RIVER WATER QUALITY ASSESSMENT
–A CASE STUDY

DISSERTATION REPORT

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By

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CANDIDATE'S DECLARATION

I hereby declare that the work being presented in this report titled **"RIVER WATER QUALITY ASSESSMENT –A CASE STUDY"** is presented on behalf of partial fulfilment of the requirement for the award of the Degree of Master of Technology with specialization in Water Resource Development and submitted to the Department of Water Resources Development and Management (WRD&M), Indian Institute of Technology, Roorkee. This is an authentic record work carried out under the supervision and guidance of **Dr. M.L Kansal**, Professor, WRD&M, IIT Roorkee, Uttarakhand, India.

The matter presented in this report has not been submitted by me for the award of any other degree rather than this M-Tech in WRD&M Department.

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CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

The water quality assessment of the Yamuna River has been carried out to explore the status of the river water in terms of Water Quality Index (WQI). Eighteen water locations along the River Yamuna were checked for seven parameters and analysed for bacteriological and physio-chemical parameters. The parameters dealt are Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Ammonia, pH, Total Kjeldahl Nitrogen (TKN), Chemical Oxygen Demand (COD) and Faecal Coliform (FC). Three Indices namely National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) and Oregon Water Quality Index (OWQI) were used in this work to determine the quality of water in these locations. The results generally range between medium to bad water quality and in some few locations especially from Palla, Nizamuddin bridge going down to Udi the quality is almost unsatisfactory. So we can say that nowadays is difficult to have pure water which can simply be consumed without treatment.

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Most of materials which I have used are collected from various journals and books to the best of my knowledge.

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Benny B. Komba

Date: 18th May 2016

Place: IIT Roorkee

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ABREVIATIONS USED

BDL	Below Detectable Level
BOD	Biological Oxygen Demand
CCMEWQI	Canadian Council of Ministers of the Environment Water Quality Index
CPCB	Central Pollution Control Board
DO	Dissolved Oxygen
NSFWQI	National Sanitation Foundation Water Quality Index
ODEQ	Oregon Department of Environmental Quality
OWQI	Oregon Water Quality Index
pH	potential of Hydrogen
TC	Total Coliform
TKN	Total Kjeldahl Nitrogen
WAWQI	Weight Arithmetic Water Quality Index
WHO	World Health Organisation
WQI	Water Quality Index
WT	Water Temperature
P1	Hathnikund
P2	Kalanaur
P3	Sonepat
P4	Palla
P5	Nizamuddin Bridge -Quarter Stream

P6	Agra Canal - Mid Stream
P7	Agra Canal - Quarter Stream
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P18	Juhika
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CHAPTER 1
INTRODUCTION

1.1 General

Water is a most important resource which is given naturally on earth and it covers the major part of life meaning. The sources of water globally can be discovered in a number of forms. They can be found in the form of ground or surface (river, lakes, sea etc.), in ice form (glaciers) or just as a rain water. Apart from drinking requirement, water resource is an important tool as it plays a vital role in economic sectors like forestry, fisheries, livestock production, generation of hydropower, industrial activities, agriculture and many other activities. The availability of water and its quality on ground as well as underground now days have been distorted because of some human development factors like urbanization, increase of number of people (population) in the world, industrial development and many others.

What is water quality?

Defining the water quality can be complicated as it has no direct definition. The quality may be good enough for drinking but not suitable for use as a coolant in an industry machines. It may be good for irrigating some crops but not good for irrigating some other type crops. It may be suitable for livestock but not for fish culture.

It is totally different from a question when one asks about water quantity which you can simply answer by a single parameter i.e. the amount of it.

In describing the quality of a given water sample, one way is to list down all the concentrations of all that the sample may contains. The list can be as long as the number of constituents found in it and so it can be either just few or hundreds.

Moreover, such a list will not make any sense to most of people except those who are well-trained in water-quality issues i.e. water quality experts.

In doing this comparison the water quality from different water sources must be taken and use the same parameters and hence it can be easily to compare these different locations in terms of their quality. If we take as an example, a sample which contains about five components in 5 percent higher than permissible (hence unacceptable) levels: iron, sulphate, hardness, chloride, and pH, their effect for drinking may not be as bad as another sample with only one constituent like mercury at 5 percent higher than the standard permitted.

1.2 Water Quality Index (WQI)

WQI aims to address this annoying problem in order to help the public and managers to easily understand the quality status of water at a particular water body in a particular time.

Water Quality Index (WQI) is one of the best and most effective ways which can be used to describe if the water source suits for consumption of a human or any animal. It depicts the suitability of water in terms of utilizing the monitored water quality data of a particular river (Shweta et al., 2003).

1.3 A brief history of water quality indices

The current WQI was founded by Horton (1965) in US by randomly picking up most commonly known and used water quality parameters among them being of specific conductance, (DO), chloride, pH, alkalinity and coliforms.

He fixed the following measures (criteria) during the WQI formulation:

1. The amount (number) of variables which will be selected at a time should be minimum to simplify the index formulation.
2. The variables which will be chosen should be available in significant amount in most of the selected locations
3. Only variables from which dependable (or reliable) data can be available, should be taken into account.

WQI have been widely applied almost worldwide up to now. It is recognized in most countries of Asia, Africa and American continents (Tyagi et al., 2013). The weight assignment to them reflects its importance for a particular use and hence causes a substantial effect on the calculation of index. Later on in 1970 (Brown et al., 1970) inaugurated another WQI which was developed in Canada and after then became popular worldwide. The weightage of parameters was based on their individual importance. In recent years, many modifications and adjustments have been done by various scientists and experts for WQI concept throughout the world (Sivaranjani et al., 2015; Dwivedi et al., 1997)

1.4 Objective

The general objective of this dissertation is to study various water quality indices used in various countries and use some of them for calculating the quality of their indices. As a case study in assessing these indices, some river reach from Hathnikund to Juhika is taken and to show how the results can be calculated presented to users. The user meant here can be decision makers; water body uses or directly to the public. A portion of River Yamuna at in various stations will be dealt to check their WQI will be as my case study.

Specific objectives:

- Study of river water quality characteristics, i.e., physical, chemical and bacteriological parameters
- Selection of river reach for case study
- Collecting data
- Calculating the WQI from data collected
- Suggestions for improvement of water quality or alternative water use at poor quality locations

1.5 Stages to be followed in formulating a WQI:

1. Parameter Selection:
   A judgment of professional experts in water quality or government institutions are required to carry out the process of parameter selection in the legislative area. In order to accomplish this, monitoring of water samples must be done to get the raw data.
2. Finding the quality function (curve) for each parameter considered as the Sub-Index
   All the parameter units are then being transformed units into a similar scale i.e. the sub-indices from the selected parameters with their different units such as ppm, percentage, counts/volume etc. have to be transformed to dimensionless scale values. (Dunnette, D.A., 1979)
3. Sub-Indices aggregation with mathematical Expression:
   The aggregations of these indices are calculated by arithmetically or geometrically averaging to sum up and produce a final index score.

It was suggested that not less than four variables which should be considered in the calculations and should appear at least four times. The maximum number of variables is not specified. However, the selection of appropriate variables for a particular area is very important to give a meaningful result (CCME, 2001).

It was also discovered that when a very small amount of variables is used it can bring a different picture from what is expected and hence to useless (CCME, 2001)

There are large number of water quality index methods which are existing that are formulated in various countries by different organisations to fulfil their local and International standards. Some of the common indices are;

- National Sanitation Foundation Water Quality Index (NSFWQI) (Brown et al., 1970)
- Weight Arithmetic Water Quality Index (WAWQI) (Abbasi, & Abbasi 2012)
- Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) (CCME, 2001)
- Oregon Water Quality Index (OWQI) (Cude CG, 2001).
- Nemerow and Sumitomo's, Prati's Implicit Index of Pollution (Abbasi, & Abbasi 2012)
- McDuffie and Haney's (Abbasi, & Abbasi 2012)
- River Pollution Index (RPI) (Abbasi, & Abbasi 2012)
- The River Ganga Index (of Ved Prakash Et Al) (Abbasi, & Abbasi 2012)
- The Florida Stream Water Quality Index (FWQI) (Abbasi, & Abbasi 2012)
- The WQI of Said at al. (2004) (Abbasi, & Abbasi 2012)

CHAPTER

DISCRIPTION OF THE STUDY AREA 2

Yamuna River is one of the largest tributaries which contribute in river Ganga. In the mythology of India especially for Hindu believers it is taken as holy river and hence some of the pilgrimage centres like Mathura – Vrindavan, Allahbad and Bateshwar in Uttar Pradesh are situated on the banks of this Yamuna river. And also famous cities like, Agra, Delhi and Mathura are also located on the banks of River Yamuna.

This river starts from Yamunotri mountains/glaciers which is in the lower Himalayas at around 6387m AMSL. Its total length is about 1370km from the origin to Allahabad where it meets with Ganges. Because of human activities the only segment which meets most of the water quality standards is Himalayan segment. The categorisation of segments of this river is described in the table below;

Table 1: Segments of River Yamuna

S/N	**Segment**	**Coverage Area**	**Length (km)**
1	Himalayan	Origin to Tajewala Barrage	172
2	Upper	Tajewala Barrage to Wazirabad Barrage	224
3	Delhi	Wazirabad Barrage to Okhla Barrage	22
4	Eutriphicated	Okhla Barrage to Chambal confluence	490
5	Diluted	Chambal confluence to Ganga Confluence	468

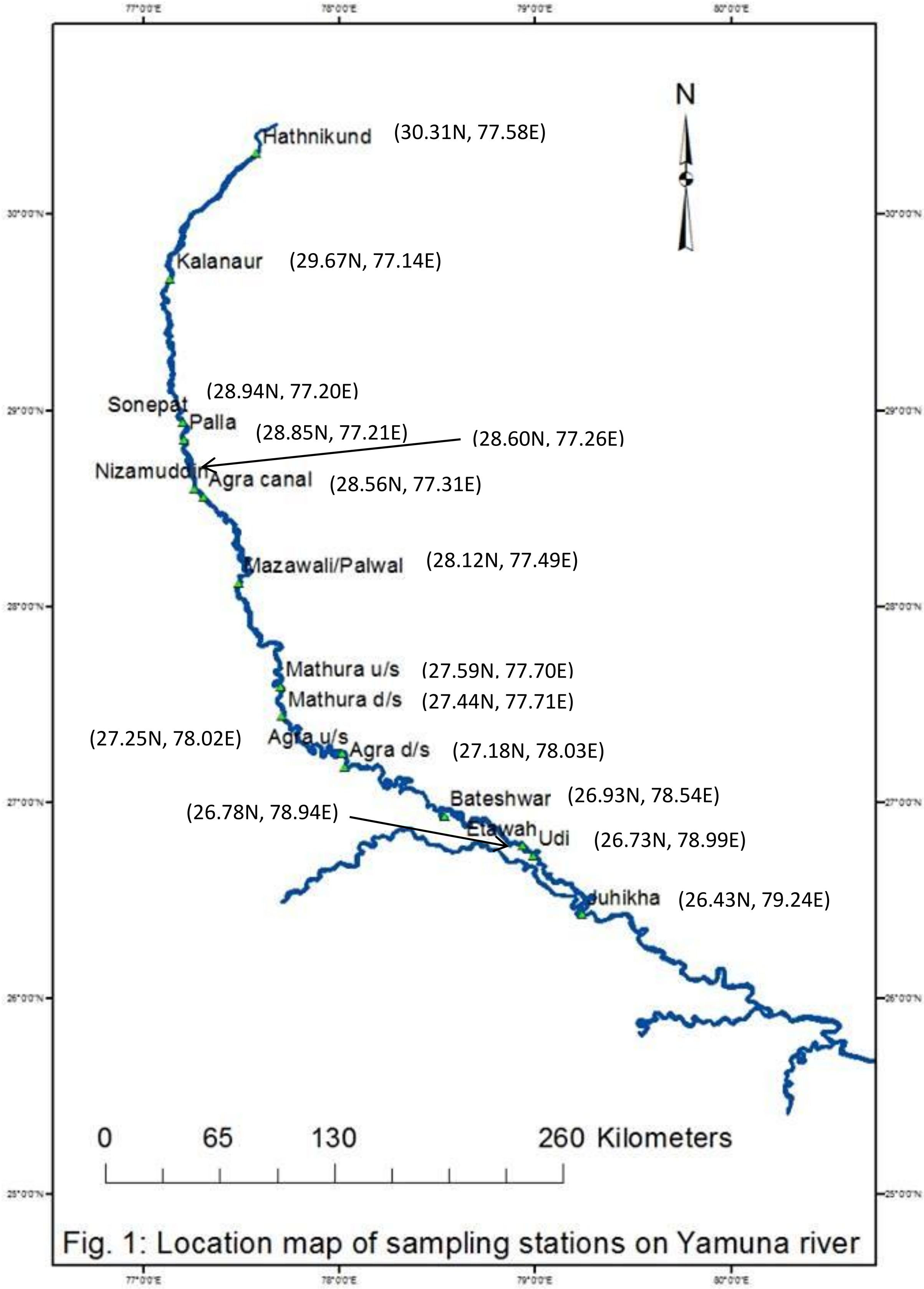


Figure 1: The map showing the sampling stations on Yamuna River

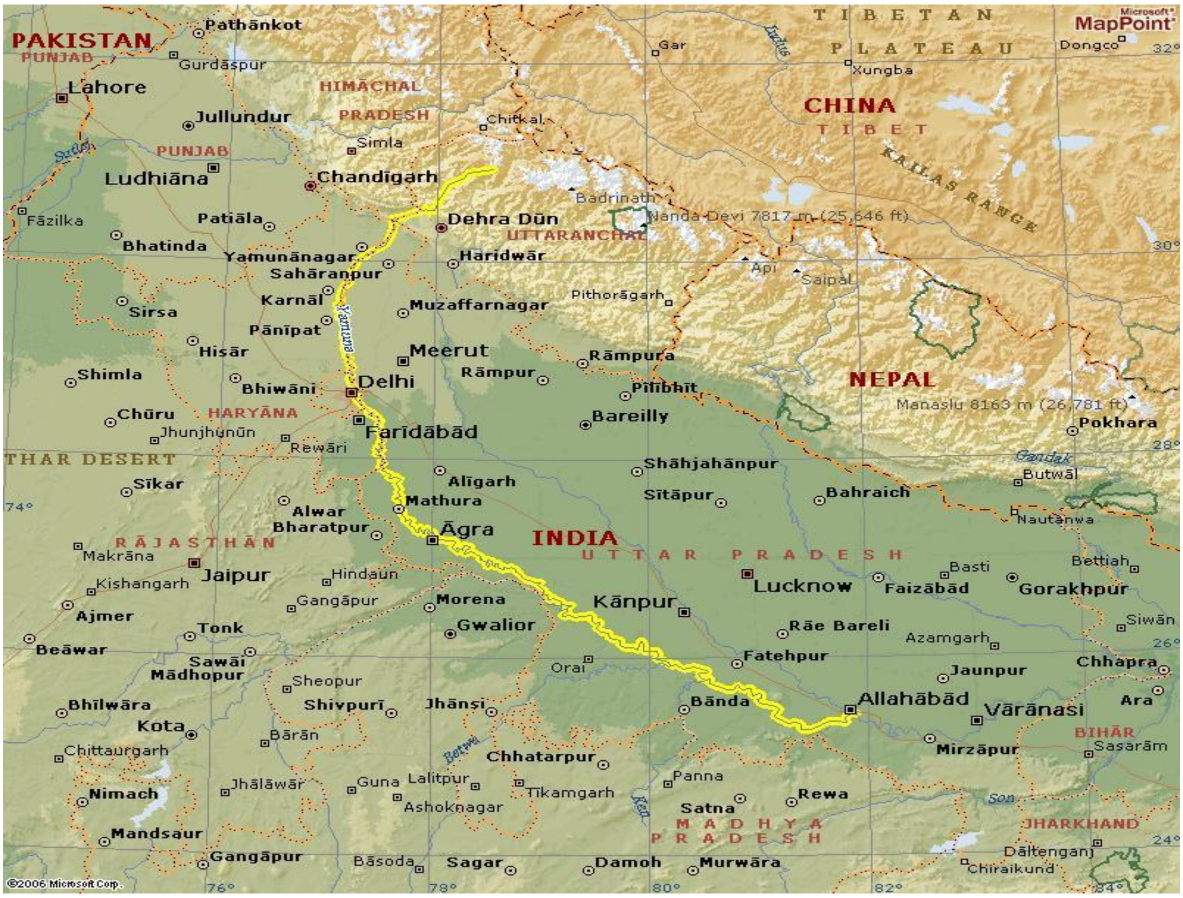


Figure 2: Indian map showing cities and town through which Yamuna River passes

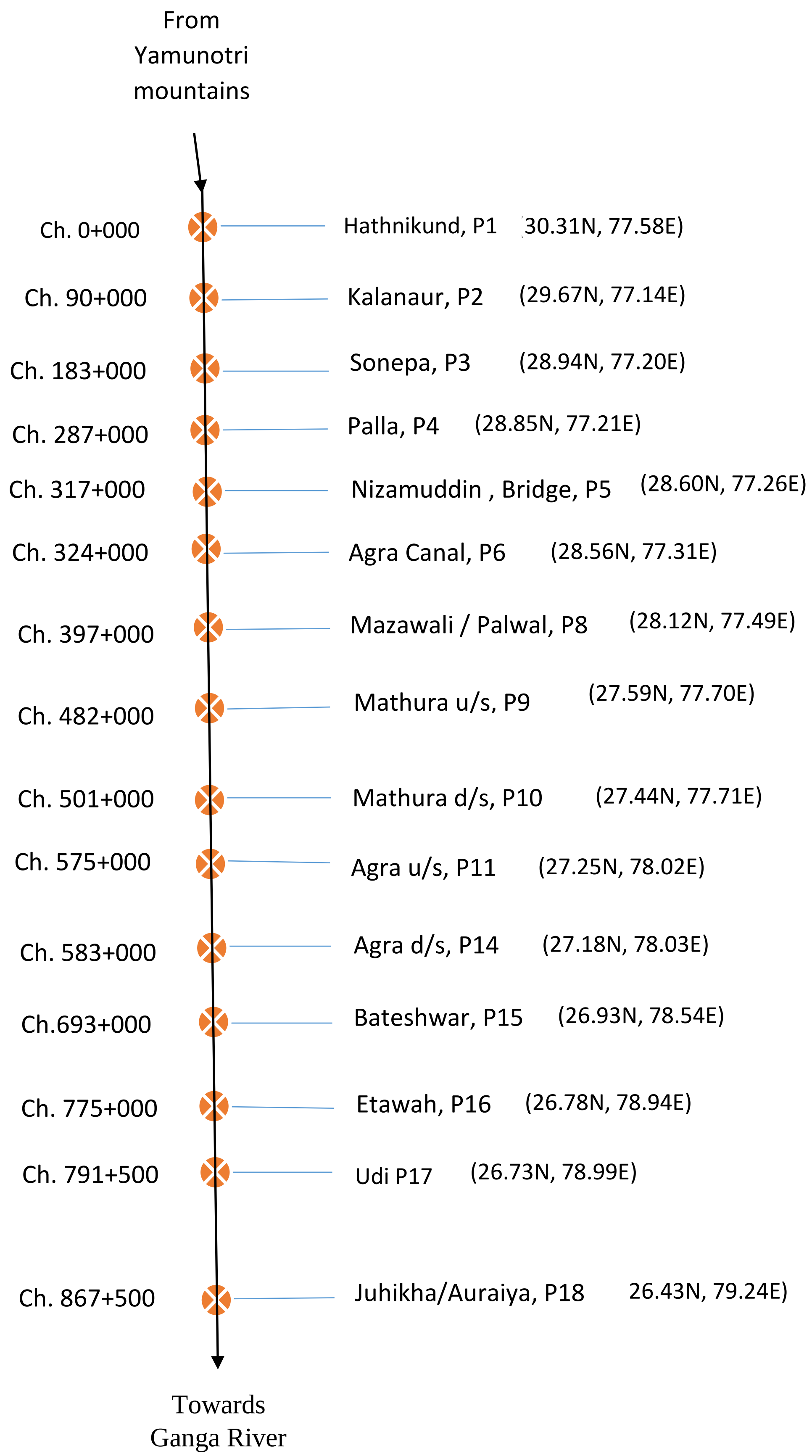


Figure 3: The descriptions of the Sampling Locations along Yamuna River;

(i) Hathnikund:

Almost thirty-eight (38) kilometres downstream from Dak Patthar and a pair of kilometres upstream from Tajewala barrage, simply upstream side of freshly made barrage. Here is a place which gives water quality once the tributaries Tons, Giri, Asan and others from lower Himalaya region joins watercourse of Yamuna. This place additionally provides info regarding the impact of drain outfalls at Paonta Sahib.

(ii) Kalanaur:

This place is situated downstream of Hathnikund / Tajewala barrage seven (7) kilometres towards east of Yamuna Nagar at Yamuna Bridge on Yamuna Nagar at Saharanpur Road close to village called Kalanaur. The place gives the quality status of water which comes from ground and a few watercourse tributaries for example Son and others. This station is about 90km from Hathnikund station.

(iii) Sonepat:

Is situated about twelve (12) kilometres in East direction of National Highway No. 2 and twenty (20) kilometres in East of the City called Sonepat at Yamuna Bridge on Sonepat-Baghpat Road. The effect of dismissals from Karnal and Panipat Cities are reflected at this point. The distance from Kalanaur is almost 93kilometers.

(iv) Palla:

The Palla station is nearly fifteen km upstream of that barrage of Wazirabad not far from Cremation ground. The tests at this place reflects the quality of water before the sewer water is received from Delhi's water supply scheme. During rainy season the river also receives Drain No. 2 upriver direction and hence at this time its water quality also replicates the effect of domestic and industrial effluents from Sonepat in Haryana District. The distance between this point and Sonepat is 104km

(v) Nizamuddin Bridge:

It is 14 km downstream from Wazirabad barrage at Delhi – Ghaziabad (Noida) Road Bridge. The status of quality of water here gives the picture on the effects of wastewater which is realised from up streams. This station is 30km from Sonepat station

(vi) Agra Canal:

Location of this point is twenty-four (24) kilometres downstream of the barrage of Wazirabad in Easten part of Delhi exactly at Agra National highway near to the village called Madanpur Khadar. At this point is where you can get a clear picture of discharged water which is fully or partly treated from Okhala Treatment plant. It is not far from Nizamuddin Bridge; it is only about eight kilometres downstream

(vii) Mazawali (Palwal):

Moving eighty-four (84) kilometres downstream away from the above barrage (Wazirabad) and about sixteen (16) km from Palwal exactly at the bridge of Palwal Aligarh. And also it is 73km from Agra Canal. The effects of effluent water from Shahdra sewers can be detected here.

(viii) Mathura Upstream:

This location is at Vrindavan close to Chirharan Ghat roughly 188 kilometers downstream away from that barrage of Wazirabad. Prior to enter in Vrindavan– Mathura, the water is checked at this point to for its quality. The distance from the previous station is 85km

(ix) Mathura Downstream:

Taking Wazirabad barrage as a reference point, this location is approximately 204 kilometres away from there. At this place the effects of discharged water coming from Mathura-Vrindavan city is being determined. From Mathura upstream to this point is 19km

(x) Agra upstream:

Moving almost 272 Kilometres from Wazirabad barrage heading to Dayalbagh you might reach at this site where status of river water is assessed moving into Agra city. This station is almost 74km from Mathura Downstream

(xi) Agra downstream:

The wastewater effects discharged from Agra city is being determined here. This location can be reached after moving 310 kilometres from our reference point and 8 kilometres from Agra upstream. It is just close to Tajmahal monument.

(xii) Bateshwar:

It is so close to Bateshwar Temple 422 Kilometres as you go down from Wazirabad. The distance from Agra downstream to this point is 110km

(xiii) Etawah:

Prior its falling into Chambal River from Yamuna the water is being checked at this point.501 kilometres from Wazirabad towards downstream is the place where it is located. From Bateshwar to this station is about 82km.

(xiv) Udi:

Prior to join the River the quality status from rive Chambal is being investigated here in Udi village 330 kilometres from the reference barrage. The distance from Etawah to this station is almost 16.5km along the river

(xv) Juhikha (also Auraiya):

This point is for examining any effect which comes from Chambal River before entering into Yamuna. It is Auraiya town where the bridge in Yamuna is situated.

The distance between this monitoring station and Udi is 76km along the river and 613 kilometres from barrage Wazirabad.

2.1 Major Sources of pollution in Yamuna River

2.1.1 Industries

Industries sector is another major source of pollutant in rivers. Industries produces effluents and other wastes which pollutes natural water because of toxicity which they contain in it. The major industries which pollute river water under this category are electroplating units, paper mills, steel plants, sugar and industries textile.

2.1.2 Agriculture

The agriculture chemicals i.e. pesticides and fertilizers when wasted near to the river; when the monsoon season comes they are all washed to the river and hence disturb the quality of the water. In India the irrigation practice has grown considerably but about the problem of salinity a very little effort has been made to try to solve it.

Cultivating in flood-plain areas is another important factor to be considered when we discussing about pollution by agriculture in rivers.

2.1.3 Domestic

This is the main source of pollution in most of rivers which passes along settlements including Yamuna River. Various researches shows that nearby 85percent of the whole pollution in this river is caused by home use activities i.e. domestic and most of them are from urban centres.

Below are photos showing domestic pollution in River Yamuna

2.1.4 Other sources

There are many other reasons which contributes to pollute the River in most of the times like Religious and other Social Practices:

One of the other reason of polluting water in rivers in India is religious practice especially for Hindus faith and their social norms. Dumping corpses of animals also is another reason. Moreover, when the dead bodies are being burned on the banks of rivers they also pollute the river drastically.

CHAPTER
LITERATURE REVIEW 3

In this chapter various materials and knowledge used in this dissertation will be explained

2.2 Water Quality Parameters for indices

2.2.1 Physical

The way the water consumer feels when drinking the water is what is called physical characteristics. Depending on the appearance, smell or its test one can judge it personally (Sheat 1992; Doria 2010). According on their own feelings they may decide to avoid the highly turbid or coloured but in other way safe waters in favour of aesthetically is more acceptable (WHO, 2004).

Physical characteristics do not have direct effect with health but may lead to many indirect consequences. For example, a turbid water may protect some pathogens from the effect of disinfection. But also it may contain some minerals which can irritate human's stomach.
Some of these characteristics are;
Taste and odor can be caused by various natural chemically polluted, biological remains and other sources like microbial activity. (WHO, 2004).

Color or cloudiness, the remainder of organic material and other bacteria after can cause the water to be objectionable for drinking. These aspects can be different from one community to another e depending on local norms and behavior.

Turbidity is another major problem in aesthetic view of water quality. It is caused by organic matter suspended or dissolved.
Turbidity guides some germs to destroyed when chlorination is being done and accelerates the multiplication of bacteria. Its acceptable value is required be less than 0.1 NTU although up 5 NTU is usually acceptable by consumers (WHO, 2004).

Temperature

Life for aquatics in water-body depends on temperature and hence it can be taken as an essential criterion: it controls the rate of metabolism activities and development and hence their cycles of life. Water temperatures can fluctuate seasonally, daily, and even hourly, especially in small sized streams. Temperature also controls the concentration of DO in a body of water. Oxygen is much dissolved in cold water than in hot one. But testing of temperature for drinking water has no significant importance as there is no control of it in water. On the other hand, for academic purposes for drinking water temperature of about 10° is highly accepted, while more than 25° is not accepted.

pH is a necessary operational water parameter of for controlling the water quality. For public water use, pH values should range between 6.5 and 8.5. Lower than this pH can lead to corrosiveness of water leading to contamination in pipes and other utensils. Also it can cause severe effects in its taste and also the appearance (WHO, 2004). Higher pH (i.e. above 11) in drinking water can cause irritation in skin and eye. On the opposite side of the of the scale (pH below 4) it causers corrosiveness which also causers irritation. (WHO, 2004). Careful consideration of pH handling is necessary as it controls chlorination in which the pH to be less than or equal to 8.5 (WHO, 2004).
The measurement of pH is done colorimetrically i.e. the more the colour concentration the greater the pH concentration in it. The intensity of colour is compared with standard colour discs containing a series of graded coloured glasses for particular determination.

Table 2 There are various indicators used for pH indication.

Indicator	**Colour change**	**pH Range**
Melthy violet	Yellow Green - Violate	0.0 to 2.5
Melthy orange	Red - Yellow	2.5 to 4.4
Congo red	Blue - Red	3.0 to 5.0
Bromocresol green	Yellow - Blue	4.5 to 5.5
Melthy red	Red - Yellow	4.8 to 6.0
Bromocresol purple	Yellow Green - Violate	5.4 to 6.8
Bromocresol blue	Yellow - Blue	6.0 to 7.6
Phenol red	Yellow – Red violate	6.4 to 8.2
Cresol red	Yellow - Violate	7.1 to 8.8
Phenolphlaein	Colourless – Dark pink	8. 3to 10.0

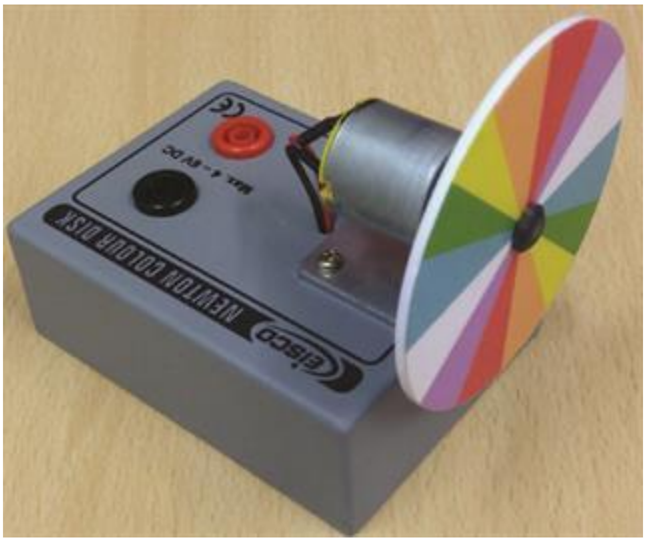


Figure 4: Modern Newton's colour disk for pH test

2.2.2 Chemical Parameters

Chemical analysis in water is carried out to determine the chemical characteristics of that particular water sample. The following are some of parameters which concerns with health; (WHO, 2004)

Fluoride: This causes the teeth to be mottled and in excess condition can cause in crippling of skeletal fluorosis.

A*rsenic* can cause cancer in human body and also leads to skin wounds.

Nitrate and nitrite leads to blue baby which can be caused from excess fertilizers and other organic wastes which are thrown into water surface.

Lead can have severe nervous effects in areas with acidic waters.

Lead: in places where acid water dominates lead can course nervous effects

Hardness is the accumulation of cations of calcium (Ca_2^{+}), (Mn_2^{+}), (Fe_2^{+}), and (Mg_2^{+}), in the water sample. Water containing these is termed as "hard." From the stream the hardness reflects the geological condition of the catchment area although sometimes it is taken as a measure of human activities around that area.

Chemical Oxygen Demand (COD)

This is the amount of oxygen taken up in the oxidation of readily oxidizable carbonaceous matter. Since it is done by using a boiling potassium dichromate chemical and concentrated sulphuric acid hence the term *Chemical oxygen demand (COD)* comes. The test is used to determine the total organic matter present in water. This test also is used as an indirect measure of total organic carbon by determining its oxidisability. It is used in surface water (lakes, rivers, ponds etc) or sewage water.

This test has the following limitations;

(i) There is some inorganic matter (like nitrites, sulphides, thiosulphate etc) which also consumes oxygen in the process of oxidation and some organic matter (like benzene, pyridine and other cyclic chemical compound) which cannot be treated in this manner.

(ii) It no indication of either of biological degradation of the organic matter or its rate of oxidation.

Besides these limitations this test is very useful because of its simplicity and quickest in giving results and hence continues to be very useful in waste water management and water quality in general.

Dissolved Oxygen (DO)

DO is that measured amount of O_2 which is dissolved up in a particular sample of water. In different ways oxygen can enter the water by several ways; it may be by directly absorbed from the air or can be formed as a residual product of plant during the process of photosynthesis water

The concentration of DO in water should range from 4 to 8 mg/l.

There are number of tests for determination of DO like Dissolved Oxygen Sensor Method, Optical Sensor Technology, Galvanic Sensors, Colorimetric Method, Titrimetric Method (i.e. Winkler Method). Winkler method in which an oxidation reduction process is carried out to liberate iodine in the same (or equivalent) amount to the oxygen originally present in the sample.

2.2.3 Biochemical Oxygen Demand (B.O.D)

B.O.D is that oxygen amount which is required for the biologically decomposing the available organic matter under aerobic conditions. Example of organic matter are such as leaves, grass and fertilizers. This test is most important in sewage as it analyses the amount of decomposable organic matter contained in the particular water under test. The large the sewage the greater the B.O.D. the test is very important in stream pollution control as it helps in determination of the pollution of the stream at any time.

The test is usually done for five days (and hence the name B.O. D_5) at a temperature of 20°C and is being performed using a DO test kit. To get the B.O.D level the difference between the

DO levels of a water sample taken during sampling, with that level that has been read after being covered or incubated in darkness for 5 days. This difference represents the amount of oxygen required for the decomposition of any organic matter which is known as BOD.

Table 3 BOD levels and their meaning

BOD Level (in ppm)	**Water Quality**	**Description**
≥100	Very Poor	Very Polluted
6 - 9	Poor	Somewhat Polluted
3 - 5	Fair	Moderately Clean
1 - 2	Very Good	Totally clean

Conductivity

Conductivity can be defined as the ability of solution (water; for this case) to carry the electrical current. Ions available in that solution defines its capability i.e. conductance. A conductivity measurement is an indicator of total dissolved solids in a water. The unit used for conductivity is micro-Siemen per centimetre (or simply μS/cm).

When a factor which ranges from 0.55 to 0.70 is multiplied this conductivity it can provide a roughly amount of dissolved solids in milligram per litre. This test is a temperature dependant and temperature which is standard used is 20℃ and 25℃.

Phosphorus

It is present in fresh water mostly in organic form such as phosphates. The major sources of phosphorus in water are domestic sewage, detergents, agriculture effluents with fertilizers and industrial waste water. High concentration of phosphate indicates that water is polluted. The phosphorous in water reacts with ammonia molybdate and forms complex heteropoly acid (called molybdo-phospheric acid) which get reduced to a complex of blue colour in the presence of stannous chloride ($SnCl_2$)

The principal of phosphate is its ability of increase the growth of algae and eutrophication of lakes. It is harmless to organisms but its presence in drinking water has little effect on health. Its concentration should not exceed 50 µg/l.

Bacteriological Parameters

The process of testing the bacterial pollutants in water can be made very easy by utilizing the availability of an indicator for organisms in it. This indicator may not necessarily cause a risk in health but just for easily isolate and also enumerate. its presence in vast, is more resistive or immune to fumigation than pathogens but the good thing is that it does not easily reproduce themselves in water (Gadgil A. 1998). This parameter is found can reproduce itself more in soil and is hence assumed as a negligible parameter for detecting the existence of dangerous microorganisms (Doria 2010).

Fecal Coliform is a bacterium which occurs in the intestinal tracks of all mammals. It aids in the process of digestion. It can go into a stream of water directly from all type of animals, or also as a runoff of agriculture, or more frequently from septic tanks or wastewater. Fecal coliform itself is not dangerous to health but its presence is the evidence of fecal wastes that might contain pathogenic microorganisms. Higher levels of this e.g. greater than 200 colonies per 100 ml of water magnifies the possibility that pathogenic microorganisms must be present.

Total solids

Total solids refer to the sum of total suspended solids (TSS) and dissolved solids (TDS) in water sample.

TSS includes those materials which can be trapped by filter; they include organic and inorganic all together the matter such as Plankton, silt and clay. TSS varies as per flow season with some rivers having thousands of mg/l during flood period. The measurement is usually on weight – volume basis and do not give any indication to type of material, settling characteristics or distribution of particles.

TDS includes dissolved salts, some amount of organic matter and dissolved gases contained in liquors mattes.

Determination of total solids is done by taking the sample and evaporating it and then drying in oven at 105°C for 1hr. Since the drinking water contains some suspended matter it is usual to filter the sample before its use.

The amount of solids 500mg/l is acceptable although sometimes may lead to physiological effect. (Duggal K.N and Chand S., 1966)

Organic Matter

These matters are caused by decomposition of waste products of animals and human being and also from vegetable or plant. Those wastes from human may contain pathogens that are dangerous for human health.

These organic matters may be in any of the following forms;

- Organic nitrogen
- Ammonia nitrogen
- Nitrites

- Nitrates

Water which contains much mostly ammonia nitrogen and organic nitrogen are found to be recently polluted and this water is most dangerous for health. Organic nitrogen is that which is present in a plant or animal as a protein before its decomposition, after decomposition it is released as ammonia nitrogen. The test used determination of organic nitrogen *is Kjeldahl method* which employs sulphuric acid as oxidizing agent. When the complete oxidation has taken place it releases ammonia nitrogen.

The ammonia nitrogen itself is determined calorimetrically by the process called Nesslerization. It is based on yellow coloration given by traces of ammonia or ammonium salts with Nessler's reagent (potassium mercuric iodide solution) in alkaline medium of potassium hydroxide. The colour which is produced is proportional to the amount of ammonia which was originally present and then is simply matched by eye with colour standards.

Water which contains mostly nitrates is found to be polluted long time ago and so is not of much consequence. Nitrites are present in water in very small amount as it is just a transitory compound which later on after oxidation changes to nitrate nitrogen. These nitrate and nitrites are measured calorimetrically by using organic compounds which then produce colour which is directly proportional to the amount of nitrate contained in that particular sample. For example, this nitrite nitrogen the chemical agents used are sulfalinic acid and α-naphthylamine which later on produce a bright pinkish-red colour; while for nitrate-nitrigen, phenoldisulphonic acid reacts to produce yellow coloured.

Nitrates when is just in small amount it has no side effect, but if exceeds 45mg/l it affects the health of infants producing a disease known as *mathemogloinemia* (or blue babies) which causes a child to be sick and vomits also it may cause death if not attended early. (Duggal K.N and Chand S., 1966)

Table 4: Primary Water Quality Criteria

Base use of designated water	**Class**	**Criteria given for the quality of designated water**	
		Parameter	**Range**
Drinking water source without conventional treatment but after disinfection.	A	1. Total Coliform organism MPN/100ml. 2. pH 3. Dissolved Oxygen 4. Biochemical Oxygen Demand 5 days 20 ^{0}C.	≤ 50 6.5 - 8.5. ≥ 6 mg/l ≤ 2 mg/l
Outdoor bathing (Organized)	B	1. Total Coliform organism MPN/100ml. 2. pH 3. Dissolved Oxygen 4. Biochemical Oxygen Demand 5 days 20 ^{0}C,	≤ 500 6.5 - 8.5 ≥ 5 mg/l ≤ 3 mg/l
Drinking Water Sources after conventional treatment	C	1. Total Coliform organism MPN/100ml. 2. pH 3. Dissolved Oxygen 4. Biochemical Oxygen Demand 5 days 20 ^{0}C,	≤ 5000 6 - 9 ≥ 4 mg/l ≤ 3 mg/l
Propagation of Wild Life Fisheries.	D	1. pH 2. Dissolved Oxygen 3. Free Ammonia	6.5 - 9.5 ≥ 4 mg/l ≤ 1.2 mg/l
Irrigation, Industrial Cooling Controlled Waste.	E	1. pH 2. Electrical Conductivity at 25-mg/cm 3. Sodium Adsorption Ratio 4. Boron	6.5 - 9.5. ≤ 2250 μmhos ≤26 ≤ 2 mg/l

Source: CPCB Delhi

2.3 WATER QUALITY INDEX

WQI can be defined as the presentation of large quantity of water parameters into a single number or it can also be defined as the technique of turning the complex data of water quality into an information that can easily be understood and used by the public and planners (Horton, 1965). It is a unit less number which ranges in scale between 0 and 100.

WQI takes information from different sources and combines them to formulate an overall status of a water at a particular area.

Some of the advantages (Tomer, 2015) of determination of WQI are as follows;

i. It helps to know the tendency or behaviour of the river in different seasons
ii. It helps to compare the water quality at different areas
iii. Makes the public to be aware of water quality status at any time as it is easy to be understood by them
iv. It helps managers to prioritize funds for water treatment

v. It helps to enforce the standards at a specific location

vi. Scientific research

The method to be selected it depend on;

- Availability of data
- Necessity of parameters to be checked
- The easy at which valuable results can be obtained

Here are some few of the above list will be explained for better understanding of them;

2.4 METHODS OF WATER QUALITY INDEX

2.4.1 National Sanitation Foundation Water Quality Index - NSFWQI

Brown et al. generated a general WQI from Delphi method by taking the parameters rigorously and developing a scale which can be common to all and giving weightage to those variables. The final parameter obtained are Dissolved Oxygen (DO), Faecal Coliform, pH, BOD (Biochemical Oxygen Demand), Temperature, Total Phosphate, Nitrates, Turbidity and Total Solids. The National Sanitation Foundation (NSF) gave a big support on its formation and accepted it, and that is why it is also known as NSFWQI (Bharti, N., & Katyal, D. 2011). NSFWQI relies on Expert Opinion (EO) rating curves which have been developed to assign values for fluctuation in the level of water quality caused by different levels of each of the selected parameters (Poonam et al., 2013). It is mathematically expressed as;

WQI = $\sum_{i=1}^{n} Q_i W_i$

Where Qi= Sub index of each parameter, n= Number of sub-indices, Wi = Weighting factor

The parameters and particular weightage assigned can be seen in the table;

Table 5: weightage of parameters by NSF

Parameter	**Weightage**	**Parameter**	**Weightage**
Dissolved oxygen	0.17	Phosphates	0.10
Faecal coliform	0.16	Temperature	0.10
pH	0.11	Turbidity	0.08
BOD_5	0.11	Total solids	0.07
Nitrates	0.10		

The results from all these nine variables different measurements defined above are summed up to give a Water quality index. In order to convert those results after test, graphs are used to give

Quality Values (Q). then the obtained value of Q is then to find aits product with weighing factor (W) and now after a Water Quality Index for at that location or waterbody cab be obtained. The ranges for gradation of the results are as shown in table

2.4.2 Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)

This index was developed to simplify the complexity and technical issues of water quality data from the BCWQI and modified by Alberta Environment. The work of reforming was done by the Canadian Council of Ministers of the Environment (CCME) and hence the name CCMEWQI (CCME, 2001). For computing the WQI by this method the standard limits (local and international) must be taken into account. (Table 4). In this method the standards are so called *"objectives"* The formula used takes into account of three elements; the first is *Scope*,2^{nd} is *Frequency* and the 3^{rd} and last is *Amplitude.*

Scope (denoted as **F_1)** - the number of variables which do not meet the water quality objectives;

$$F_1 = \frac{\text{Number of failed variables}}{\text{Total number of variables}}\ x\ 100$$

Frequency (denoted as **F_2) -** the number of times these individual tests have failed

$$F_2 = \frac{\text{Number of failed test}}{\text{Total number of variables}}\ x\ 100$$

Amplitude (denoted as **F_3)** - the range by which the unsuccessful tests differ from their standards.

Three stages have to be followed when calculating the amplitude;

i. As a start an "excursion" which refers to the number of times by which an individual concentration goes beyond (or its deficit, when the minimum is required as a standard (also called objective)) the allowable standard.

The expression may be in one of the two forms;

If the test value must not go beyond the standard value, then:

$$Excursion_i = \left(\frac{Failed\ Test\ Value_i}{Standard_j}\right) - 1$$

And for the cases in which the test value must not fall below the objective

$$Excursion_i = \left(\frac{Standard_j}{Failed\ Test\ Value_i}\right) - 1$$

ii. Normalised sum of excursions, or *nse*, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\#oftests}$$

iii. Now F_3 is simply calculated as;

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right)$$

Once the factors have been obtained, the CCMEWQI is now calculated just by summing these three factors like vectors as can be seen below;

$$\text{WQI} = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right)$$

This index ranges between 0 and 100 which means the worst water quality and best water quality respectively. The denominator 1.372 is there to assure that result from the formula only ranges between the prescribed ranges. The categories of the quality of water according to this is shown in the coming table 6.

2.4.3 Oregon Water Quality Index (OWQI)

The OWQI was initiated by the Department of Environmental Quality in Oregon State (ODEQ) in 1970s. It has been modified several times and now is doing well and hence being one of the most frequent used formula for public indices (Cude CG, 2001). OWQI uses eight variables for calculation of the index. The variables are pH, temperature, biochemical oxygen demand (BOD), bacteria, dissolved oxygen (DO), ammonia and nitrate nitrogen, total phosphorus and total solids (Dunnette, D.A., 1979). ODEQ was used originally for water quality of Oregon's stream but it was also being applied in other regions or water body (Bharti, & Katyal, 2011). The original OWQI was reformed after the NSFWQI where the method of Delphi was used for variable selection (McClelland 1974). This method was used to formulate recreational water quality index by that time.

1. The original weighted arithmetic mean function used in the OWQI was;

WQI = $\sum_{i=1}^{n} S_i\, W_i$

2. Weighted geometric mean function was used by the NSF WQI [19] was

$$WQI = \prod_{i=1}^{n} SI^{W^{i}}$$

Where, SI= Sub-index of each parameter, Wi= Weighting factor, n= Number of sub-indices

It has been suggested that the improved unweighted harmonic square mean formula should be introduced to aggregate sub index results over both formulae above. The equation makes the most number of impaired variable to impart the greatest influence on the water quality index (Balan et al., 2012). The merit of OWQI is that it gives the significance of different parameters on the whole water quality at different seasons and locations and is free from the arbitration in weighting the parameters. It employs the concept of harmonic averaging (Shweta et al., 2003). The formula is given by:

$$WQI = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{SI_i^2}}}$$

Where, SIi= Sub-index of each parameter, n= Number of sub-indices (as defined above). The rating scale (Cude CG, 2001) is given in table 2 above.

2.4.4 Weighted Arithmetic Water Quality Index Method (WAWQI)

WAWQI method groups the water quality to their respective degree of purity by using the most common variables measured. Various scientists have been using this method; (Balan et al., 2012; Chowdhuryet al., 2012; Chauhan & Singh, 2010).

The mathematical formula for this index (Brown et al., 1970) is

$$WQI = \sum Q_i W_i \Big/ \sum W_i$$

$$Q_i = 100[\frac{V_i - V_o}{S_i - V_o}]$$

Where; Q_i = quality rating scale

V_i = estimated concentration of *i*th parameter in the analysed water

V_o = the idea value of nth parameter in pure water. (i.e. 0 for all other parameters except the parameter pH =7.0 and DO = 14.6 mg/l)

S_i = recommended standard value of *i*th parameter.

W_i = unit weight of water parameter is obtained from by using the following formula:

$$W_i = K/S_i$$

Where K = proportionality constant which can also be calculated as;

$$K = \frac{1}{\sum(1/S_i)}$$

The rating of WAWQI is given accordingly in Table 6 below.

The WQI have to be applied for evaluation of water quality in a particular area (Lumb et al., 2006). As we have seen above that each index has its special merits and shortcomings. Up to now no attempt has been made to quantitatively 'weigh' different indices and give a new idea which pulls how much weight. Hence, it becomes difficult to say exactly why some indices are more popular than some others. Fernandez et al. (2004) compared 36 WQIs to observe if there are any considerable differences which exist between these classifications which are given by different indices on the same water sample. The differences raised primarily were found to be caused by;

- differing the type parameter and numbers used
- the assignments weightage to parameters and
- aggregation of formulae on used to calculate these indices

As WQIs have been developed in different geographical, regional and management circumstances, and there is no procedure in place to now to compare their performance, all one can do is to look at complementarities of those material information, amount of reliability, the easy in which these indices can be formulated, meaningfulness of key parameters and comparability of results, to make a respective judgement on the suitability of the WQI.

Table 6: Different WQI and their ratings

S/N	Method name	Formula	Definition symbols in formula	WQI Value	Rating of quality of water
1.	NSFWQI (Brown et al., 1970)	WQI = $\sum_{i=1}^{n} Q_i W_i$	Qi= Sub index of each parameter n= Number of sub-indices, Wi = Weighting factor	91 - 100	Excellent water quality
				71 - 90	Good water quality
				51 - 70	Medium water quality
				26 - 50	Bad water quality
				0 - 25	Very bad water quality
2.	CCME WQI (CCME, 2001)	WQI = $100 - \left(\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}\right)$ $F_1 = \frac{\text{Number of failed variables}}{\text{Total number of variables}}\ x\ 100$ $F_2 = \frac{\text{Number of failed test}}{\text{Total number of variables}}\ x\ 100$ $F_3 = \left(\frac{nse^*}{0.01nse + 0.01}\right)$	nse^*= normalized sum of excursions $nse = \frac{\sum_{i=1}^{n} excursion_i}{\#oftests}$ and $Excursion_i$ ** $= \left(\frac{Failed\ Test\ Value_i}{Objective_j}\right) - 1$ *$Excursion_i$ ** →see its full description on CCM WQI just after this table*	95 -100	Excellent water quality
				80 - 94	Good water quality
				60 -79	Fair water quality
				45 - 59	Marginal water quality
				0 - 44	Poor water quality
				85 - 89	Good water quality
				80 - 84	Fair water quality
				60 - 79	Poor water quality
				0 - 59	Very poor water quality
				26- 50	Good water quality
				51 - 75	Poor water quality
				76 - 100	Very Poor water quality
				Above 100	Unsuitable for drinking purpose
				65 – 89	Permissible
				35 – 64	Marginally suitable
				11 – 34	Inadequate for use
				< 10	Totally unsuitable

Table continues…

3.	OWQI (Cude CG, 2001)	WQI = $\sqrt{\frac{n}{\sum_{i=1}^{n}\frac{1}{SI_i^2}}}$	SIi= Sub-index of each parameter, n= Number of sub-indices	90 -100	Excellent water quality
				85 - 89	Good water quality
				80 - 84	Fair water quality
				60 - 79	Poor water quality
				0 - 59	Very poor water quality
4.	WAWQI (Abbasi, & Abbasi 2012)	WQI = $\sum Q_i W_i / \sum W_i$ Where $Q_i = 100[\frac{V_i - V_o}{S_i - V_o}]$ $W_i = K/S_i$ and $K = \frac{1}{\sum(1/S_i)}$	Q_i = quality rating scale V_i = estimated concentration of *i*th parameter in the analysed water V_o = the idea value of n^{th} parameter in pure water. (i.e. 0 for all other parameters except the parameter pH =7.0 and DO = 14.6 mg/l) S_i = recommended standard value of *i*th parameter. W_i = unit weight of water parameter K = proportionality constant	0 - 25	Excellent water quality
				26- 50	Good water quality
				51 - 75	Poor water quality
				76 - 100	Very Poor water quality
				Above 100	Unsuitable for drinking purpose

Table 7: Pros and Cons of selected Water Quality Indices

Pros	Cons	References
National Sanitation Foundation (NSF) WQI		
1. Large number of data are summarized in a single value in an objective, rapid and consistent manner 2. Evaluation between areas is possible and hence identification of changes in water quality is possible 3. The value of index has a direct relation with a potential use of water 4. Makes easy the communication with lay person	1. The index which is represent is too general 2. Data loss during manipulation 3. Lack of handling subjective matter present in complex environments	(Mnisi, 2012; Poonam et al., 2013)
Canadian Council of Ministers of the Environment (CCME) WQI		
1. Variety of variables are simply represented single number 2. The selection of input variables to be used is flexible 3. Different legal requirements for different uses can be adapted 4. The complex multivariate data of water can be put in very simplified form 5. Perceived diagnostic for managers and the general public is made simple 6. It is a desirable object for rating the water quality in a desired location 7. Its calculate is simple and simply understood 8. In this method the missing data is tolerable 9. Analysis of data coming from automated sampling is suitable in 10. It combine various measurement units in a single unit	1. Some information are lost on a single number representation 2. During interactions of variables some information are lost 3. Lack of portability of the index to different ecosystem types 4. It is easily biased 5. All variables are equally treated 6. No combination with other indicators or biological data 7. Only partial diagnostic of the water quality 8. When working on too few variables, the value of is not F_1 quiet reliable	(Terrado et al., 2010; Abbasi, & Abbasi 2012)
Oregon WQI		
1. The most imparted parameter to influence the water quality index can easily be obtained	1. It Does not take into account any changes in toxics concentrations, habitat or biology	(Cude CG, 2001;

by un-weighted harmonic square mean formula 2. This method recognizes that different water quality parameters will reduce differing significance to overall quality of water in varying different seasons and locations 3. Formula is a sensitive tool to change conditions and hence significant impacts on the quality of water	2. It is not possible to make illation of water quality conditions outside of the actual close network site locations 3. Unless all physical, chemical and biological data are considered it cannot determine the water quality for specific use 4. Difficult to evaluate all health hazards	Hubler et al., 2009)
Weighted Arithmetic WQI		
1. It merges data from multiple parameters into a single number 2. Less number of parameters are required in comparison of all parameters of water quality for particular use 3. It is very useful for communication of overall quality information of water to the intended citizens and policy makers 4. It reflects the exactly influence of composite parameters in a particular sample 5. It can be used to describe the suitability of surface and sub-surface water	1. It may not carry really information on the quality condition of the water at a particular place. 2. Sometimes the uses of water quality data may not converge with index itself 3. Using a single number only cannot bring the complete information on water quality 4. Mass of uses of water quality data are not fulfilled with these indices.	(Akoteyon et al.; Yogendra & Puttaiah 2008)

CHAPTER 4
DATA ANALYISIS AND DISCUSSION OF RESULTS

In this study the four years data were used to study the properties and hence the water quality trend of the river Yamuna. Year 2000, 2002, 2004 and 2005 were taken for reason of understanding the process WQI analysis and calculations.

The tables for analysed data from Yamuna River in years 2000, 2002, 2004 and 2005 for 18 monitoring stations namely; Hathnikund, Kalanaur, Sonepat, Palla, Nizamuddin, Agra Canal (mid and quarter streams), Mazawali, Mathura u/s, Mathura d/s (mid and quarter streams), Agra u/s, Agra d/s (mid and quarter streams), Bateshwar, Etawa, Udi and Judikha.

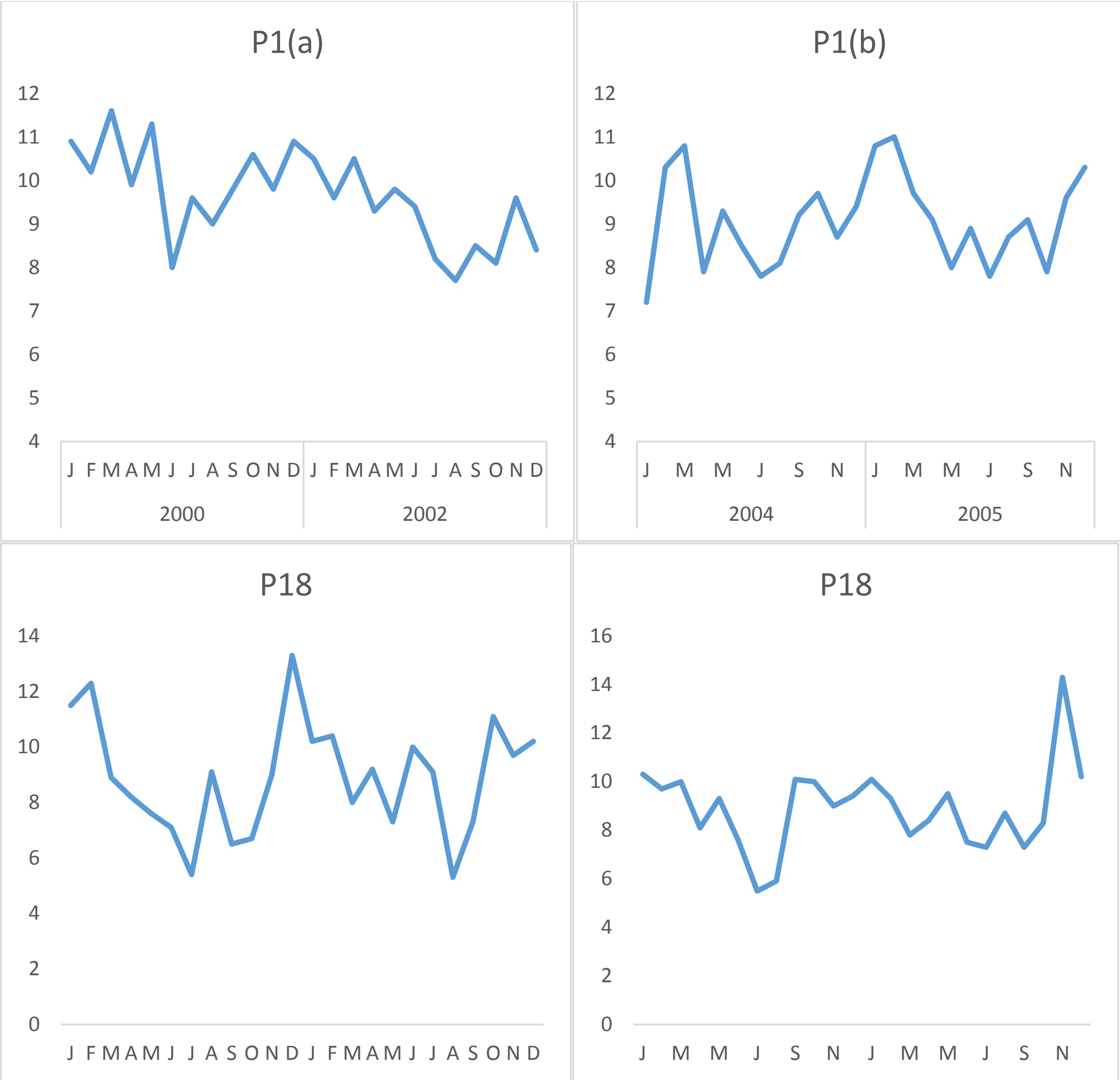
The data used were obtained from CPCB website. The parameters used are analysed below; in each parameter two graphs showing the trend showing the trend of a particular parameter at the start and at the end are shown. *The complete trend graphs and tables are attached as an appendix (iii).*

Dissolved oxygen (DO)

The presence of dissolved oxygen (DO) in river depends on rate of and period of photosynthesis, and how much it is used by aquatic microorganisms in water. The discrepancies which can be experienced may also be caused by time of the day when the measurement was taken. Usually the DO occurs maximum in the afternoon and minimum in night time. For this reason, the changes in DO observed in this study may also be due to differential in the sampling time.

The presence of BOD and DO in Yamuna River may be caused by settled sludge in the bed of the river. As it can be seen in figure xx from origin to Palla the DO level has found to be normal.

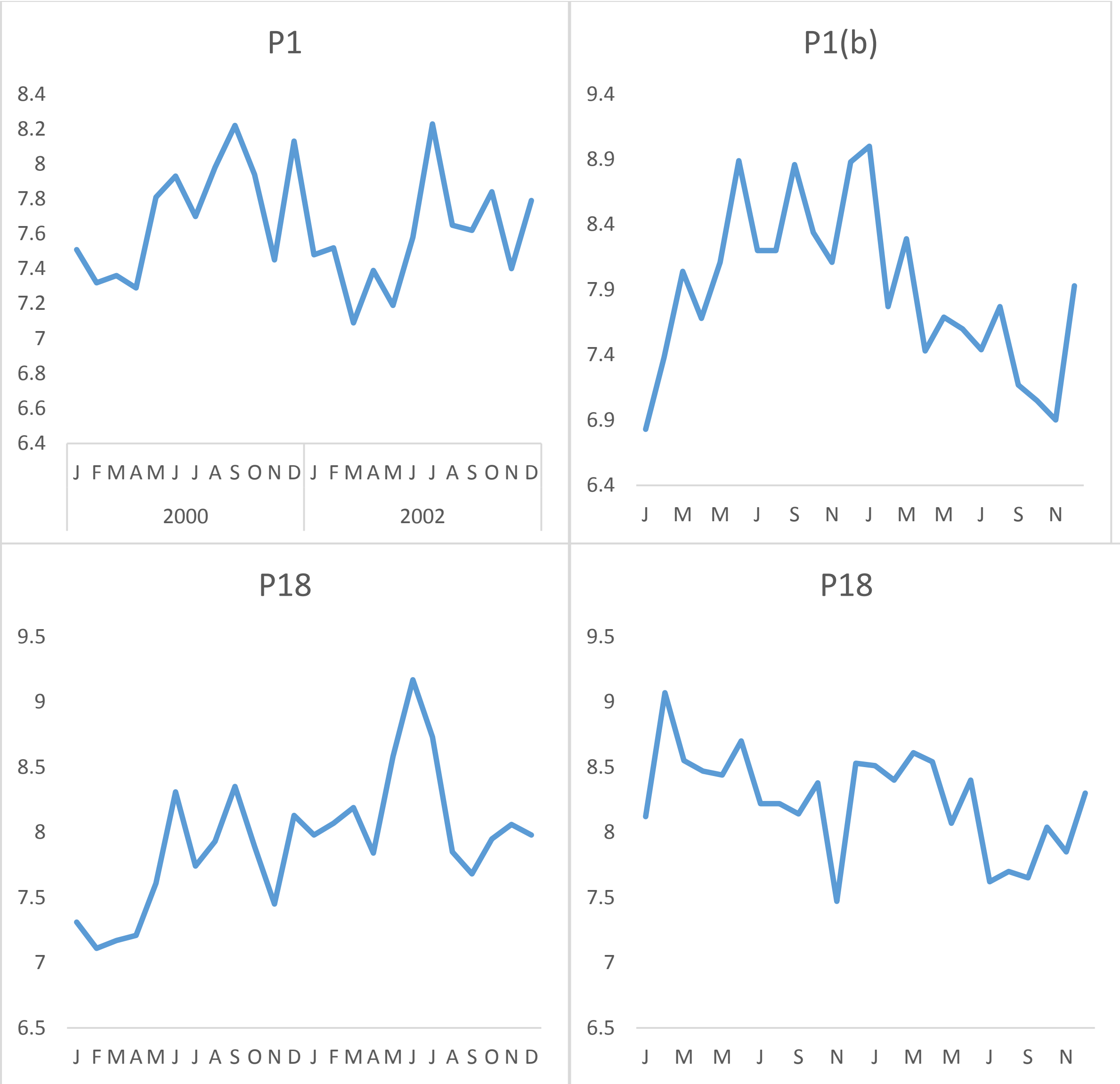
The DO has been found to be nil from Delhi towards downstream locations, even so, its level was observed to meet the standards in these locations during the monsoon season, due to flood of water in the river.



pH

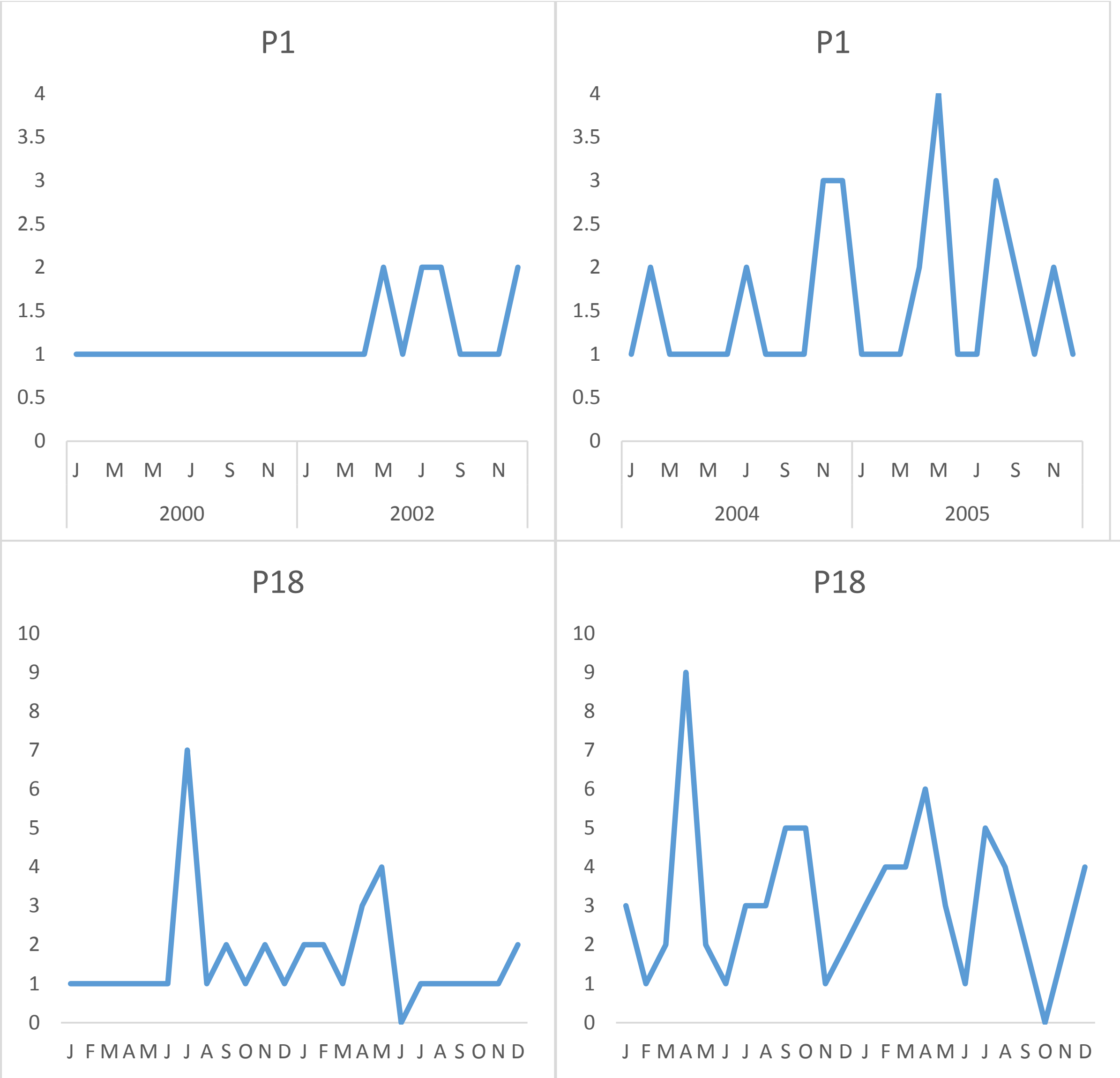
The value of pH in the entire stretch of the river stretch varied from 6.11 at Yamunotri where the river starts to 9.39 at Bateshwar. So the pH value is almost within prescribed limit. Small amount of pH at Yamunotri may be caused to presence of sulphur springs which joins the river. The reason which may cause the pH value to raise up may be either the discharge or dismissal from the industry or the formation of bicarbonates ions in the soil itself.

Figures below



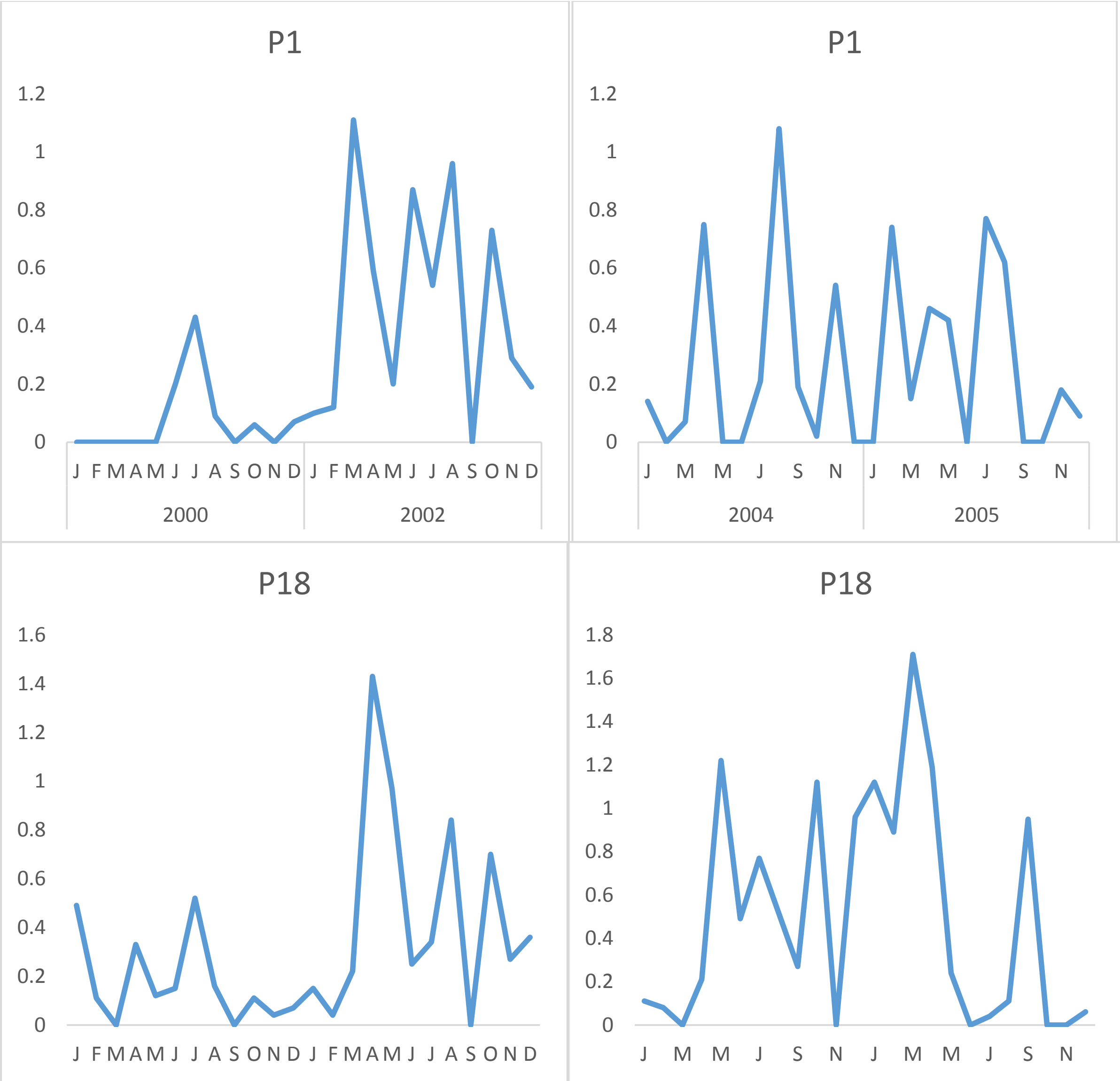
BOD

The level of BOD in the Yamuna from its origin up to Palla has been varying between 1 - 3 mg/l. It's average value for the year is not exceeding 3 mg/l. This shows that there is no substantial wastewater outfall in the river and adequate water which is fresh is available. But the BOD level rises to 6.0 mg/l from 3.0 mg/l which is beyond the standard between Kalanaur and Palla. The cause of this raise up may be due to discharges of wastewater from settlements located upstream of these sites or may be caused by human/animal execrators when contacts the river itself. BOD standard has been met i.e. complied again at Allahabad after being sufficient diluted from the tributaries. Around Nizamuddin Bridge in Delhi the BOD level varies in the range of 3 to 51 mg/l which shows how the water has been polluted.



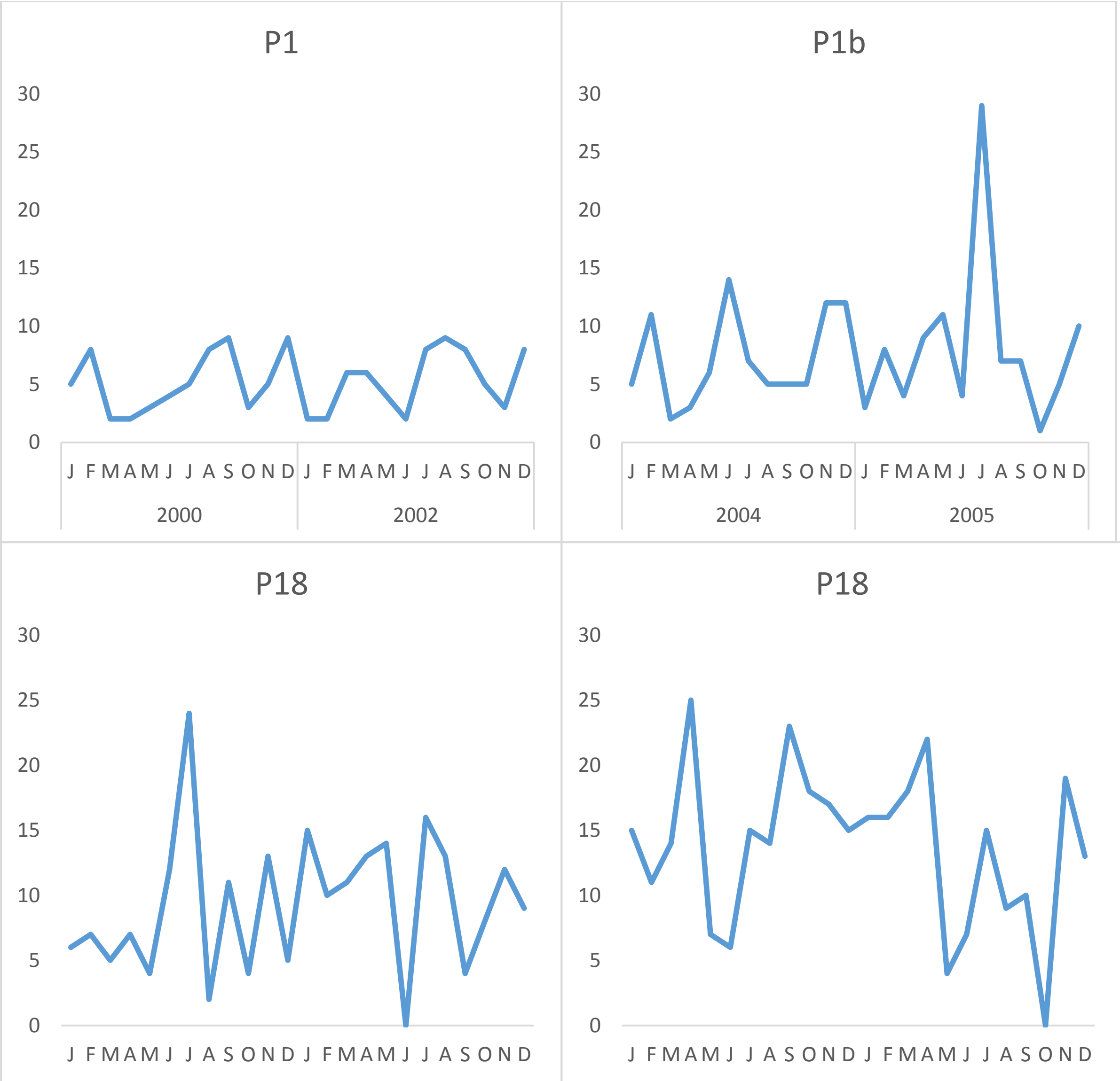
Ammonia and Kjeldahl Nitrogen (TKN)

These two parameters almost follow the same trend as BOD. Their values were low in relatively clean stretches of river and high in polluted stretch from Wazirabad to Bateshwar. The values of ammonia in varies from BDL to 43.34 mg/l. Significant concentration of ammonia might be caused due to industrial activities.



Chemical Oxygen Demand (COD)

COD is observed to be caused by wastewater discharges and excessive presence of algal mass (due to Eutrophication). From the beginning to Palla the COD was ranging between 1 - 49 mg/l. In foothill areas, the COD was observed to be very low. Up to Kalanaur the annual average of COD never exceeded 10 mg/l. Then again it increases largely to 46mg/l. This must be due to human activities.



(BOD), bacteria, dissolved oxygen (DO), ammonia and nitrate nitrogen, total phosphorus The WQ analysis is done by three methods which are;

2.1 Oregon Water Quality Index (OWQI)

In this method

OWQI uses maximum of eight variables for calculation of the index. The variables required are pH, biochemical oxygen demand and Total Coliform

According to the available data the following data were available; pH, TC, BOD, Dissolved Oxygen (DO), and Ammonia

In calculating this index tables and graphs were used to arrive at the destination of categorise the water; tables and graphs. The results from these two were calculated using this formula;

$$WQI = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{SI_i^2}}}$$

Where

SI_i= Sub-index of each parameter, n= Number of sub-indices.

Now taking Hathnikund as a sample station in January 2002, the calculations are done as below;

Table 8: WQI by OWQI method

HATHNIKUND				
JAN 2002				
	Raw value	Si	Si^2	1/(Si^2)
pH	7.48	100.00	10000	0.0001
BOD	1.00	80.00	6400	0.0002
AMM.	0.10	97.00	9409	0.0001
DO	10.5	100.0	10000	0.0001
FC	100	95	9025	0.0001
				0.0006
				93.3858

The value of *Si* can be read from the provided charts by ODEQ *(Appendix ii).*

According to categorisation by this OWQI, the range 90 -100 it means Excellent water quality at this sampling point.

2.2 National Sanitation Foundation Water Quality Index (NSFWQI)

NSFWQI relies on Expert Opinion (EO) rating curves that have been formulated to assign all the values for variation in their levels of water quality caused by different levels of each of the selected parameters. It is mathematically expressed as;

WQI = $\sum_{i=1}^{n} Q_i W_i / \sum_{i=1}^{n} W_i$

Where Qi= Sub index of each parameter, n= Number of sub-indices, Wi = Weighting factor. The Q values is obtained from the NSF charts (Appendix (i))

Table 9: WQI by NSF method

HATHNIKUND				
JAN 2002				
		Q	Wi	QWi
pH	7.48	92.00	0.12	11.04
BOD	1.00	90.00	0.12	10.80
DO	10.50	8.00	0.18	1.44
FC	100.00	43.00	0.17	7.31
			0.59	31
				52

According to NSF scale 52 falls in the range of 51 - 70 which means Medium water quality (Ref. table1)

The overall results for all four years are attached in *appendix (iii)*

2.3 Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)

The numbers marked with red in the table below shows that they are out of the required standard limits.

Table 10: WQI by CCME method

2002														
HATHNIKUND														
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	limits	**RECOMMENDED BY**
pH	7.48	7.52	7.09	7.39	7.19	7.58	8.23	7.65	7.62	7.84	7.40	7.79	6.5–8.5	CPCB
COD	2.00	2.00	6.00	6.00	4.00	2.00	8.00	9.00	8.00	5.00	3.00	8.00	10	CPCB
BOD	1.00	1.00	1.00	1.00	2.00	1.00	2.00	2.00	1.00	1.00	1.00	2.00	5	CPCB
AMM.	0.10	0.12	1.11	0.59	0.20	0.87	0.54	0.96	BDL	0.73	0.29	0.19	0.5	WHO
TKN	1.67	0.31	1.31	1.19	1.40	0.90	1.37	1.19	0.91	1.37	1.03	1.58	1	WHO
DO	10.5	9.6	10.5	9.3	9.8	9.4	8.2	7.7	8.5	8.1	9.6	8.4	>5	IS
FC	100	700	1700	2000	3200	120	40	92	1370	620	40	450	400	IS

The formula used takes into account of three elements; *Scope, Frequency* and *Amplitude.*

Scope (denoted as $\mathbf{F_1}$) - the number of variables which do not meet the water quality objectives;

$$F_1 = \frac{\text{Number of failed variables}}{\text{Total number of variables}} x\ 100$$

F1 = 3/7 x 100 = 42.86.

Frequency (denoted as $\mathbf{F_2}$**)** - the number of times these individual tests have failed

$$F_2 = \frac{\text{Number of failed test}}{\text{Total number of variables}}\ x\ 100$$

F2 = 16/84 x 100 = 19.05

Amplitude (denoted as $\mathbf{F_3}$**)** - the extent by which the failed test does not meet their objectives.

The amplitude is calculated in three steps;

i. First an "excursion" which is the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective.

The expression may be in one of the two forms;

When the test value must not exceed the objective:

$$Excursion_i = \left(\frac{Failed\ Test\ Value_i}{Objective_j}\right) - 1$$

For Ammonia in April;

0.59/0.5 – 1 = 0.18

The remaining numbers in red are done in the same procedure and their results are tabulated below;

0.18	0.74	0.08	0.92	0.46	
0.67	0.31	0.19	0.37	0.03	0.58
0.75	3.25	4	7	0.125	

And for the cases in which the test value must not fall below the objective

$$Excursion_i = \left(\frac{Objective_j}{Failed\ Test\ Value_i}\right) - 1$$

ii. Normalised sum of excursions, or *nse*, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\#\,of\,tests}$$

nse = 19.66/84 = 0.233988

iii. Now F_3 is simply calculated as;

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right)$$

*F3 = 0.233988/ (0.01*0.233988+0.01) = 18.9619*

Once the factors have been calculated and obtained, the WQI can now be easily calculated by summing the three factors as if they were vectors as follows;

$$\text{WQI} = 100 - \left(\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}\right)$$

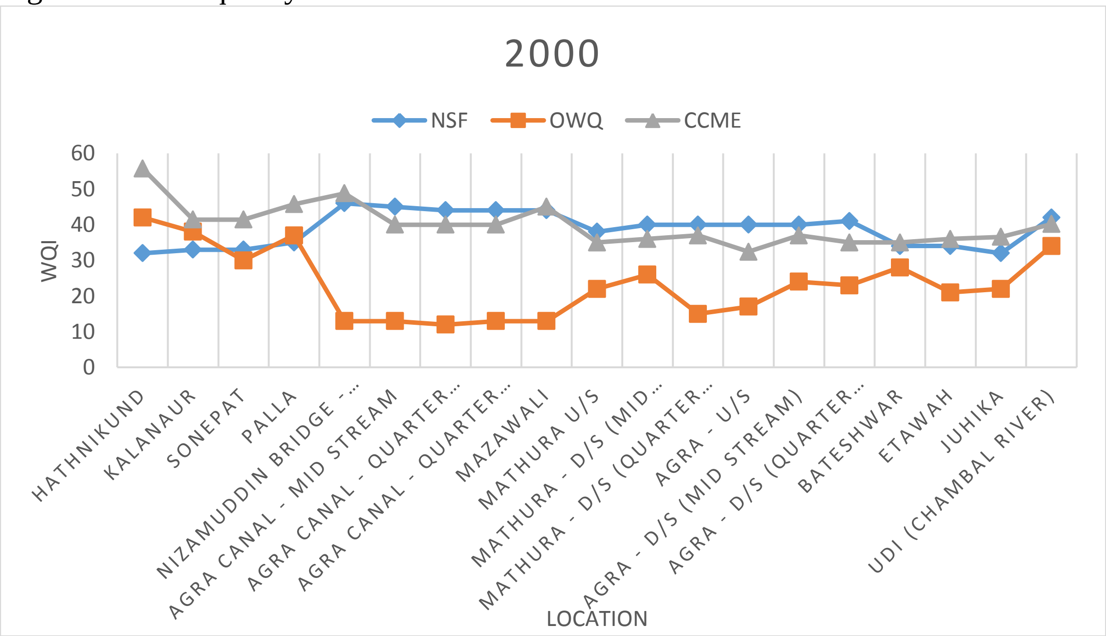
$$\text{WQI} = 100 - \left(\frac{\sqrt{42.86^2+19.05^2+18.96^2}}{1.732}\right) = \mathit{70.7924}$$

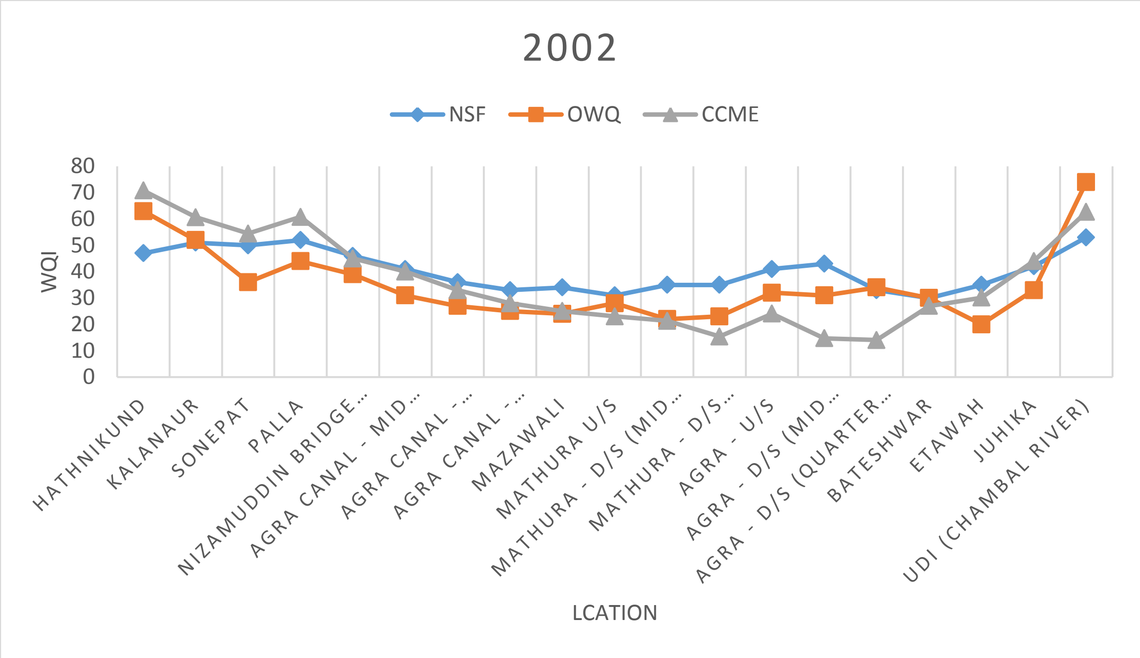
Since it lies between 95 -100 then it is categorised as Excellent water quality

This index ranges between 0 and 100 which means the worst water quality and best water quality respectively. The denominator 1.372 is there to assure that result from the formula only ranges between the prescribed ranges. The categories of the quality of water according to this is shown in the table 2 above.

Below are water quality charts for four years shown. The complete yearly and their tables are attached as index (iv)

Figure 5: Water quality status from 2000 - 2005




2002
NSF
OWQ
CCME
WQI
0
10
20
30
40
50
60
70
80
HATHNIKUND
KALANAUR
SONEPAT
PALLA
NIZAMUDDIN BRIDGE…
AGRA CANAL - MID…
AGRA CANAL - …
AGRA CANAL - …
MAZAWALI
MATHURA U/S
MATHURA - D/S (MID…
MATHURA - D/S…
AGRA - U/S
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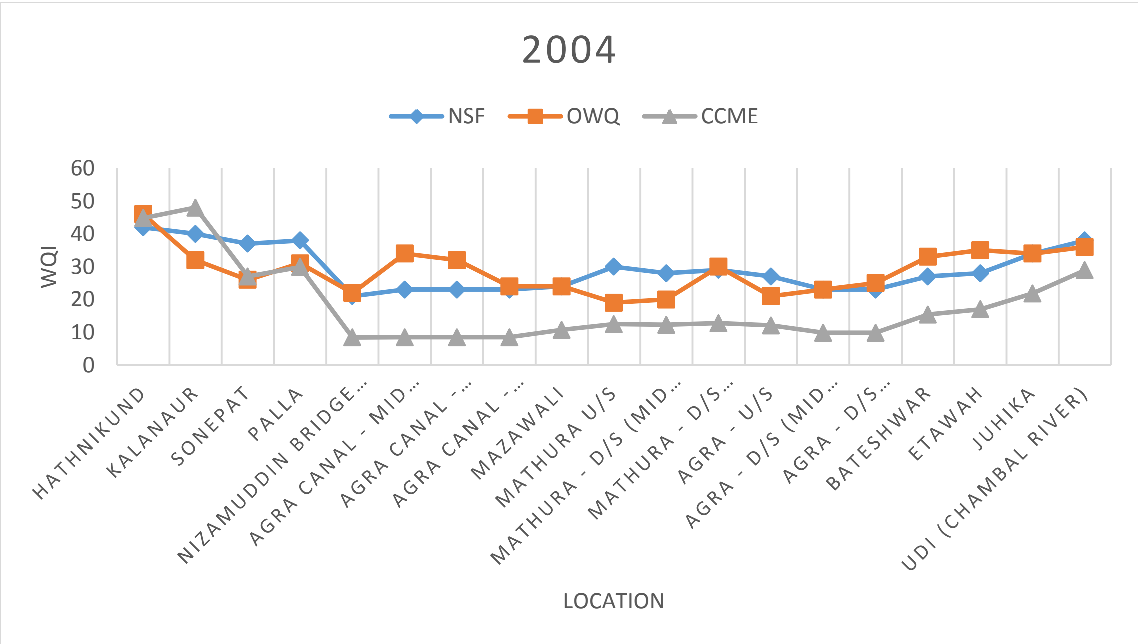
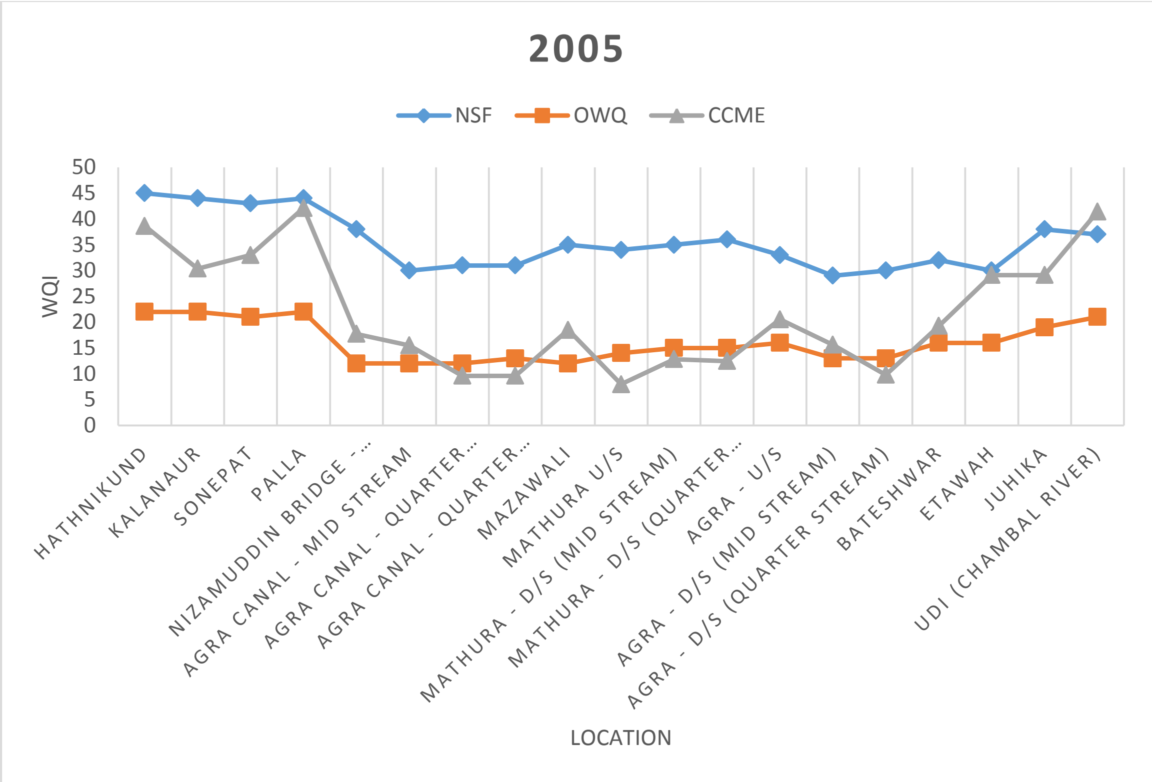
BATESHWAR
ETAWAH
JUHIKA
UDI (CHAMBAL RIVER)
LCATION


2004
NSF
OWQ
CCME
WQI
0
10
20
30
40
50
60
HATHNIKUND
KALANAUR
SONEPAT
PALLA
NIZAMUDDIN BRIDGE…
AGRA CANAL - MID…
AGRA CANAL - …
AGRA CANAL - …
MAZAWALI
MATHURA U/S
MATHURA - D/S (MID…
MATHURA - D/S…
AGRA - U/S
AGRA - D/S (MID…
AGRA - D/S…
BATESHWAR
ETAWAH
JUHIKA
UDI (CHAMBAL RIVER)
LOCATION


2005
NSF
OWQ
CCME
WQI
50
45
40
35
30
25
20
15
10
5
0
HATHNIKUND
KALANAUR
SONEPAT
PALLA
NIZAMUDDIN BRIDGE -…
AGRA CANAL - MID STREAM
AGRA CANAL - QUARTER…
AGRA CANAL - QUARTER…
MAZAWALI
MATHURA U/S
MATHURA - D/S (MID STREAM)
MATHURA - D/S (QUARTER…
AGRA - U/S
AGRA - D/S (MID STREAM)
AGRA - D/S (QUARTER STREAM)
BATESHWAR
ETAWAH
JUHIKA
UDI (CHAMBAL RIVER)
LOCATION

SUMMARY

The characteristics of Yamuna river varies much during non-monsoon period (January to June again October to December) and again in monsoon period i.e. July to September. All parameters were attempted to find out their variation in river water quality for the whole period of the year. Appendix (iii) shows the variation of each parameter for the whole four years period.

It can be observed that for most time around Delhi stretch from Nizamuddin the amount of DO was too low compared to the prescribed standard. But after Delhi, the DO level drops down partially during monsoon which may be caused by diminishing of eutrophics in the river itself.

The BOD amount from the beginning to Palla is generally below the standard limit almost all the time. Then it seems to overlap standards up to around Allahabad. During the rainy season i.e. monsoon period its levels reduces to around prescribed limit.

TC generally reduces significantly in monsoon period almost in the entire stretch of Yamuna although still were above the limits.

The Faecal coliforms (FC) also increases between Delhi and Agra and generally may be caused due to flushing of materials containing much faecal in it into the river.

pH for most of time was not affected as it was within the prescribed limits.

COD were ranging from of 4 mg/l to 68 mg/l during non-monsoon period.

Ammonia and TKN were just reduced during monsoon otherwise it was going beyond the standards.

The WQI follows the trend of the parameters for the period. It is just an aggregation of separate parameters results for the easy presentation to the public and Managers. Hence observing these graphs for WQI it can be observed that the quality varies from medium to very poor water quality.

Hence although it is cumbersome in its calculation it is advisable to use WQI just because of its easy of understanding by audience.

CHAPTER 5

CONCLUSION

The study generally shows that around a stretch from origin of the Yamuna Rive to Nizammudin barrage the water quality is a least acceptable. But from this point going down especially in Delhi City and the water is very risky for consumption, the major reason being;

- Discharging the wastewater in river
- Dumping of domestic wastes (as seen in previous) attached photos
- Industrial wastes and agricultural activities.

All these and other possible reasons they tend to take the river water out of the local and international standard or limits leading to the risk of human and aquatic health.

The data collected though they are old but can be used to give a clear picture of what is happening along the river.

The quality of the water generally improves after the river water being diluted. This dilution as it has seen in the study comes either during monsoon season or after the river being joined with another tributary which is less contaminated. For example, it can be seen that at Juhika most of the variable parameters improves after just after water is received from Chambal river which is less polluted.

The acceptability of water quality criteria relies upon the situations and it differs from time to time and from place to place. WQI is necessary for resolving a huge multi-parameter water investigation an summarise the results data into single digit scores.

However, according to researchers up to now it is found to be so difficult to formulate an index which can be acceptable universally. But the regional and specific WQI can be developed by local researchers.

WQI method although is not more perfect but as it can be seen above, it gives a clear picture of what is happening about the water status in the particular water body and hence gives a cation to water users against the risk which one may have if he/she uses the water untreated.

RECOMMENDATION AND WAY FORWARD

As it has been seen that generally the water from this river nowadays is not safe for general consumption. The following should be abided and intentionally practised

- Continuous monitoring for water use should be much serious otherwise a drastic disaster may occur which can consume a mass lives.
- Government should enforce the cleanness to each and every one from household level to institutions.
- Great care should be taken not to overuse pesticides and fertilisers so that to prevent runoffs of the material into the river
- People should be encouraged to do plantation around their premises as it helps in preventing fertiliser, chemicals/pesticides and other contaminated water from running off into the river.
- Proper handling of sewage from household should be put into practice so that they cause no harm to environmental.
- Throwing of wastes like paints, oils or other forms of litter in the river should completely be banned
- Factories are expected to extensively treat its effluent wastes prior to discharge into the waterbody. Toxic material must be treated chemically and converted into harmless materials. Recycling the treated water in factories when possible is well insisted.
- Enforcement of obedience to water laws: Strong punishment should be applied to law breakers.
- In cities all drainage water should be collected and well treated before allowing them to mix with water bodies.
- Keeping the river clean by avoiding the activities like washing in the river, bathing of livestock.
- Sanitation system should be improved from home base to any institute and public places. People should about the benefits and problems which they may get by sanitising their environments.
- General public awareness should always be given to alert the community about the water safety. When Charitable association should go door-to-door to educate the people about their safety.
- For effective performance of these WQI each major river in India should be prepared its own index.

CHAPTER 6
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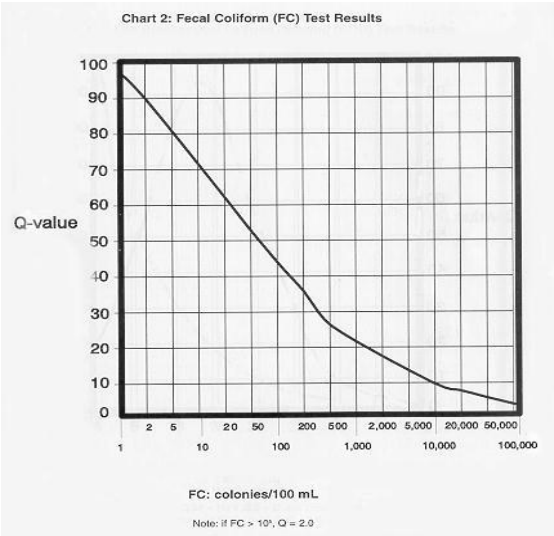
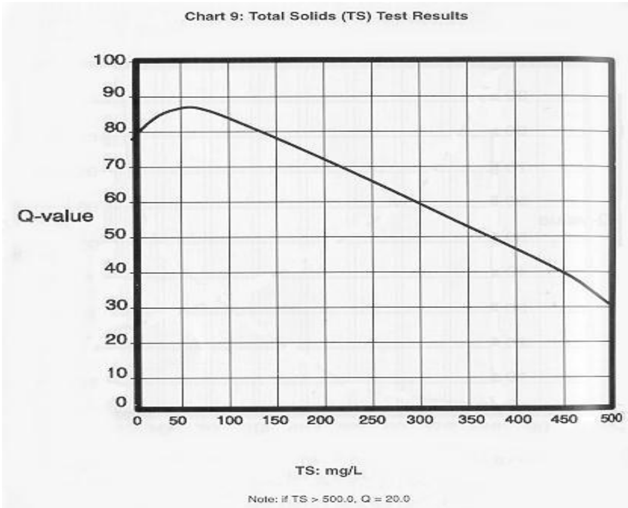
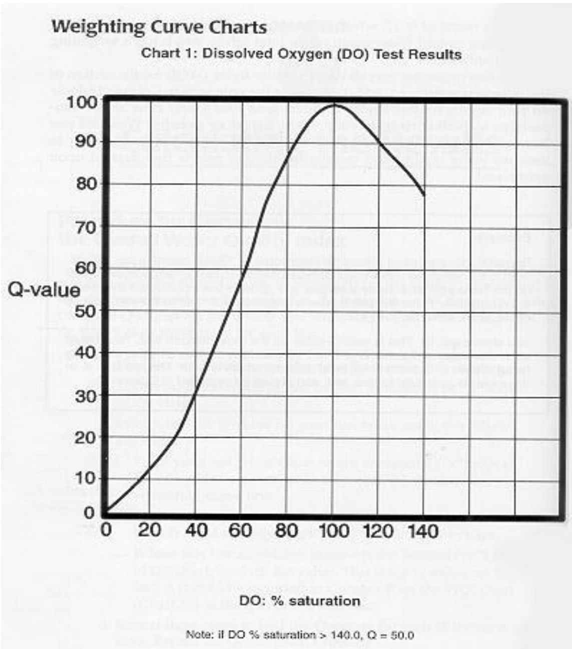
APPENDICES

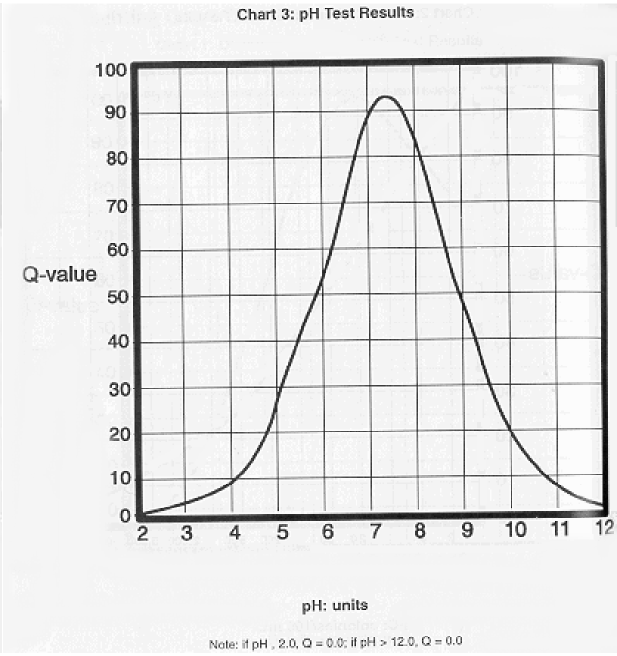
Appendix (i)

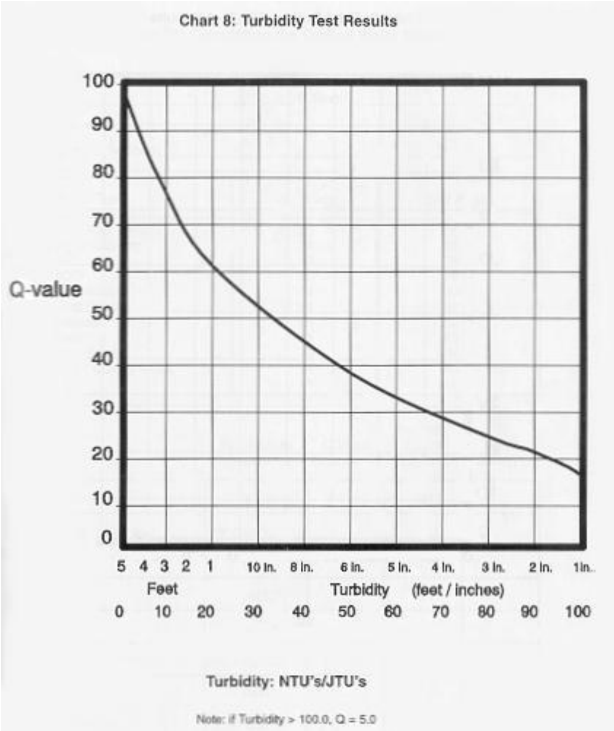
NSF tables for Q-value

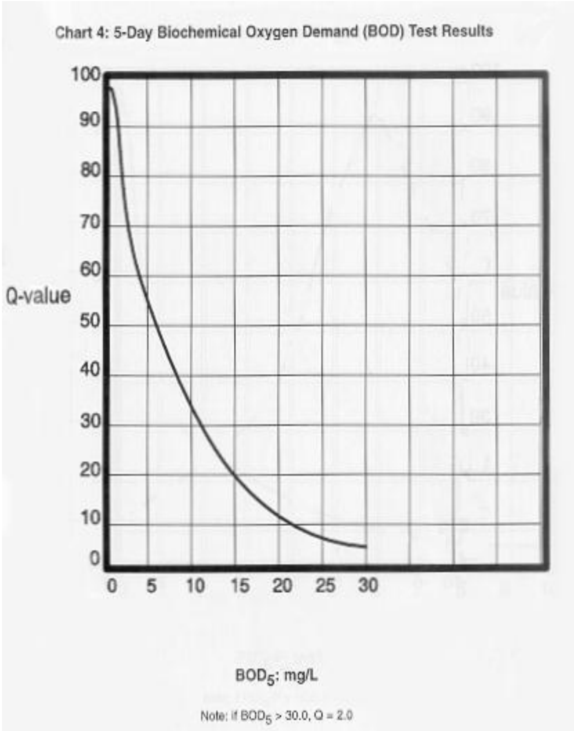




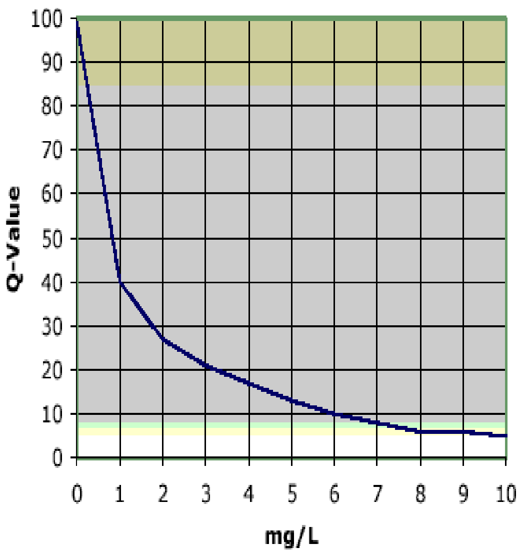






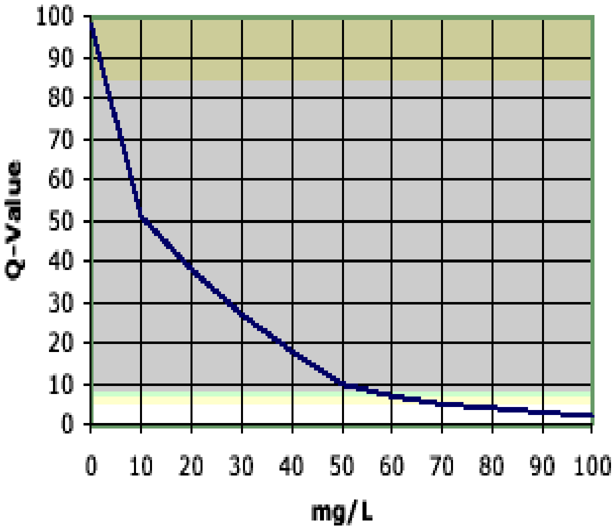


Phosphate Results



(Note: If phosphate > 10.0, Q=2.0)

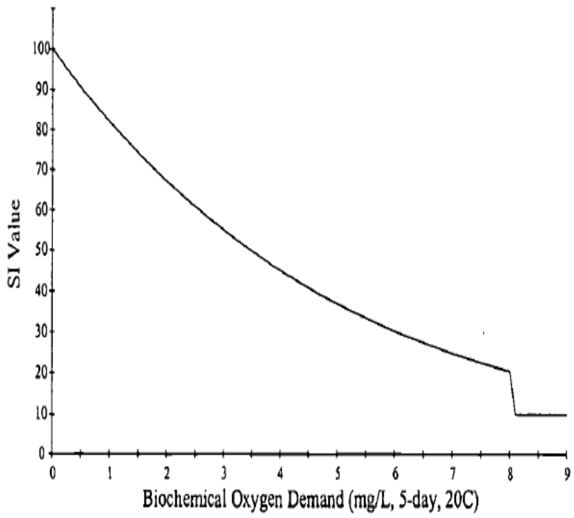
Nitrate Results

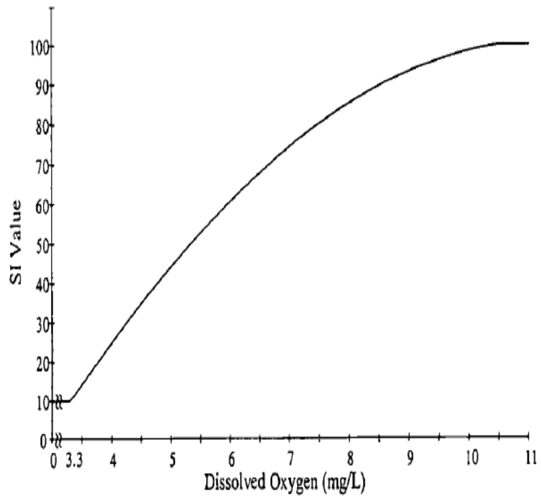


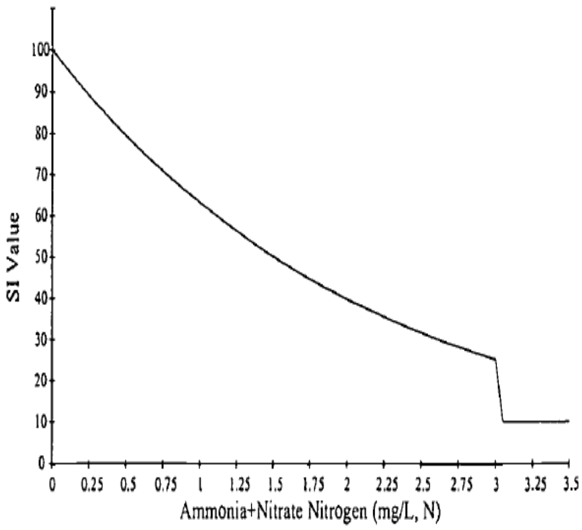
(If Nitrates > 100.0, Q=1.0)

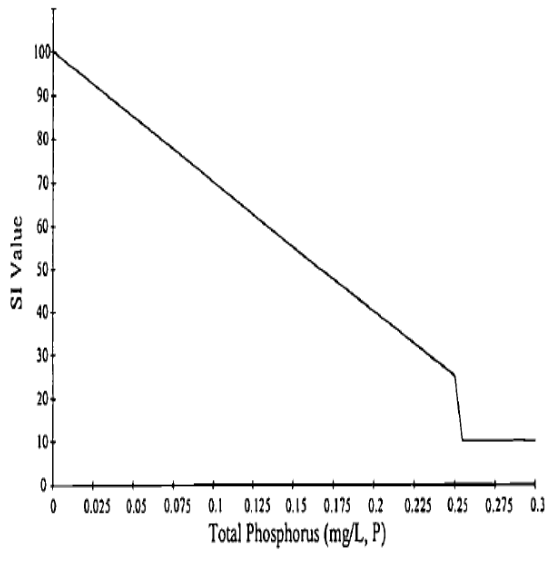
Appendix (ii)

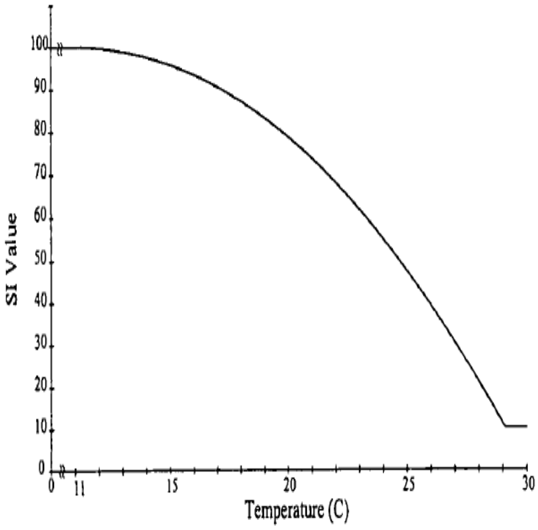
Oregon Water Quality Index tables

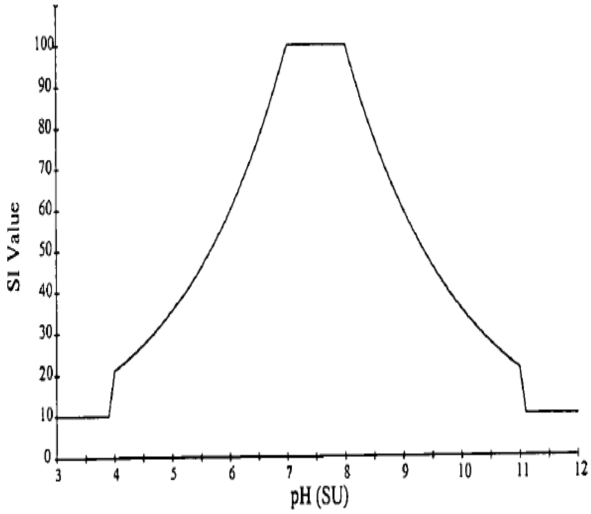


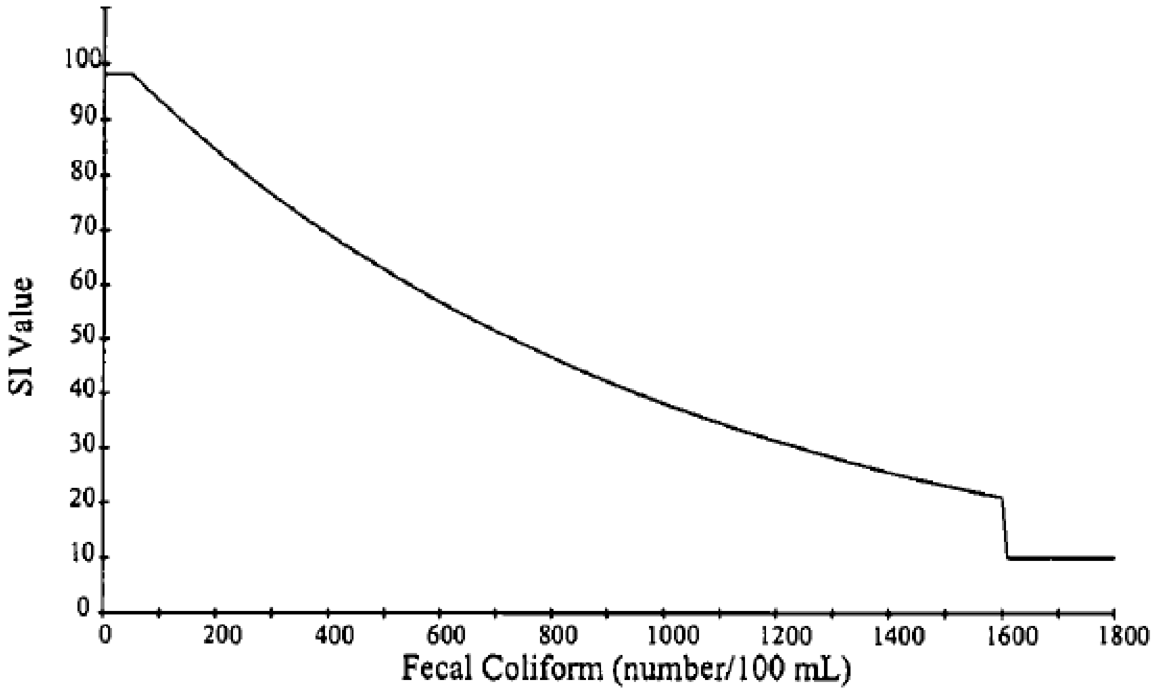







SI Value
100
90
80
70
60
50
40
30
20
10
0
0
11
15
20
25
30
Temperature (C)


SI Value
100
90
80
70
60
50
40
30
20
10
0
3
4
5
6
7
8
9
10
11
12
pH (SU)


SI Value
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
Fecal Coliform (number/100 mL)