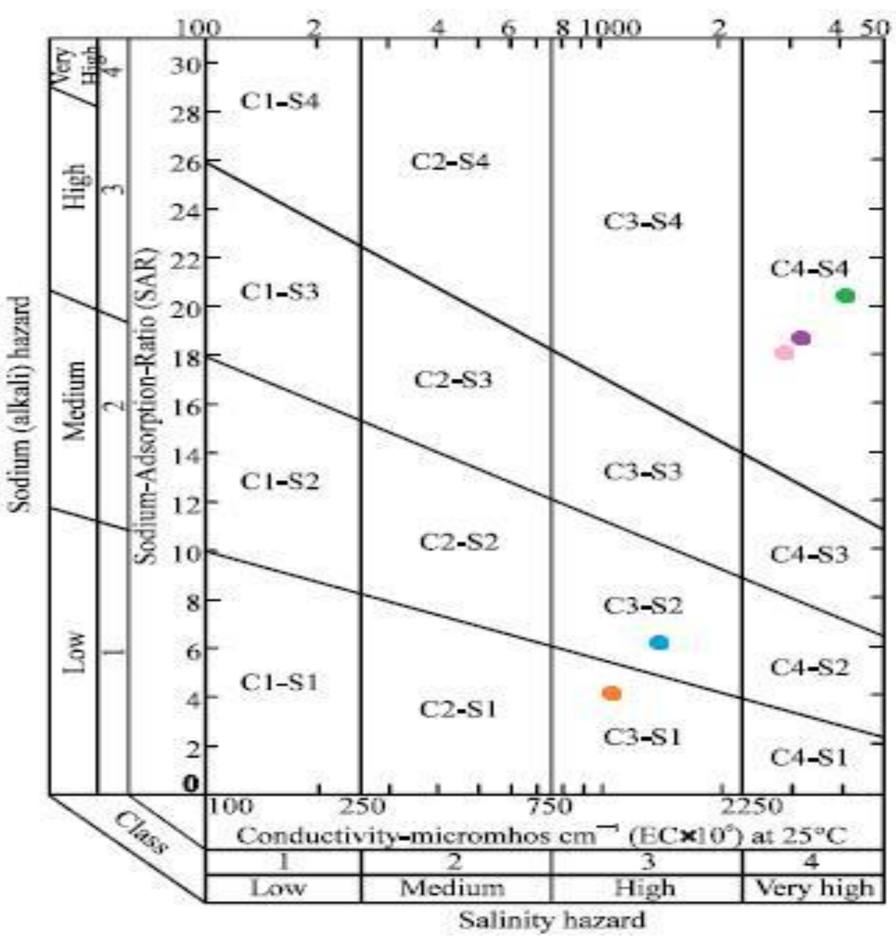

Figure 4.27 US Salinity lab Diagram

4.4.3. Sodium Percentage

Sodium percentage is evaluated to determine the tendency of water to enter into cation- exchange reactions. As the divalent cations are prone to extensive displacement in clay minerals if the percentage of sodium is high in irrigation water (Hem 1989). So, for the classification of irrigation water, sodium percent is an important criterion. If sodium is present in high amount in water then it accumulates in the pore spaces in plants and thus inhibits the growth of plants by disturbing the proportion of air and water in the pore spaces. According to Indian Standards, for irrigation water maximum of 60% sodium is permissible.

Wilcox (1955) suggested a graphical method for knowing the suitability of water for irrigation purposes. The proposed method is widely used and is based on percent sodium and electrical conductivity plot. The diagram consists of five distinct areas i.e., excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable and unsuitable. The data was calculated and subsequently plotted on the Wilcox diagram (Figure 4.28). As per the Walcox Diagram, at Palla the water quality falls under good to permissible area whereas for Wazirabad, Gurudwara and Okhla Barrage the water quality is in Doubtful to Unsuitable area and at the pontoon Bridge the water Quality is Unsuitable for irrigation purposes.

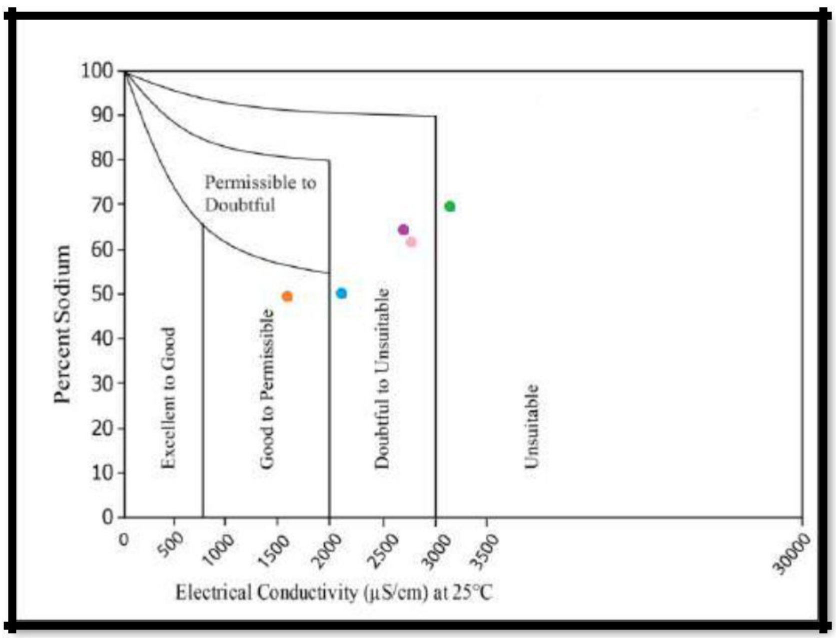

Figure 4.28 Walcox Diagram

4.4.4. Residual sodium carbonate

Residual sodium carbonate (RSC) has been evaluated to estimate the toxic impact of carbonate and bicarbonate in the irrigation water. It is expressed by the equation

$RSC = (CO_3 + HCO_3) - (Ca + Mg)$

where all ionic concentrations are expressed in meq/l (Eaton 1950).

The water quality based on RSC has been given in Table . As per this criteria the water at all the locations is safe for irrigation purposes. The lowest RSC ia at Palla with value 0.3631 and the maximum value is 1.213 at Pontoon Bridge. All the value are less than 1.25 therefore falls under safe category.

Table 4.12 : Water quality based on RSC (after Richards 1954)

RSC(meq/l)	Water Quality
<1.25	Safe/Good
1.25-2.5	Marginal/Doubtful
>2.5	Unsuitable

4.4.5. Magnesium ratio

High concentration of magnesium affects soil adversely as it enhances the alkaline nature of soil. The yield of crop is reduced considerably if magnesium is present to undesirable level. It is expressed as

Mg ratio = [Mg / (Ca + Mg)] x 100, where all values are in meq/l.

Magnesium ratio of more than 50% in a water body will make the water poisonous to plants. The magnesium ration calculated is minimum at Palla (30%) and is maximum at Pontoon Bridge (70.28%). In Delhi stretch the Magnesium ratio is above the acceptable limit of 50%. So, all the samples of Yamuna fall in the dangerous category after it starts receiving waste from NCT- Delhi. The high Magnesium content in water leads to heart diseases.

4.4.6. Kelly's ratio

Suitability analysis of water for irrigation purposes is also performed by Kelly's ratio (Kelly 1951). Ratio of sodium verses calcium and of sodium verses magnesium is used as Kelly's ratios. water having Kelly's ration more than one is considered not-suitable for irrigation purposes. Kelly's Ratio is greater than one for all the samples. So as per this criteria , the Water is not suitable for irrigation purposes.

Table 4.13 Water quality based on Kelly's Ratio

Range of Kelly's Ratio	Category
<1	Suitable
1-2	Marginal
>2	Unsuitable

Table 4.14 Irrigation Water Quality Parameters

Location/ parameter	Palla	Wazirabad	Pontoon bridge	Gurudwara	Okhla
SAR	4.5	7.25	21.5	19.4	18.5
RSC	0.3631	0.5743	1.213	1.15	1.025
Sodium percentage	50.33	53.59	70.28	67.63	64.75
Magnesium	30	45	56.17	48.95	53.14
Kelly's Ratio	1.064	1.435	2.34	2.12	1.984

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

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5.1 CONCLUSIONS

The study done on samples taken from five different locations in river Yamuna clearly indicates that despite of all efforts undertaken to clean river most of the water quality parameters were found to exceed the permissible limits set by BIS. Most importantly critical concentrations were of dissolved oxygen (DO) and biochemical oxygen demand (BOD) having values 0mg/l and 68mg/l respectively which must be 4mg/l and 3mg/l. Also, the maximum value total dissolved solids was found to be 2210mg/l which is 1.5 times the permissible limit set for class C standard of surface water. Only the ph value was in accordance with standards (6.5-8.5) at all the sampling locations. The results are in accordance with R.S.Dubey, 2015for the water quality parameter.

The results obtained shows the deteriorated water quality in the river. It indicates that various treatment plants installed on the drains and river are not efficient enough. The Najafgarh Drain was found to be carrying high amount of organic matter and BOD load of nearly 75 mg/l. The water of river Yamuna trapped between Wazirabad and Okhla has no fresh water access except during Monsoon. All these factors have taken up the contamination level to a order that if this water cannot be used even for irrigation works without treatment. The toxins present in it could reach the food chain and can cause disorders in humans.

After analyzing the water quality at various sampling location throughout the stretch of the river Yamuna and the Najafgarh Drain it can be concluded that there is an urgent need to strategize and implement the proper treatment of sewage before the Najafgarh drain as well as all the other drains discharge the waste water into the river Yamuna. level is found to be increasing day by day which has completely deteriorated the water quality of river after its Delhi stretch and the river has now become a drain and has been declared as the most polluted river in India. In the analysis done it has been found that the water quality parameters in the river are crossing high contamination levels and their concentration in the river was found much more than the prescribed standards. The Najafgarh drain sample when analyzed shows that the effluents discharged in the river does not follow the BIS norms and CPCB standards.

5.2 RECOMMENDATIONS

It is the need of the hour to identify viable remedial methods for cleaning the river Yamuna. For this purpose, both Government as well as residents of Delhi should give their efforts and save the holy river. The initiative of forming 10 feet high barricades all over Yamuna bridges in Delhi is appreciable as it has restrained the people from dumping things into the river.

For restoring the water quality to desirable standards following few ways could be recommended:

- Recycling the waste water with the help of various emerging technologies as the present sewerage system is not efficient enough to deal with the situation. So it should be changed.
- Treatment facilities should be constructed in vicinity of the source of generation of sewage and where the raw sewage could be treated immediately thereby saving the expenses made on transportation and handling practices. This could help in controlling the damage due to dumping of raw sewage into the river. The gap between sewage generation and treatment can be minimized.
- The upgradation of existing sewage treatment system which has become obsolete and inadequate should be done. The areas where there is absence of treatment system requires more concerned as from these areas sewage is being dumped directly into the river.
- The agricultural practices on the banks of river has added various toxins in form of insecticides, pesticides to the water. As per various estimations about half of the amount of pesticides and fertilizers applied to the field are washed away into nearby water bodies. For this type of situation organic farming and use of bio-fertilizers should be emphasized.
- In Delhi, a large amount of solid waste is being generated and is a major source polluting the river. this solid waste can be recycled and effectively used in daily lives. Various household items like newspapers, containers, cans, plastic detergents bottle etc. can be manufactured from partially or completely recycled solid wastes.
- There is no proper sanitation facilities in the slum areas in Delhi and open defecation is quite prevalent there. This has been directly discharged into the river and contaminating the water with high level of fecal pollution. Due to lack of proper hygiene and sanitation malnutrition, anemia, retarded growth , blindness or cholera cases are very common in these slums in Delhi. To prevent further deterioration of Yamuna Public Sanitation

facilities should be properly maintained specially in the slums situated on either side of the river.

- The cremation practices on the banks of river also causes water pollution. Although it is concerned with the religious beliefs but the absence of adequate cremation facilities has led to a large number of partially burnt corpses floating down the river Yamuna. One of the effective way to solve this issue is electric cremation as it is not only environment friendly but also least expensive. So, it would be a great initiative if government give efforts to guide, aware and convince people for this.

- Afforestation wherever possible on the stretch of river Yamuna as well as Najafgarh drain should be done as it helps in reducing soil erosion. the trees help in maintaining the proper temperature in the river by preventing direct sunlight exposure. This helps in oxygenation of water body.

- The various policies implemented by the government could be successful only when thre will be strict provisions of penalties and fines for the violators. Delhi and its residents has taken Yamuna to that level of deterioration from where it can be brought back to life by strict implementation of policies only.

- The water should be used optimally and equal distribution of water must be done so that people having more supply of water could not waste it for lavish uses. To optimize the use of water, enforcing and applying sewage collection cess and also cess should be on irrigation water so that farmers use water effectively. The existing cess on drinking water should be hiked to control domestic uses.

- A rehabilitation plan should be initiated for big drains like Najafgarh and Shahdara drain etc. A management plan that include desilting, strengthening of wall and channel and encroachment prevention should be made.

- Industrial waste contains large proportions of toxins as compared to other wastes. therefore, industries should be setup after following proper guidelines of site selection and Environment Impact Assessment as per MoEF. The industries should have their own effluent treatment plant or otherwise connected to Common Effluent treatment plants (CETPs) so that no industry find its way directly into the river.

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