A NOVEL APPROACH FOR ASSESSMENT OF HEALTH OF RIVER YAMUNA USING FUZZY INDEX AND WQI BY NSF

A Project Dissertation Submitted in the Partial Fulfilment of the Requirements for the Degree of

MASTER OF TECHNOLOGY

IN

ENVIRONMENTAL ENGINEERING

Submitted by

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June 2016

CERTIFICATE

This is to certify that the work which is being presented in thesis entitled " **A NOVEL APPROACH FOR ASSESSMENT OF HEALTH OF RIVER YAMUNA USING FUZZY INDEX AND WQI BY NSF "** is submitted by SALILA BHARTI, ROLL NO- 2K14/ENE/015 in the partial fulfillment of the requirement for the award of degree of MASTER OF TECHNOLOGY IN ENVIRONMENTAL ENGINEERING to DEPARTMENT of ENVIRONMENTAL ENGINEERING, DELHI TECHNOLOGICAL UNIVERSITY.

It is a record of the student's own work prepared under the supervision and guidance.

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DECLARATION

I, hereby declare that the work being presented in the project entitled " **A NOVEL APPROACH FOR ASSESSMENT OF HEALTH OF RIVER YAMUNA USING FUZZY INDEX AND WQI BY NSF "** is an original work and an authentic report carried out as a part of my major project . The contents of this report have not been previously formed the basis for the award of any degree, diploma or other similar title or recognition and is being utilized by me for the submission of my Major-2 Report to complete the requirements of Master's degree of Examination in Environment Engineering, as per Delhi Technological University curriculam.

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ABSTRACT

The water quality (WQ) status of water bodies is highly uncertain and subjective in nature. The present paper addresses a “Fuzzy Water Quality Index” (FWQI) which is capable to deal with subjectivities and uncertainties concerning river health at five sites of the Yamuna river, India.The five sites where the water quality were analysed are Palla, Nizamuddin, OKHLA, Agra Canal (Kalinidi Kunj), Agra Canal (Madanpur Khadar). By defining four parameters like pH, dissolved oxygen (DO), biological oxygen demand (BOD), total coliform (TC) fuzzy model is established. Model uses triangular membership functions for fuzzification, and centroid method for defuzzification.The proposed proficient method includes a fuzzy model which include IF-THEN ideas that helps to determine River health using WQ parameters. Further, the performance of models is compared with Water Quality Index as evolved by National Sanitation Foundation. The indices were compared using Pearson product moment Correlation coefficient. The coefficient of correlation were as follows:-

1. The correlation between FWQI and NSF WQI at Palla is 0.82058
2. The correlation between FWQI and NSF WQI at Nizamuddin is 0.90838
3. The correlation between FWQI and NSF WQI at Agra Canal(Kalinidi kunj) is 0.893
4. The correlation between FWQI and NSF WQI at OKHLA is 0.902117
5. The correlation between FWQI and NSF WQI at Agra Canal(Madanpur Khadar) is 0.86459.

The correlation at all the sites were found to be strong as they were above 0.8. The proposed FWQI provides the flexibility for decision making in an integrated WQ management policies.

CHAPTER – 1

INTRODUCTION

1. INTRODUCTION

1.1 General

Water is one of the most important elements responsible for life on this planet earth. The 7.6 billion people on earth use nearly 30 percent of the world's total accessible renewal water supply. Yet billions of people are deprived of basic water. It is said that 1 in 10 people lack access to safe water. Among other countries in the world, India is one of the few selected countries having endowed with reasonably good land, mineral resources as well as water resources. India is a country with vast geographic, biological and climatic diversity. Average annual precipitation including snowfall is approx. 4000 billion cubic meters (BCM) over the country. The average annual water resources in various river basins are estimated to be 1869 BCM, of which 1086 BCM is utilizable including 690 BCM of surface water and 396 BCM of ground water. The rest of the water is lost by evaporation or flows into the sea and goes unutilised.

There are seven major rivers in India with more than four hundred rivers in total.India's surface water flows through 14 major river basins beyond innumerable medium/minor basins. These rivers are fast flowing and are mostly monsoon fed. Due to the spatial and temporal variations in precipitations as well as the rapid growth of population and improved living standards, the demand for supply of water resources in general and fresh water in practical is increasing. As a result of this, per capita availability of water is reducing day by day. However, surface water resources in the country are in much greater volume when compared to the groundwater resources. The climate change is affecting the precipitation and ultimately affects the quantity of water available, on the other hand, increasing loads from point and non-point sources are deteriorating the quality of surface as well as ground water resources. As the majority of the rivers in the country are not perennial, groundwater actually sustains much of the population during the lean months. There is a tremendous variation both in the quantity and quality of discharge from region to region in these river basins. With a few exceptions, all the medium and minor river basins originate in the mountains, and thus exhibit a common feature of fast flowing and monsoon-fed streams in the hilly regions. By the time they reach the plains they are mostly transferred as tidal streams. The treated or untreated discharges from such sources would always find a way into the rivers that oscillate like a pendulum due to the seasonal flow character of these rivers. During monsoon, when rainwater flows down the river the discharge in the pollutants, the flow rate and flow depth oscillate because of the tides in the tidal reaches. As the storm water moves downstream, the flushing out time for the pollutants decreases substantially. All the major river basins are not perennial. Many of the major river basins also go dry during the summer leaving insufficient water for dilution of waste water discharged in them.

The study area in this project covers river Yamuna in Delhi. The river Yamuna ,also sometimes called Jamuna is the longest and the second largest tributary river of the Ganga in northern India. . This river is as prominent and sacred as the great River Ganga itself. It has been acclaimed as a holy river in Indian mythology and various pilgrimage centers e.g. Yamunotri (Uttaranchal), Paonta Sahib (Himachal Pradesh), Mathura, Vrindavan, Bateshwar & Allahabad (all in Uttar Pradesh) are located at the banks of this river. Originating from the Yamunotri Glacier at a height of 6,387 metres on the south western slopes of Banderpooch peaks in the uppermost region of the Lower Himalayas in Uttarakhand, It travels a total length of 1,376 km and has a drainage system of 366,223 square kilometres , 40.2% of the entire Ganges Basin, before merging with the Ganges at Triveni Sangam, Allahabad, the site for the Kumbha Mela every twelve years. It is the longest river in India which does not directly flow to the sea.

The flow of the Yamuna River varies significantly during monsoon and nonmonsoon seasons. The river constitutes maximum flow i.e. around 80% of the total annual flow during monsoon period. During non-monsoon period the Yamuna cannot be designated as a continuous river but segregated into four independent segments due to the presence of three barrages from where almost the entire water is being diverted for various human activities. The river water is used for both abstractive and in stream uses. Irrigation is the important use of Yamuna Water followed by domestic water supply, industrial and other uses.

The sources contributing pollution are both point & non-point type. Urban agglomeration at NCT – Delhi is the major contributor of pollution in the Yamuna River followed by Agra and Mathura. About 85% of the total pollution in the river is contributed by domestic sources. The condition of river deteriorate further due to abstraction of significant amount of river water, leaving almost no fresh water in the river, which is essential to maintain the assimilation capacity of the river.

About 580 km long river stretch in between Wazirabad barrage and Chambal river confluence is critically polluted. This stretch is characterized by high organic contents, high nutrients, significant depletion or increase in dissolved oxygen, severe odours etc. The 22 km long Delhi stretch is polluted severely.

It is believed that New Delhi dumps about 58 percent of its waste into this river. Reports have also suggested that the river is full of excreta and is thus, unfit for bathing or even washing clothes, let alone drinking.While there were 81 industries along the periphery of Yamuna in the year 2000, now about 500 factories exist and produce waste such as leather discharging chromium, arsenic and cadmium.

Its not only the industrial sector that needs to be blamed, but also the poor sewage system, saturated landfills, human settlements around the river and the agricultural waste that gets washed into it. Insecticides and pesticides contribute to the pollution. There are also the people who wash clothes, utensils and defecate in or around the river, thus leading to pollution.

Other reasons that can be attributed to the pollution are cattle washing, untreated waste either domestic or industrial and religious activities including immersion of idols.Unbelievable as it is, even Delhi Metro has had its fair share of opportunity to sully the holy river. Delhi Metro Rail Corporation (DMRC) has dumped over 50,400 metric tones of debris in the riverbed. They have also admitted that 10,000 metric tones of debris has been dumped at a site near Sarai Kale Khan on the western bank of Yamuna.

Its not surprising that our actions have backfired. Yamuna in Delhi has a zero amount of dissolved oxygen, due to which it is unable to support any marine life. And the biodegradable waste dumped into the water has led to the formation of algae (also called Eutrophication) which is also leading to a reduction in the levels of oxygen in water.

The arsenic levels have increased 20 times in the last 20 years. It is infamously known as “slow poison” and cause cancer and skin problems. Studies have suggested that farmers using water with high arsenic levels have suffered from such diseases. The present area of study further researches into the deterioting condition of river Yamuna based on the river quality parameters from year 2011to 2015.

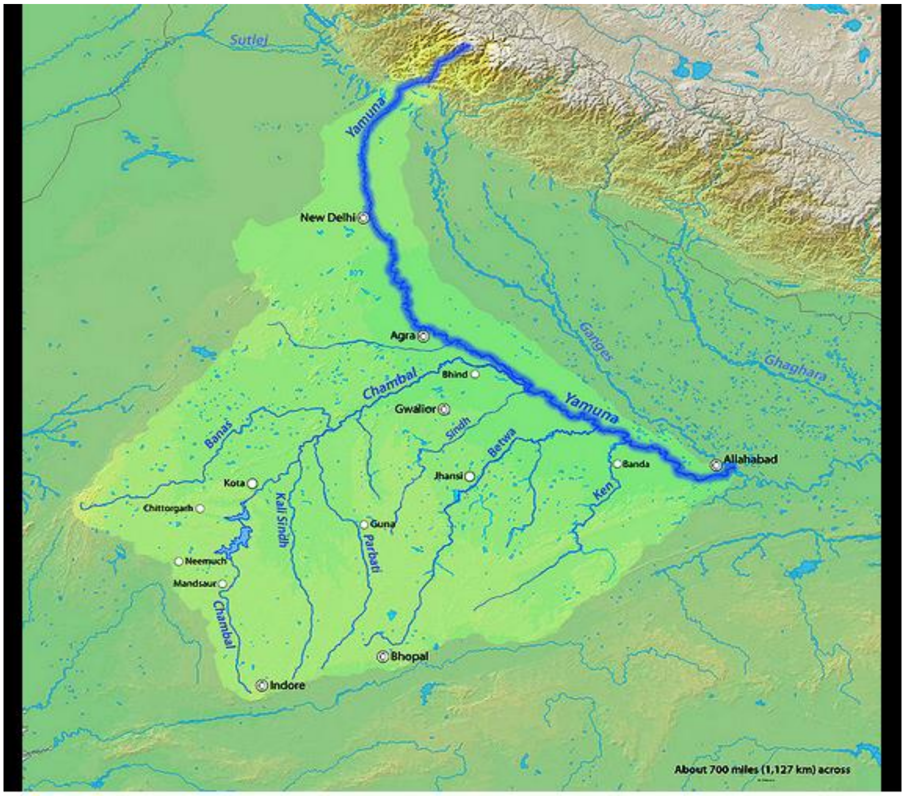

Figure1.1- River Basin of Yamuna

Figure 1.2 – Sampling Points

1.2 Objective of study

1. To calculate the fuzzy water quality index using fuzzy logic.
2. To calculate the Water quality index as given by National Sanitation Foundation
3. To derive the correlation between FWQI and WQI by NSF.
4. To find the monthly variation of different parameters at Palla using Trend Analysis.
5. Comparison between yearly variations of different parameters at different locations.

CHAPTER – 2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 General

Yamuna as we all know is in dire condition. The present sresearch aims to study the miserable Condition of river Yamuna based on the water quality parameters from year 2011 to 2015 based on fuzzy modeling . A comparative study was carried out using fuzzy modeling and water quality index by National Sanitation Foundation and correlation was developed between them.

2.2 About Water Quality Indices

The present study involves the study of water quality parameters using fuzzy logic and comparing it with WQI as given by NSF. Indiscriminate usage of natural resources has caused an imbalance to the environment and policies related to water, river and environment have a direct effect on social and economic development.Proper assessment of water quality (WQ) status in a river system based on limited observations is an essential task for meeting the goals of environmental management.WQ has a direct impact on the quality of life. A high WQ leads to healthy ecosystems thereby improving human well-being while poor WQ adversely affects both environment as well as human well-being. According to Silvert, any environmental index should take into consideration the various ramifications caused due to anthropogenic as well as natural activities and reflect it in a coherent, quantitative and qualitative manner [1]. Deterioration of WQ and ecological integrity of rivers can be attributed to anthropogenic activities in the catchments [2]. River health is highly threatened by the land-use and development activities which are not ecologically sustainable. River health originates from ecosystem health and cannot be confined to river ecosystem only . A healthy river is one which maintains its physical, chemical & biological structure and function, has the ability to recover after short-term natural disturbance like floods and droughts, sustains local flora and fauna, and maintains key processes (sediment transport, nutrient cycling, assimilation of waste products) and energy exchange. Ecological health refers to productivity of an ecosystem, its biological diversity and its resilience to the negative impacts of a variety of pressures. Two approaches have been used to study about the WQ. Although there are several reasons for applying fuzzy logic to complex situations existing in determination of river health index, the most important amongst all is probably the need to combine different indicators so as to have better result and conclusion which are helpful to take further decisions.Methods to integrate several variables relating to WQ in a specific index are increasingly needed in national and international scenarios. A number of authors have integrated WQ variables into indices, technically called Water Quality Indices (WQIs) [2] in which most are based out of concept developed by the U. S. National Sanitation Foundation [NSF, 4].

Fuzzy logic or fuzzy inference system is one the most widely used soft computing techniques. Soft computing techniques belong to the category of heuristic techniques which render rational solutions to highly complex real world problems [16]. By offering a set of syntax and semantics, fuzzy logic transforms qualitative knowledge to numerical reasoning. Zadeh introduced fuzzy logic in 1965 [11] and coined the word "computing with words"in 1994 [30]. Rather than numerical reasoning Zadeh proposed and explained the notions of linguistic reasoning. Linguistic reasoning is gaining significance in many emergent fields including engineering and applied sciences and has been applied successfully by many authors in numerous disciplines [18-26].

The ability to deal effectively and efficiently with uncertainties (encompassing vagueness), has been the key to the rising demand in the applicability of fuzzy logic approach in vague or uncertain scenarios. Fuzzy approach has been applied in environmental systems modelling and risk assessment to develop fuzzy WQI for different river basins by many authors [7-10]. The integration of fuzzy logic and fuzzy inference systems to the variables of environmental monitoring require a conceptual change. In the present analysis, fuzzy inference system has been used to develop river health index. . This section elaborates on the development of Fuzzy Water Quality Index (FWQI) to assess the quality of river water flowing in the Yamuna River using WQ parameters such as pH, DO, BOD, total coliform (TC). The proposed index formulation consists of three major steps, Fuzzification, Aggregation and defuzzification which have been dealt subsequently [31]. The concept of WQ provides the major driving force for this methodology. The total of 4 parameters have been categorized in 2 groups each consisting of two WQ parameters. Then the compositional rules are framed to ascertain the group index. These group indices are used to calculate the river health index. Analysis involving fuzzy consists of three important steps: a) to establish fuzzy set values; b) grouping (aggregation) of the WQ parameters; c) calculation of river health index using aggregatedvalues.

Fuzzification translates crisp values into membership grades of the linguistic terms for the fuzzy sets and transforms an actual scalar value to a fuzzy one where each linguistic term is related to a membership grade by means of membership functions. The relationship between x (a parameter) and μ (the membership grade), is described by way of a fuzzy number, μ taking values between zero and one. The fuzzy number assumes any justified shape according to information available. The triangular or trapezoidal fuzzy numbers are most frequently used functions to represent linguistic variables [18]. In present study, five fuzzy subsets (excellent, good, medium, poor and very poor) have been used for the assessment of river health(Figure 2.2). Fuzzy subsets has been defined using triangular and trapezoidal fuzzy numbers. Fuzzy sets and linguistic terms for input parameters of Group 1 and 2. The values of WQ parameters obtained from the sites are fuzzified using the membership functions which are called as the membership grades which are further used in the calculation of FRHI.

Trapezoidal:

$$f(x;a,b,c,d) = \begin{cases} 0 & x < a \; or \; d < x \\ \dfrac{a-x}{a-b} & a \le x \le b \\ 1 & b \le x \le c \\ \dfrac{d-x}{d-c} & c \le x \le d \end{cases}$$

Triangular:

$$f(x;a,b,c,d) = \begin{cases} 0 & x < a \; or \; d < x \\ \dfrac{a-x}{a-b} & a \le x \le b \\ \dfrac{c-x}{c-b} & b \le x \le c \end{cases}$$

Fuzzy rule-base is established to determine the health index. The rules were created on the basis of expert's knowledge and it was assumed that the human mind is incapable of handling this kind of high amount of data [15 & 27]. Hence, to reduce possible imprecision, the 4 parameters were divided into 2 groups, so only 2 parameters were left for decision making at each step. The algorithm was developed for the WQI based on fuzzy logic . In the first step, the 4 parameters were normalized to a value between 0-100 and put into 2 groups. These groups were then normalized to values between 0 and 100 at each step to generate the final 2 groups. Finally, the last 2 groups were processed through the new inference system to give the final WQI. In the present study, the normalization was performed using the fuzzy inference system; therefore, the Mamdani inference system was used for its ability to mimic an expert's knowledge in a way that is close to human thoughts and manners [28]. The algorithm and normalization of the 2 parameters developed at each step reduced the number of the rules to 175.

For this study the following linguistic variables and groups were defined: first group (G1):DO and BOD; G2: pH and TC..FRHI is defined by linguistic values: Excellent (E), Good (G), Medium (M), Poor (P) and Very Poor (VP).The rules for normalization and aggregation followed the logic described below and the consequent always obeyed the prescription of the minimum operator:

If first parameteris E and second parameteris Ethen group output is E

If first parameteris E and second parameteris G then group output is E

If first parameter is Eand second parameteris M then group output is G

If first parameteris VP and second parameteris P then group output is VP

If first parameteris VP and second parameteris VP then group output is VP

The analysis and computations were carried out using the ''fuzzy logic toolbox'' for MATLAB R2013a. Regarding the ranges of the output variable, the most common scoring system for WQ assessment is values between 0 -100, in which values near to 100 represents excellent river health . FRHI is the resultant fuzzy set formed by parameters as explained in the schematic diagram .

Defuzzification, a very crucial component of multi-criteria decision-making is a process to determine the crisp output of a fuzzy set. The crisp value can represent the deterministic features of the fuzzy reasoning process based on the assessment matrix. There are many defuzzification methods with the common ones in general practice being centre of area (centroid), mean of maximum, first of maximum, and last of maximum methods [29]. In this study centroid method has been employed for defuzzification.

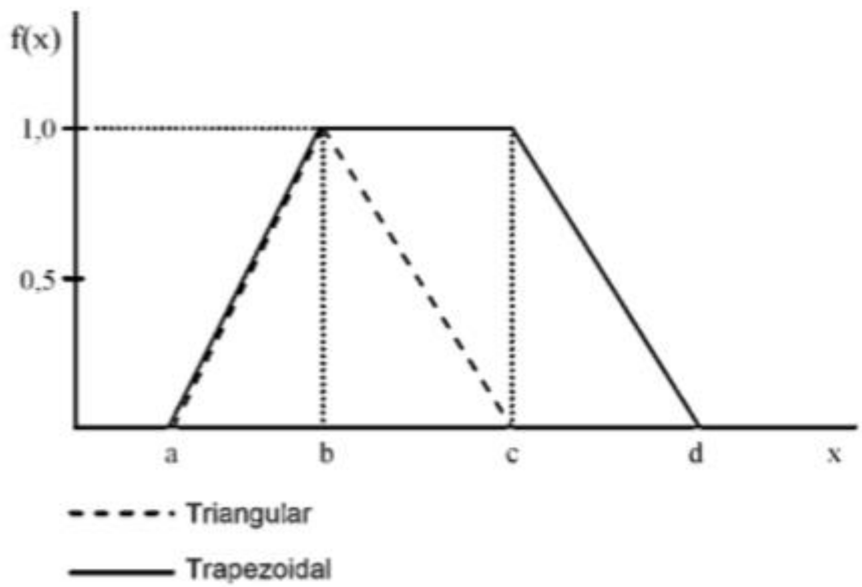

Figure2.1- Trapezoidal and triangular membership functions
(Source – River Quality analysis using Fuzzy Water Quality Index, Ribeira Do Iguape River watershed ,Brazil : Andre Lemontov)

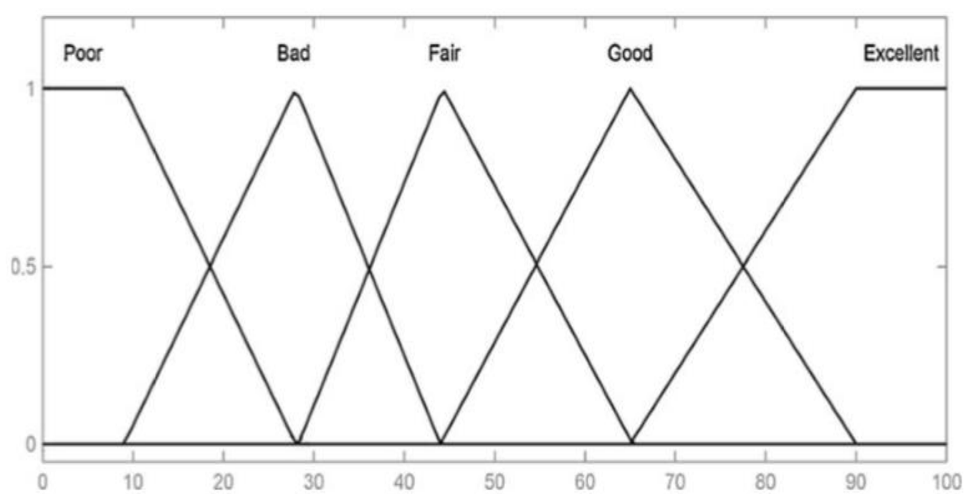

Figure 2.2- Membership Function
(Source – River Quality analysis using Fuzzy Water Quality Index, Ribeira Do Iguape River watershed ,Brazil : Andre Lemontov)

Gr 01, 02 and FWQI 0-100 WQI Classes

	a	*b*	*c*	*d*	
Excellent	65	90	100	100	$79 < WQI \leq 100$
Good	44	65	90		$51 < WQI \leq 79$
Fair	28	44	65		$36 < WQI \leq 51$
Bad	0	28	44		$19 < WQI \leq 36$
Poor	0	0	9	28	$0 \leq WQI \leq 19$

Figure 2.3- Input and Output fuzzy sets for inference.
(Source – River Quality analysis using Fuzzy Water Quality Index, Ribeira Do Iguape River watershed ,Brazil : Andre Lemontov)

CHAPTER – 3

METHODOLOGY

3. METHODOLOGY

3.1 General

For the study , daily averages of five pollutants are taken that are DO(dissolved oxygen), BOD (Biochemical Oxygen Demand),pH, total Coliform and COD(Chemical Oxygen Demand) for five years 2011 to 2015 at five stations.The water quality indices are calculated using Water Quality Index as given by National Sanitation Foundation . The Fuzzy Water Quality Index is calculated using graphical user interface of MATLAB by fuzzy logic.

3.2 Study Area

Yamuna is one of the major rivers of India which originates from Yamuotri Glacier and ends up meeting Ganga at Allahabad. Water quality parameters of river Yamuna were accessed at five different locations i.e at palla, Nizamuddin, Agra canal(Kalindi Kunj),Okhla after meeting Shahdara drain and at Agra canal at Madanpur Khadar. The sampling points are shown in fig 3.2. The data of various water quality parameters were taken from Central Pollution Control Board .

The analysis of data have been done comprehensively for -

1. To compute the fuzzy water quality index using fuzzy logic.
2. To compute the Water quality index as given by National Sanitation Foundation
3. To derive the correlation between FWQI and WQI by NSF.
4. To find the monthly variation of different parameters at Palla.
5. Comparison between yearly variations of different parameters at different locations.

Figure 3.2 – Sampling Points

CHAPTER – 4

EVALUATION OF FUZZY WATER QUALITY INDEX USING FUZZY LOGIC

4. EVALUATION OF FUZZY WATER QUALITY INDEX USING FUZZY LOGIC

4.1 Fuzzy Water Quality Index using Fuzzy Logic

To calculate the fuzzy water quality index, four parameters were taken i.e DO , BOD, pH and total coliform . These four parameters were grouped into two parameters i.e DO and BOD were grouped as G1 and the other two parameters i.e pH and total coliform were grouped as G2.

G1 and G2 were grouped together to form FWQI .

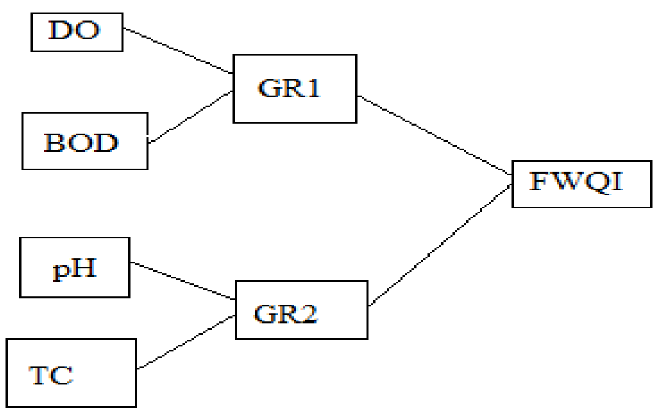

Figure 4.1- Graphical representation of FWQI

There are four basic steps of building fuzzy logic. They are:-

1. Defining inputs and outputs.
2. Creating membership functions.
3. Creating rules.
4. Defuzzification

Step 1- Defining inputs

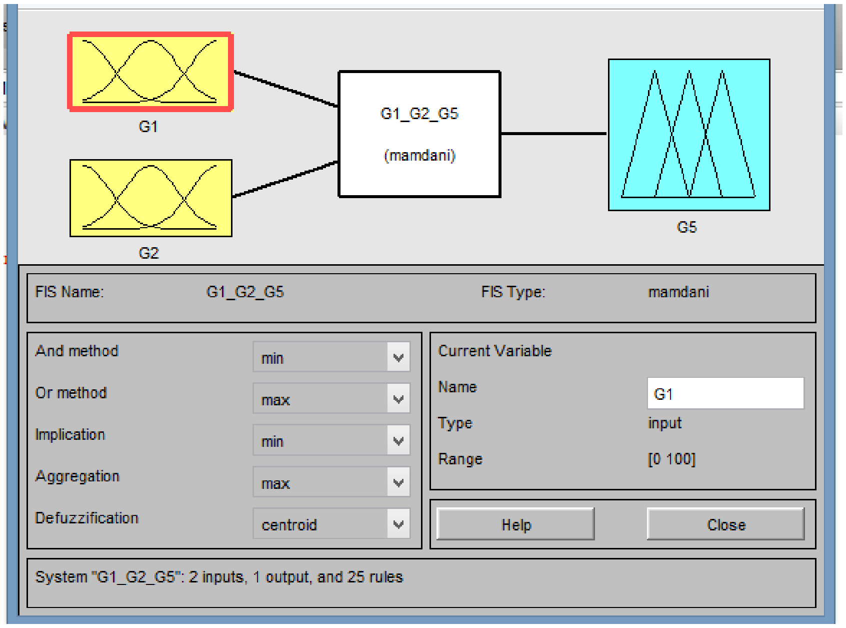

Figure 4.2- Defining inputs G1 and G2

Step 2- Create membership functions

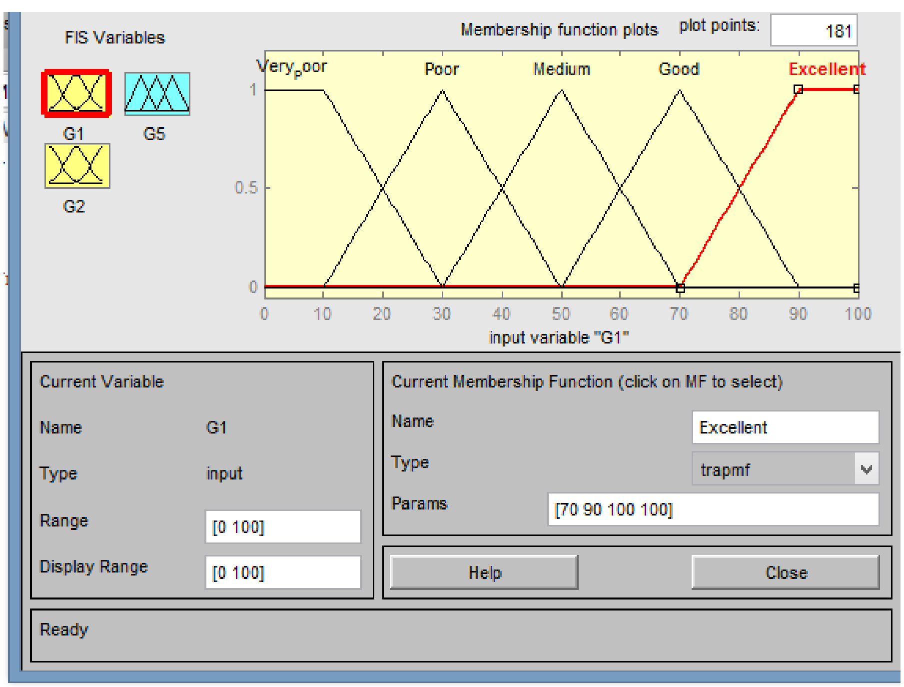

Figure 4.3- Membership Functions

Step 3 – Create Rules

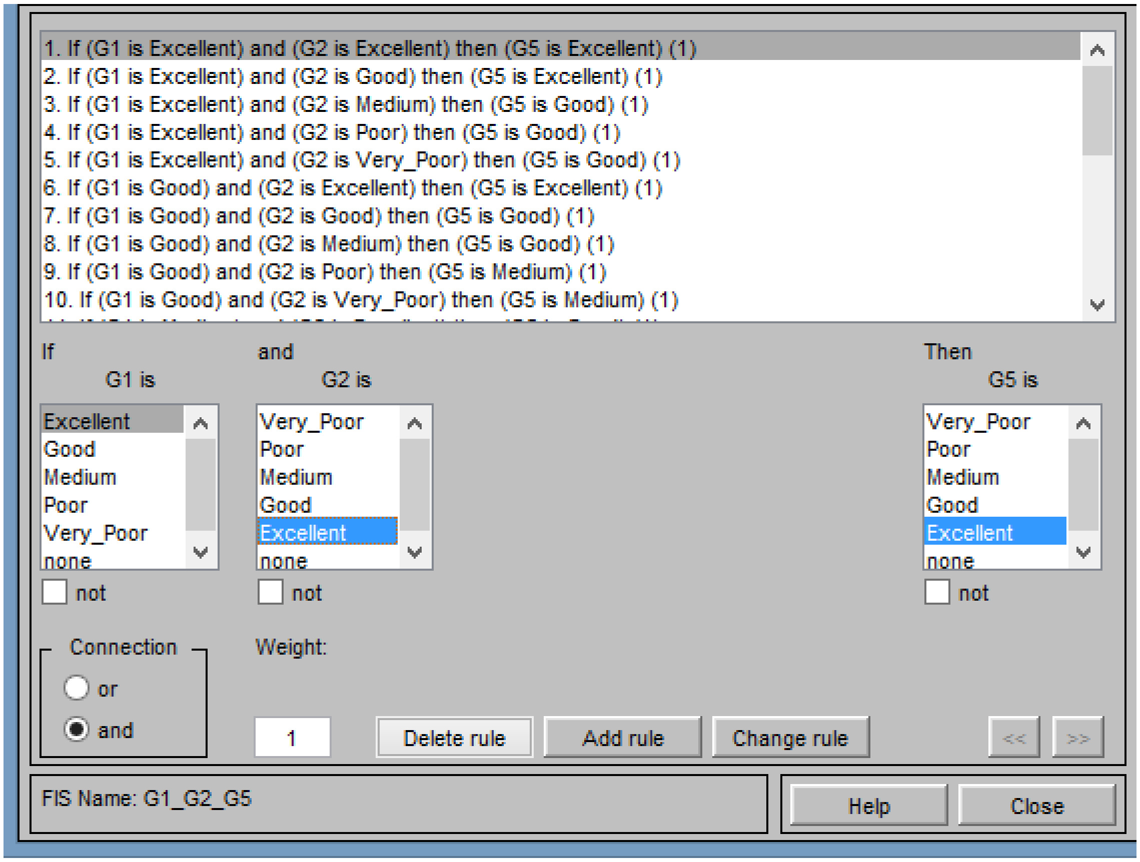

Figure 4.4 – Rule base

RULE BASE FOR G5

If G1 is Excellent and G2 is Excellent then FWQI is Excellent

If G1 is Excellent and G2 is Good then FWQI is Excellent

If G1 is Excellent and G2 is Medium then FWQI is Good

If G1 is Excellent and G2 is Poor then FWQI is Good

If G1 is Excellent and G2 is Very Poor then FWQI is Good

If G1 is Good and G2 is Excellent then FWQI is Excellent

If G1 is Good and G2 is Good then FWQI is Good

If G1 is Good and G2 is Medium then FWQI is Good

If G1 is Good and G2 is Poor then FWQI is Medium

If G1 is Good and G2 is Very Poor then FWQI is Medium

If G1 is Medium and G2 is Excellent then FWQI is Good

If G1 is Medium and G2 is Good then FWQI is Good

If G1 is Medium and G2 is Medium then FWQI is Medium

If G1 is Medium and G2 is Poor then FWQI is Medium

If G1 is Medium and G2 is Very Poor then FWQI is poor

If G5 is Poor and G2 is Excellent then FWQI is Medium

If G1 is Poor and G2 is Good then FWQI is Medium

If G1 is Poor and G2 is Medium then FWQI is Poor

If G1 is Poor and G2 is Poor then FWQI is Poor

If G1 is Poor and G2 is Very Poor then FWQI is very Poor

If G1 is Very Poor and G2 is Excellent then FWQI isMedium

If G1 is Very Poor and G2 is Good then FWQI is Poor

If G1 is Very Poor and G2 is Medium then FWQI is very Poor

If G1 is Very Poor and G2 is Poor then FWQI is very Poor

If G1 is Very Poor and G2 is Very Poor then FWQI is very Poor

Step 4 - Defuzzification

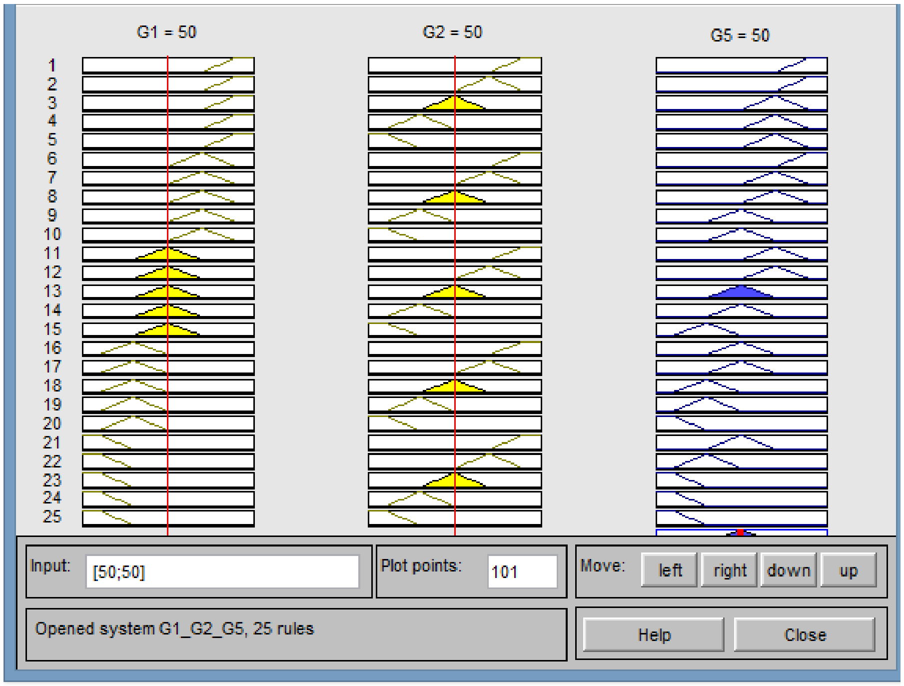

Figure 4.5- Defuzzification

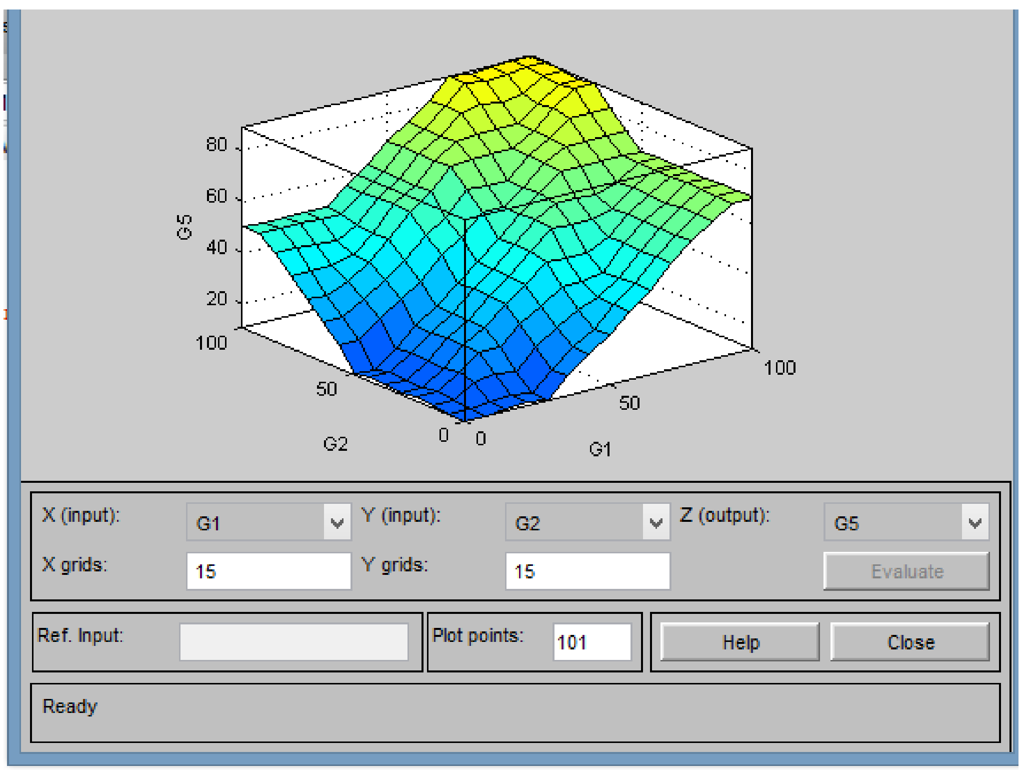

Figure 4.6 – Surface Viewer

CHAPTER – 5

CALCULATION AND OBSERVATIONS

5. CALCULATION AND OBSERVATIONS

5.1 General

Water quality index using fuzzy logic toolbox and NSF (National Sanitation Foundation) are calculated subsequently. The correlation between the two is further checked to ascertain the relevancy of Fuzzy index. If the coefficient of correlation comes above 0.6, it means that correlation isgoodand Fuzzy index can be used to check the health of rivers. Further monthly and Yearly analysis of different parameters are carried out.

5.2 Calculation of Water Qualityas given by National Sanitation Foundation and Fuzzy Index

Water quality index ,as given by National Sanitation Foundation , is calculated by taking nine parameters into consideration. The various nine parameters used in calculation are Dissolved Oxygen saturated (%), Fecal coliform, pH, BOD,Temperature, Total Phosphate, Nitrate, Turbidity, Total Solids.These nine parameters are chosen based on their importance and so a weighted mean is used to combine the values. For the calculation of WQI in this thesis , I have used four parameters ie DO,BOD,Total Coliform and pH. The indices were calculated using the online calculator made available by NSF. The water quality is given in the range of 1 to 100.

1	Water Quality Index Calculator						
2		TEST			Weighting	Weighting	
3	Parameter	RESULT	Units	Q-value	Factor	Factor	Subtotal
4	pH	7.5	pH units	92	0.12	0.12	10.99
5	Change in temp		degrees C	NM	0.11	NM	NM
6	DO	5	% saturation	5	0.18	0.18	0.83
7	BOD	36	mg/L	2	0.12	0.12	0.24
8	Turbidity		NTU	NM	0.09	NM	NM
9	Total Phosphorus		mg/L P	NM	0.11	NM	NM
10	Nitrate Nitrogen		mg/L NO3-N	NM	0.10	NM	NM
11	E. coli*		CFU/100 mL	NM	0.17	NM	NM
12	Fecal Coliforms*	16000000	CFU/100 mL	2	0.17	0.17	0.34
13	*Only use one microorganism,				TOTALS:	0.59	12.40
14	not fecal coliforms AND E. coli		NM = Not Measured		Water Quality Index =		21.02
15					Water Quality Rating =		VERY BAD
16							

Figure 5.1- Water Quality Index Calculator

Table 5.1- FWQI and NSF WQI at Palla

YAMUNA SITE AT PALLA		Chemical Oxygen Demand (mg/l)	Dissolved Oxygen (mg/l)	Bio-chemical Oxygen Demand (mg/l)	pH	Total coliform (MPN/100 ml)	G1	G2	FWQI	NSF WQI
Primary water quality criteria for river		-	4.0(MIN)	3 (Max)	6 to 9	5000 (Max)				
JANUARY	2011	19	9.6	2	7.6	15000	89.4	65.2	83	65.948251
	2012	29	7.9	3	8.4	2200	89.4	72.8	88.1	64.913856
	2013	5	10.2	1	7.4	6800	89.4	82.4	87	67.669081
	2014	10	9.8	2	7.8	43000	89.4	58.4	76.2	64.231842
	2015	10	12.1	2	7.8	2200	89.4	88	88.3	55.056537
FEBRUARY	2011	13	10.3	2	8.1	1500	89.4	83.9	87.2	66.45
	2012	13	9.2	1	7.7	3300	89.4	84.8	87.6	70.260493
	2013	10	8.4	2	8.2	110000	89.4	41.6	69	63.78
	2014	10	9.1	1	7.9	1300	89.4	88.8	88.4	71.29
	2015	BDL	15.5	1	8.6	2300	89.4	67.3	85.6	52.82
MARCH	2011	7	7.6	2	8.4	7000	89.4	62.7	80.3	64.22
	2012	11	6.2	2	8.5	17000	89	30	68.6	57.81
	2013	8	9.1	2	8.3	1300	89.4	75.9	87.4	67.834089
	2014	8	11	2	7.8	450	89.4	88	88.3	68.072288
	2015	35	5.5	3	7.4	17000	80.9	70	78.5	56.83
APRIL	2011	8	6.6	1	8.0	1500	88	89.4	88.3	67.319599
	2012	8	6.5	1	8.1	30000	88.3	45.2	67.6	62.74
	2013	22	13.1	6	7.8	1100	88.8	88	87.5	50.06
	2014	5	8.8	1	7.5	2500	89.4	89.4	88.5	71.58
	2015	BDL	12.2	1	7.9	5000	89.4	74.8	87.7	55.14
MAY	2011	7.7	7.7	7.7	7.7	9300	87.8	66.9	85	58.83
	2012	13	7.5	3	7.7	13000	89.4	61.6	79.2	64.5
	2013	14	7.7	4	8.3	7800	89.4	58.4	76.3	61.45
	2014	13	10.6	3	7.2	1100	89.4	89.4	88.5	66.26
	2015	21	13.4	5	7.8	1000	89.4	88	88.3	51.53
JUNE	2011	12	9.3	1	7.8	240000	89.4	58.4	76.3	65.68
	2012	13	7.2	2	8.0	160000	88.8	50	70	62.36
	2013		8.2	2	7.8	10000	89.4	62.4	79.9	67.21
	2014	10	9.4	4	7.4	9400	89.4	70	88.5	63.53
	2015	16	5.6	4	8.3	1300	82.4	75.9	79.9	56.12
JULY	2011	12	5.0	2	7.8	15000	74.8	58.4	73.8	55.03
	2012	12	7.3	1	8.1	13000	89	44.9	68.5	65.94
	2013		6.1	2	7.3	9200	89.2	70	88.2	54.9

YAMUNA SITE AT PALLA		**Chemical Oxygen Demand (mg/l)**	**Dissolved Oxygen (mg/l)**	**Bio-chemical Oxygen Demand (mg/l)**	**pH**	**Total coliform (MPN/100 ml)**	**G1**	**G2**	**FWQI**	**NSF WQI**
Primary water quality criteria for river	**-**	**4.0(MIN)**	**3 (Max)**	**6 to 9**	**5000 (Max)**					
	2014	15	8.5	3	7.4	11000	89.4	70	88.5	66.42
	2015	32	9	8	8.8	4600	88	61.4	79	54.32
AUGUST	2011	13	6.6	4	7.9	24000	88	54.8	73.4	59.05
	2012	42	6.2	2	7.8	13000	89	58.4	76.4	61.23
	2013	34	6.1	2	7.3	9200	89.2	70	88.2	61.74
	2014	18	6.4	2	7.4	24000	88.5	70	87.2	62.59
	2015	9	6.9	1	7.7	4900	88	79.5	84.2	67.65
SEPTEMBER	2011	27	7.1	2	7.7	110000	88.5	61.6	79.2	63.08
	2012	18	6.1	2	8.1	17000	89.2	45.2	68.8	59.5
	2013	28	6.5	1	7.8	17000	88.5	58.4	76.3	64.28
	2014	14	9.1	5	7.6	1700	89.4	88.8	88.4	65.18
	2015	22	9.4	5	8.6	780	89.4	67.3	85.6	61.47
OCTOBER	2011	8	6.5	3	8.2	1100	88.3	79.5	84.7	63.19
	2012	11	11.4	1	7.6	3500000	89.4	65.2	83	62.11
	2013	BDL	7.4	1	7.7	3300	89.2	84.8	87.3	69.65
	2014	9	7.2	3	8.3	17000	88.8	38.4	68	61.16
	2015	16	8.5	3	7.8	20000	89.4	58.4	76.3	65.33
NOVEMBER	2011	5	6.9	2	8.6	79000	88	28.6	67.3	59.13
	2012	7	8.0	2	8.2	150000	89.4	41.6	69	63.12
	2013	9	9.5	2	8.5	1700	89.4	70	88.5	65.52
	2014	BDL	8.9	2	7.7	7900	89.4	75.5	87.5	67.6
DECEMBER	2011	11	8.9	3	8.4	160000	89.4	34.8	69.1	60.39
	2012	5	9.3	1	7.9	48000	89.4	54.8	73.4	66.6
	2013	19	11.5	4	7.7	3300	89.4	84.8	87.6	60.7
	2014	8	12.8	1	7.5	680	89.4	89.4	88.5	59.2

Source – Central Pollution Control Board

Table 5.2 - FWQI and NSF WQI at Nizamuddin

YAMUNA AT NIZAMUDDIN		COD (mg/l)	DO (mg/l)	BOD (mg/l)	pH	Total coliform (MPN/100 ml)	G1	G2	FWQI	NSF WQI
Primary water quality criteria for river		**-**	**4.0(MIN)**	**-**	**6.5 to 8.5**	**-**				
JANUARY	2011	46	0.0	15	7.3	1100000000	10.6	70	30.9	23.55
	2012	91	0.0	35	7.7	17000000	10.6	61.6	24.7	19.29
	2013	89	0.8	31	7.1	5400000	10.6	70	30.9	21.68
	2014	69	1	32	7.5	54000000	10.6	70	30.9	22.33
	2015	65	1.5	21	7.8	16000000	11.2	58.4	22.8	24.87
FEBRUARY	2011	71	0.0	26	7.5	1100000000	10.6	70	30.9	20.65
	2012	87	0.0	39	7.2	160000000	10.6	70	30.9	19.52
	2013	23	3.4	8	8.2	2200000	56.6	41.6	57.6	34.71
	2014	31	0.3	4	7.6	9400000	50	65.2	64.4	33.52
	2015	90	0.9	40	7.8	2400000	10.6	58.4	21.8	21.57
MARCH	2011	47	0.0	24	7.5	240000000	11.2	70	31.7	20.88
	2012	123	0.0	37	7.5	17000000000	10.6	70	30.9	19.61
	2013	26	0.4	5	8.1	9200000	50	45.2	50	30.67
	2014	42	1.2	13	7.5	35000000	20.5	70	40.4	27.37
	2015	83	0	29	7.8	3500000	10.6	58.4	21.8	21.43
APRIL	2011	56	0.0	19	8.3	9300000	11.2	38.4	14.2	19.50
	2012	41	0.0	13	7.5	7000000	20.5	70	40.4	24.31
	2013	50	0.5	18	7.9	5400000	12	54.8	20.5	23.19
	2014	36	1.2	16	7.5	1300000	11.2	70	31.7	26.23
	2015	15	1	5	7.6	1000000	50	65.2	64.4	33.55
MAY	2011	87	0.0	25	7.6	930000	10.6	65.2	27.5	20.62
	2012	103	0.0	22	7.7	35000000	12	61.6	26.6	20.97
	2013	80	0.3	25	7.7	920000	10.6	61.6	24.7	21.62
	2014	36	2	19	7.4	5400000	19.1	70	39.3	27.03
	2015	34	0.7	12	7.7	6000000	24.1	61.6	36.5	26.44
JUNE	2011	72	0.0	17	7.7	110000000	12	61.6	26.6	22.51
	2012	97	0.0	20	7.9	≥1600000	10.6	61.6	24.7	20.94
	2013		0.7	12	7.7	5000000	24.1	61.6	36.5	25.85
	2014	42	1.3	18	7.1	5400000	12	70	32.7	25.43
	2015	83	0.2	21	8.1	2800000	11.2	45.2	13.2	20.63
JULY	2011	36	2.2	4	7.7	11000000	50	61.6	61.3	37.33
	2012	80	0.0	23	7.7	1600000	12	61.6	26.6	20.74

YAMUNA AT NIZAMUDDIN		COD (mg/l)	DO (mg/l)	BOD (mg/l)	pH	Total coliform (MPN/100 ml)	G1	G2	FWQI	WQI
Primary water quality criteria for river		**-**	**4.0(MIN)**	**-**	**6.5 to 8.5**	**-**				
	2013		0.3	20	7.7	1200000	10.6	61.6	24.7	22.73
	2014	50	1.1	15	7.6	1100000	10.6	65.2	27.5	26.29
	2015	55	0.1	16	8.1	9200000	11.2	45.2	13.2	22.03
AUGUST	2011	18	2.3	4	7.7	1500000	50	61.6	61.3	37.54
	2012	81	5.4	10	7.6	280000	70	65.2	70	46.15
	2013	15	3.5	6	7.3	1600000	57.3	70	70	39.42
	2014	19	2.8	6	7.4	330000	46.5	70	65.7	36.56
	2015	15	2.4	4	7.4	68000	50	70	70	39.19
SEPTEMBER	2011	35	4.5	5	7.7	2100000	70	61.6	70	47.06
	2012	30	3.9	4	7.7	540000	61.6	61.6	61.3	43.88
	2013	23	2.4	10	7.8	2400000	41.6	58.4	50	31.18
	2014	42	0.3	18	7.6	9200000	12	65.2	29.3	23.57
	2015	37	1.6	15	7.8	3500000	12.6	58.4	24.7	26.85
OCTOBER	2011	29	0	11	8.0	54000000	27.2	50	28.2	24.01
	2012	36	0.6	12	7.6	5400000	24.1	65.2	39.1	26.45
	2013	24	1.4	10	7.9	3500000	30	54.8	35.6	28.56
	2014	34	1.9	15	7.6	3500000	17.6	65.2	34.5	28.03
	2015	56	1.2	16	7.9	3500000	11.2	54.8	19.2	25.32
NOVEMBER	2011	66	0.0	20	8.5	94000000	10.6	30	11.5	18.05
	2012	106	0.7	37	7.9	35000000	10.6	54.8	18.2	20.70
	2013	36	0.6	17	8.2	9200000	12	41.6	15.4	22.47
	2014	59	0.8	14	7.6	3500000	16.1	65.2	33.3	26.14
DECEMBER	2011	54	0.0	20	7.7	22000000	10.6	61.6	24.7	21.53
	2012	128	0.8	56	7.7	17000000	10.6	61.6	24.7	21.65
	2013	50	0.6	11	7.3	9200000	27.2	70	46.4	27.11
	2014	79	0.4	36	7.5	16000000	10.6	70	30.9	21.02

Source – Central Pollution Control Board

Table 5.3- FWQI and NSF WQI at Agra canal (Kalinidi Kunj)

YAMUNA RIVER AT AGRA CANAL		COD(mg/l)	DO (mg/l)	BOD (mg/l)	pH	Total coliform (MPN/100 ml)	G1	G2	FWQI	WQI
Primary water quality criteria for river			4.0(MIN)	3 (Max)	6 to 9	5000 (Max)				
JANUARY	2011	86	0.0	26	7.2	210000000	10.6	70	30.9	20.56
	2012	122	0.1	28	7.7	11000000	10.6	61.6	24.7	20.74
	2013	44	0.9	17	7.3	1300000	12	70	32.7	20.39
	2014	95	0.9	37	7.4	160000000	10.6	70	30.9	22.2
	2015	82	2.6	22	7.4	3500000	24.1	70	43.4	22.33
FEBRUARY	2011	156	0.0	28	7.7	>1600000000	10.6	70	30.9	20.19
	2012	148	0.0	38	7.2	28000000	10.6	70	30.9	19.52
	2013	18	2.4	5	7.6	9200000	50	65.2	64.4	36.71
	2014	85	0.8	11	7.5	92000000	27.2	70	46.4	27.65
	2015	100	0.8	28	7.8	1700000	10.6	58.4	21.8	22.29
MARCH	2011	57	0.0	16	7.5	9000000	11.2	70	31.7	23.17
	2012	148	0.0	40	7.5	17000000000	10.6	70	30.9	19.61
	2013	32	0.6	9	8.1	940000	34.8	45.2	35.6	26.73
	2014	117	0.9	29	7.7	4600000	10.6	61.6	24.7	22.62
	2015	75	0	27	7.8	5400000	10.6	58.4	21.8	20
APRIL	2011	57	0.0	18	8.1	2300000	12	45.2	14.2	20.79
	2012	61	0.0	20	7.6	6000000	10.6	65.2	27.5	21.72
	2013	62	0.6	17	8.2	3500000	12	41.6	15.4	22.47
	2014	21	1.4	8	7.6	450000	38.4	65.2	52.8	30.91
	2015	71	1.4	21	7.7	500000	11.2	61.6	25.5	24.79
MAY	2011	78	0.0	14	7.8	930000	16.1	58.4	28.5	23.32
	2012	142	0.0	24	7.6	2100000	11.2	65.2	28.3	20.75
	2013	98	0.6	26	7.7	110000	10.6	61.6	24.7	22.13
	2014	60	1.5	18	7.4	9200000	12	70	32.7	26.45
	2015	38	1.7	10	7.7	5400000	33.4	61.6	45.7	29.65
JUNE	2011	98	0.0	10	7.7	46000000	30	61.6	41.3	25.58
	2012	-	0.7	7	7.7	1600000	41.6	61.6	51.9	30.15
	2013		3.3	5	7.3	920000	54.8	70	70	40.02
	2014	69	2.4	17	7.1	450000	24.1	70	43.3	28.41

YAMUNA RIVER AT AGRA CANAL		COD(mg/l)	DO (mg/l)	BOD (mg/l)	pH	Total coliform (MPN/100 ml)	G1	G2	FWQI	WQI
Primary water quality criteria for river			4.0(MIN)	3 (Max)	6 to 9	5000 (Max)				
	2015	59	1.2	17	8	230000	12	50	13.5	24.61
JULY	2011	26	1.0	3	7.7	930000	50	61.6	61.3	36.44
	2012	71	0.0	26	7.7	240000	10.6	61.6	24.7	20.33
	2013		3.3	5	7.3	920000	54.8	70	70	40.75
	2014	66	1.3	16	7.6	2400000	11.2	65.2	28.3	26.27
	2015	54	1.1	16	8.1	1300000	11.2	45.2	13.2	24.36
AUGUST	2011	11	0.9	3	7.7	430000	50	61.6	61.3	36.26
	2012	28	0.7	7	7.7	1600000	41.6	61.6	51.9	30.15
	2013	32	3.3	5	7.3	920000	54.8	70	70	40.02
	2014	12	3	5	7.5	2200000	50	70	70	38.4
	2015	17	1.6	7	7.6	460000	41.6	65.2	55	32.25
SEPTEMBER	2011	20	3.5	5	7.7	930000	57.3	61.6	61.3	40.4
	2012	20	3.9	4	7.8	170000	61.6	58.4	61.3	43.62
	2013	24	1.6	9	7.8	260000	34.8	58.4	45	29.94
	2014	41	1.7	20	7.5	5400000	14.4	70	35.2	25.93
	2015	50	0.9	15	7.6	790000	10.6	65.2	27.5	25.94
OCTOBER	2011	-	0.0	22	8.5	49000000	12	30	13.5	17.49
	2012	38	0.7	12	7.7	5400000	24.1	61.6	36.5	26.44
	2013	52	1.2	19	7.9	1100000	11.2	54.8	19.2	24.31
	2014	47	1	18	8.1	2400000	12	45.2	14.2	23.51
	2015	56	0.3	13	7.8	2500000	20.6	58.4	31.8	24.93
NOVEMBER	2011	89	0.0	22	8.5	49000000	12	30	13.5	17.49
	2012	125	0.7	40	7.8	160000000	10.6	58.4	21.8	21.02
	2013	34	0.7	19	8.1	2200000	11.2	45.2	13.2	22.46
	2014	47	1.4	17	7.6	5400000	12	65.2	29.3	26.27
DECEMBER	2011	56	0.0	15	7.6	4900000	10.6	65.2	27.5	23.4
	2012	170	1.0	60	7.7	21000000	10.6	61.6	24.7	22
	2013	90	0.7	15	7.4	3500000	10.6	70	30.9	25.58
	2014	42	0.4	12	7.7	1300000	24.1	61.6	36.5	25.85

Source – Central Pollution Control Board

Table 5.4 – FWQI and NSF WQI at Agra Canal (Madanpur Khadar)

AGRA CANAL AT MADANPUR KHADAR		**Chemical Oxygen Demand (mg/l)**	**Dissolved Oxygen (mg/l)**	**Bio-chemical Oxygen Demand (mg/l)**	**pH**	**Total coliform (MPN/100 ml)**	**G1**	**G2**	**FWQI**	**WQI**
Primary water quality criteria for river			4.0(MIN)	3 (Max)	6 to 9	5000 (Max)				
JANUARY	2011	67	0.0	23	7.3	1122	12	89.4	49.1	26.8
	2012	128	0.0	29	7.8	1337	10.6	88	47.3	25.26
	2013	49	0.9	19	7.1	2200000	11.2	70	31.7	24.41
	2014	94	0.9	31	7.5	160000000	10.6	70	30.9	22.15
	2015	81	1.3	23	7.5	1700000	12	70	32.9	24.29
FEBRUARY	2011	133	0.0	25	7.6	1166	10.6	88.8	48.3	26.27
	2012	144	0.0	39	7.3	1390	10.6	89.4	49.1	25.01
	2013	35	1.4	13	7.5	2200000	20.5	70	40.4	27.88
	2014	68	0.5	8	7.6	7900000	38.4	65.2	52.8	28.96
	2015	96	0.8	49	7.9	16000000	10.6	54.8	18.2	21.07
MARCH	2011	66	0.0	16	7.5	1073	11.2	89.4	49.1	28.96
	2012	146	0.0	41	7.6	1573	10.6	88.8	48.3	24.67
	2013	46	0.6	20	8.1	9200000	10.6	45.2	12.3	21.96
	2014	108	1.1	54	7.5	6300000	10.6	70	30.9	22.5
	2015	93	0.8	29	7.7	16000000	24.7	61.6	37	22.44
APRIL	2011	67	0.0	18	8.1	1057	12	83.9	43.2	26.6
	2012	38	0.0	11	7.6	1196	27.2	88.8	48.3	30.78
	2013	63	2.8	27	7.8	16000000	11	58.4	22.5	26.87
	2014	36	1.2	11	7.5	35000000	27.2	70	46.4	28.35
	2015	38	1.5	13	7.6	35000000	20.5	65.2	36.6	28.09
MAY	2011	75	0.0	19	7.5	1325	11.2	89.4	49.1	27.62
	2012	103	0.0	22	7.7	1359	12	88	47.3	26.38
	2013	106	0.3	28	7.8	170000	10.6	58.4	21.8	21.13
	2014	68	2	22	7.5	35000000	19.7	70	39.8	26.1
	2015	34	1.9	10	7.7	35000000	36.1	61.6	48.3	30.2
JUNE	2011	69	0.0	9	7.7	1150	34.8	88	55.6	31.98
	2012	-	0.0	26	7.7	1062	10.6	88	47.3	26.13
	2013		0.3	28	7.8	170000	10.6	58.4	21.8	21.13
	2014	56	1.4	19	7.1	1100000	11.2	70	31.7	25.44
	2015	64	0.9	17	8.1	1100000	12	45.2	14.2	23.67
JULY	2011	28	0.8	4	7.6	493	50	88.8	70	41.69
	2012	85	0.0	26	7.7	1062	10.6	88	47.3	26.13
	2013		2.2	5	7.3	540000	50	70	70	36.2

AGRA CANAL AT MADANPUR KHADAR		**Chemical Oxygen Demand (mg/l)**	**Dissolved Oxygen (mg/l)**	**Bio-chemical Oxygen Demand (mg/l)**	**pH**	**Total coliform (MPN/100 ml)**	**G1**	**G2**	**FWQI**	**NSF WQI**
Primary water quality criteria for river			4.0(MIN)	3 (Max)	6 TO 9	5000 (MAX)				
	2014	75	1.5	21	7.6	330000	11.2	65.2	28.3	25.33
	2015	51	1.2	15	8.1	1100000	10.6	45.2	12.3	24.89
AUGUST	2011	15	1.0	3	7.7	452	50	88	70	43.59
	2012	27	0.6	5	7.6	347	50	88.8	70	40.21
	2013	23	2.2	5	7.3	540000	50	70	70	36.2
	2014	23	3	9	7.4	460000	50	70	70	34.41
	2015	15	1.5	4	7.4	210000	50	70	70	36.39
SEPTEMBER	2011	21	3.6	6	7.6	418	58.4	88.8	76.3	46.93
	2012	33	2.7	6	7.8	390	45.2	88	64.4	43.04
	2013	23	1.5	8	7.7	5400000	38.4	61.6	50	31.06
	2014	53	1.9	26	7.5	9200000	11.5	70	32	25.27
	2015	48	1.3	15	7.6	790000	10.6	65.2	27.5	26.63
OCTOBER	2011	-	3.6	6	7.6	418	58.4	88.8	76.3	46.93
	2012	41	0.7	11	7.5	1128	27.2	89.4	49.1	32.99
	2013	23	0.7	7	7.9	5400000	41.6	54.8	47.2	29.56
	2014	61	0.4	27	7.8	3500000	10.6	58.4	21.8	21.41
	2015	60	1.4	15	7.9	3500000	10.6	54.8	18.2	26.19
NOVEMBER	2011	88	0.0	25	8.5	1436	10.6	70	30.9	22.27
	2012	121	0.6	41	7.9	400000	10.6	54.8	18.2	20.51
	2013	41	0.6	19	8.1	3500000	11.2	45.2	13.2	22.27
	2014	58	0.4	19	7.6	5400000	11.2	65.2	28.3	23.45
DECEMBER	2011	65	0.0	13	7.7	1267	20.5	88	46.7	29.51
	2012	148	0.9	62	7.7	4900000	10.6	61.6	24.7	21.83
	2013	75	0.8	14	7.3	2400000	16.1	70	36.8	26.29
	2014	69	0.8	24	7.8	1700000	11.2	58.4	22.8	22.65

Source – Central Pollution Control Board

Table 5.5 – FWQI and NSF WQI at OKHLA after meeting Shahdara Drain

YAMUNA RIVER AT OKHLA AFTER MEETING SHAHDARA DRAIN		COD (mg/l)	DO (mg/l)	Bio-chemical Oxygen Demand (mg/l)	pH	Total coliform (MPN/100 ml)	G1	G2	FWQI	NSF WQI
Primary water quality criteria for river		-	4.0(MIN)	3 (Max)	6 to 9	5000 (Max)				
JANUARY	2011	127	0.0	45	6.80	93000000	10.6	70	30.9	18.24
	2012	142	0.0	63	7.7	160000000	10.6	61.6	24.7	19.29
	2013	132	3.5	43	7.3	2400000	19.1	70	39.3	29.4
	2014	104	1	44	7.6	>160000000	10.6	70	30.9	22.2
	2015	284	2.4	93	8	5400000	12	50	13.5	24.2
FEBRUARY	2011	156	0.0	59	7.60	>1600000000	10.6	50	11.5	19.49
	2012	175	0.0	82	7.1	92000000	10.6	70	30.9	19.32
	2013	28	6.1	7	7.6	790000	79.6	65.2	77.3	51.94
	2014	131	0.9	10	7.7	17000000	30	61.6	41.3	28.12
	2015	190	1	64	7.9	9200000	10.6	54.8	18.2	21.42
MARCH	2011	74	0.0	16	7.60	43000000	11.2	65.2	28.3	23.05
	2012	354	0.0	99	7.5	17000000000	10.6	70	30.9	19.61
	2013	42	0.7	12	8.0	1100000	24.1	50	25.8	25.48
	2014	100	1.5	26	7.7	2300000	10.6	61.6	24.7	24.23
	2015	240	0.5	97	7.8	2400000	10.6	58.4	21.8	20.64
APRIL	2011	106	0.0	35	8.00	4300000	10.6	50	11.5	18.33
	2012	78	0.0	30	7.5	1700000000	10.6	70	30.9	20.18
	2013	51	2.6	10	7.6	1700000	43.9	65.2	56.5	32.12
	2014	173	0.8	67	7.4	17000000	10.6	70	30.9	22.02
	2015	76	1.1	27	7.5	17000000	10.6	70	30.9	23.47
MAY	2011	122	0.0	42	7.70	1500000	10.6	61.6	24.7	19.29
	2012	177	0.0	47	8.6	600000000	10.6	28.6	11.6	15.15
	2013	146	0.3	30	7.5	220000	10.6	70	30.9	21.39
	2014	107	1.7	34	7.4	17000000	11	70	31.4	23.74
	2015	105	1.7	33	7.9	17000000	11	54.8	18.9	22.78
JUNE	2011	93	0.0	35	7.60	>240000000	10.6	54.8	18.2	19.49
	2012	93	0.0	20	7.9	600000	10.6	54.8	18.2	20.94
	2013		0.3	30	7.5	220000	10.6	70	30.9	21.39
	2014	169	1.1	79	7	450000	10.6	70	30.9	21.93
	2015	148	0.9	38	8	4000000	10.6	50	11.5	20.87

YAMUNA RIVER AT OKHLA AFTER MEETING SHAHDARA DRAIN		COD (mg/l)	DO(mg/l)	Bio-chemical Oxygen Demand (mg/l)	pH	Total coliform (MPN/100 ml)	G1	G2	FWQI	NSF WQI
Primary water quality criteria for river	-		4.0(MIN)	3 (Max)	6 to 9	5000 (Max)				
JULY	2011	75	0.0	17	7.50	110000000	12	70	32.7	22.83
	2012	107	0.0	43	7.7	920000	10.6	61.6	24.7	19.29
	2013		3.9	4	7.3	1600000	61.6	70	70	44.23
	2014	101	1.4	36	7.6	2400000	10.6	65.2	27.5	23.05
	2015	72	1.2	19	8.1	3500000	11.2	45.2	13.2	23.52
AUGUST	2011	53	0.0	14	7.50	1500000	16.1	70	36.8	23.91
	2012	38	5.1	6	7.6	130000	75.9	65.2	74.2	47.92
	2013	26	3.9	4	7.3	1600000	61.6	70	70	44.23
	2014	27	2.9	9	7.5	490000	48.1	70	67.5	33.77
	2015	56	1.7	13	7.7	3500000	24.5	61.6	36.8	28.07
SEPTEMBER	2011	61	2.4	12	7.40	11000000	35	70	55.8	30.69
	2012	33	4.9	8	7.8	920000	74.1	58.4	73.3	44.3
	2013	26	4.1	9	7.7	3500000	63.9	61.6	62.7	39.39
	2014	49	1.5	24	7.4	1700000	11.2	70	31.7	24.83
	2015	109	0.1	52	7.6	3500000	10.6	65.2	27.5	20.04
OCTOBER	2011	64	0	23	7.90	14000000	12	54.8	20.5	20.15
	2012	300	0.5	113	7.5	16000000	10.6	70	30.9	21.22
	2013	32	0.9	15	7.8	2200000	10.6	58.5	21.9	25.48
	2014	94	1.4	42	7.7	790000	10.6	61.6	24.7	22.85
	2015	119	0	35	7.9	3500000	10.6	54.8	18.2	18.7
NOVEMBER	2011	181	0.0	49	8.0	33000000	10.6	50	11.5	18.33
	2012	168	0.8	57	7.9	200000	10.6	54.8	18.2	21.07
	2013	42	0.6	20	8	3500000	10.6	50	11.5	22.37
	2014	94	1.1	35	7.6	3500000	10.6	65.2	27.5	22.37
DECEMBER	2011	110	0.0	55	7.5	160000000	10.6	70	30.9	19.61
	2012	204	1.5	104	7.7	2700000	10.6	61.6	24.7	23.19
	2013	131	0.7	43	7.3	9200000	10.6	70	30.9	21.63
	2014	78	1.16	24	7.9	330000	11.2	54.8	19.2	23.03

Source – Central Pollution Control Board

5.2 VARIATION BETWEEN INDICES AT DIFFERENT SITES

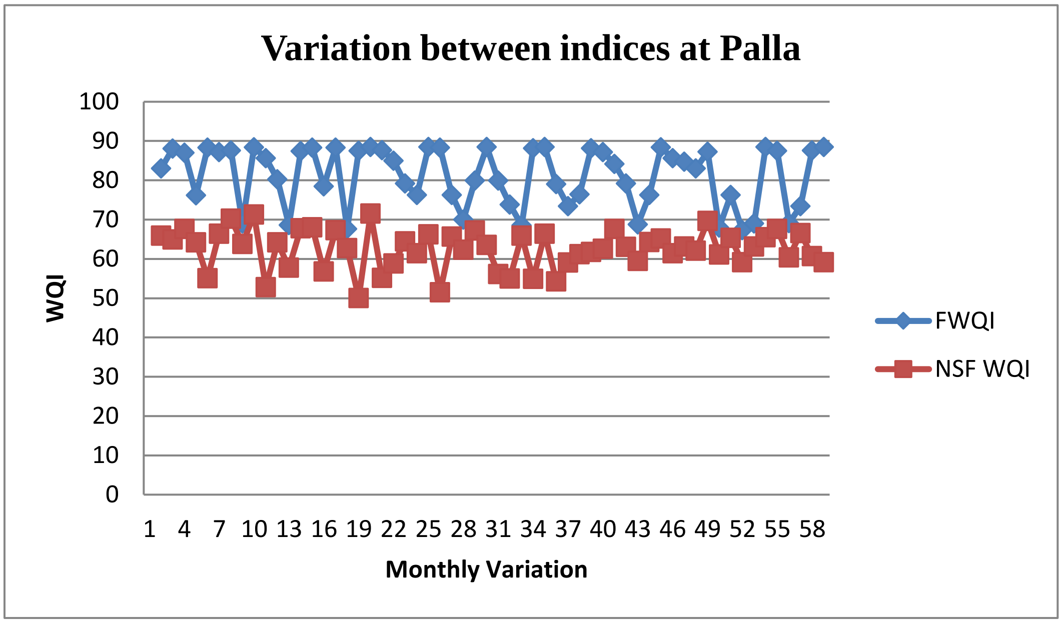

Figure 5.2 - Variation between indices at Palla

The correlation between FWQI and NSF WQI at Palla is 0.82058

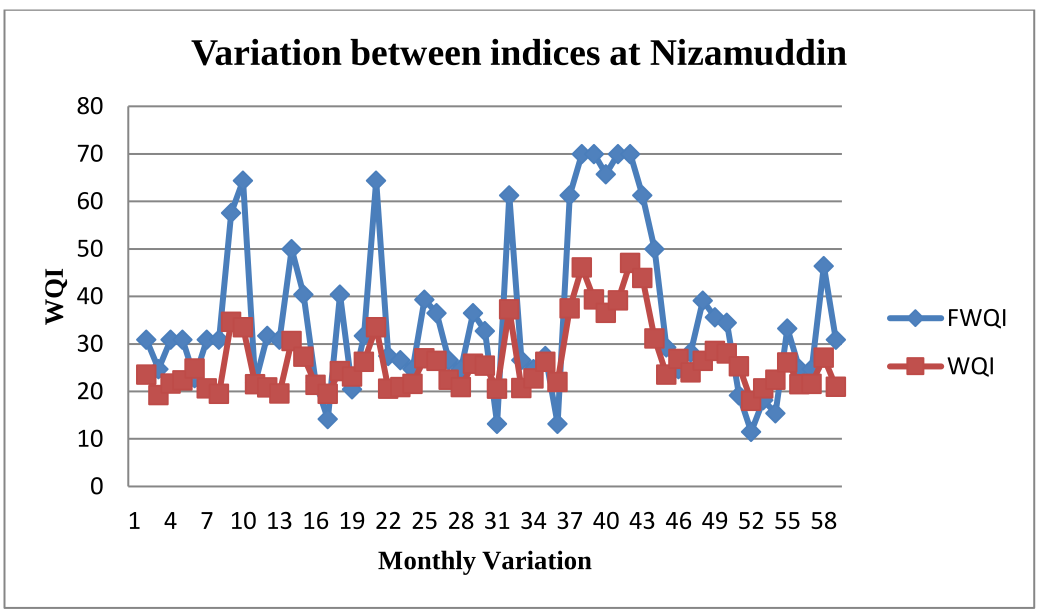

Figure 5.3- Variation between indices at Nizamuddin

The correlation between FWQI and NSF WQI at Nizamuddin is 0.90838

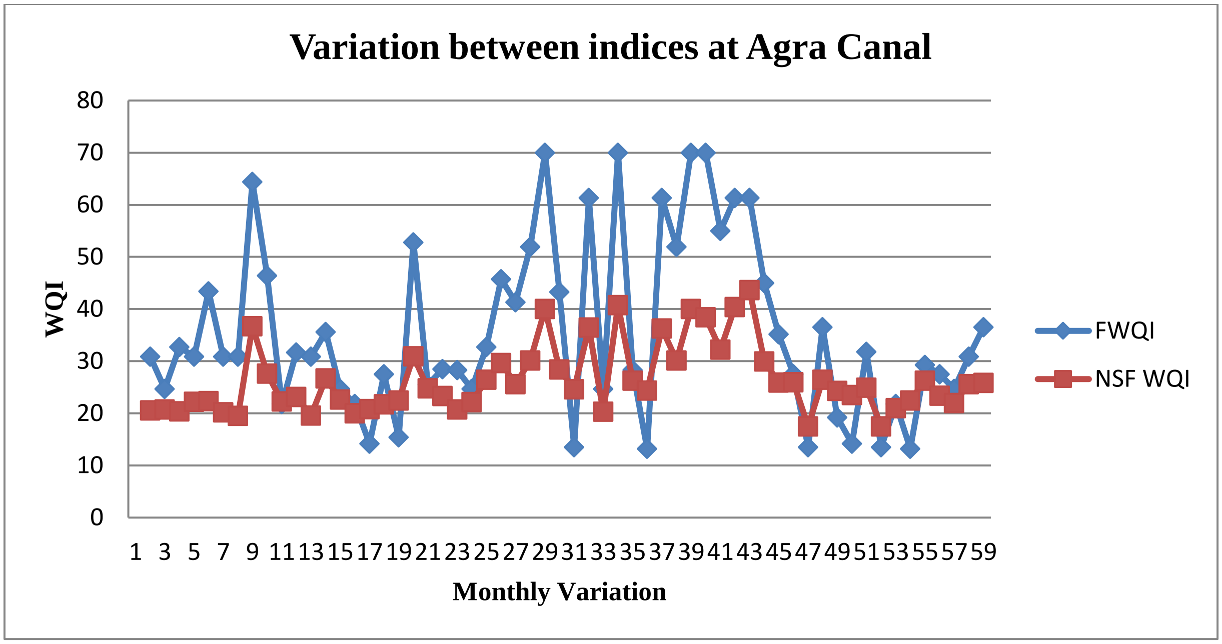

Figure 5.4 - Variation between indices at Agra Canal(Kalinidi Kunj)

The correlation between FWQI and NSF WQI at Agra Canal(Kalinidi kunj) is 0.90838

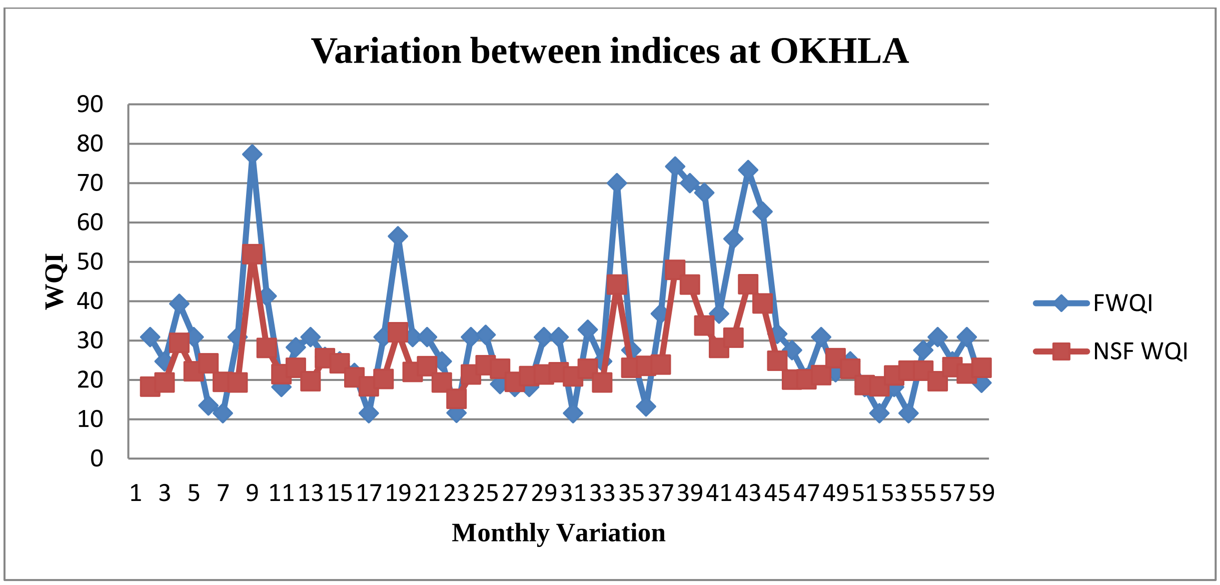

Figure 5.5 - Variation between indices at OKHLA after meeting Shahdara Drain

The correlation between FWQI and NSF WQI at OKHLA is 0.902117

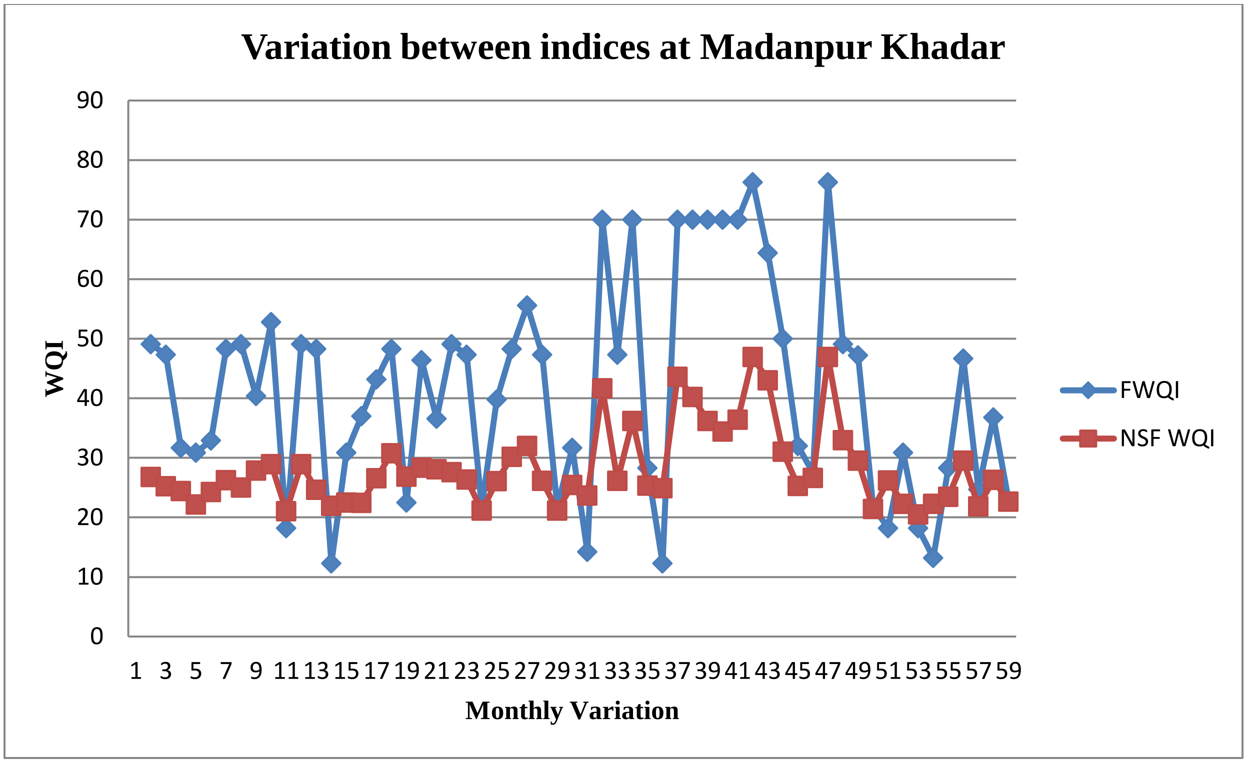

Figure 5.6 - Variation between indices at Agra Canal (Madanpur Khadar)

The correlation between FWQI and NSF WQI at Agra Canal(Madanpur Khadar) is 0.86459

5.3 YEARLY VARIATIONS OF BOD PARAMETERS AT PALLA

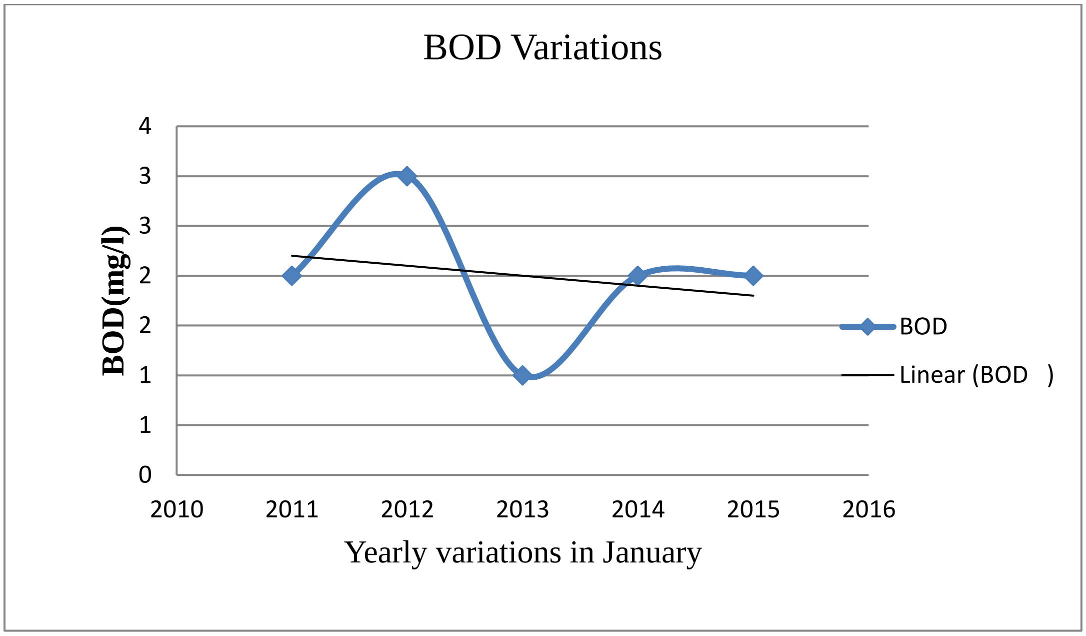

Figure 5.7- Variation of BOD in January

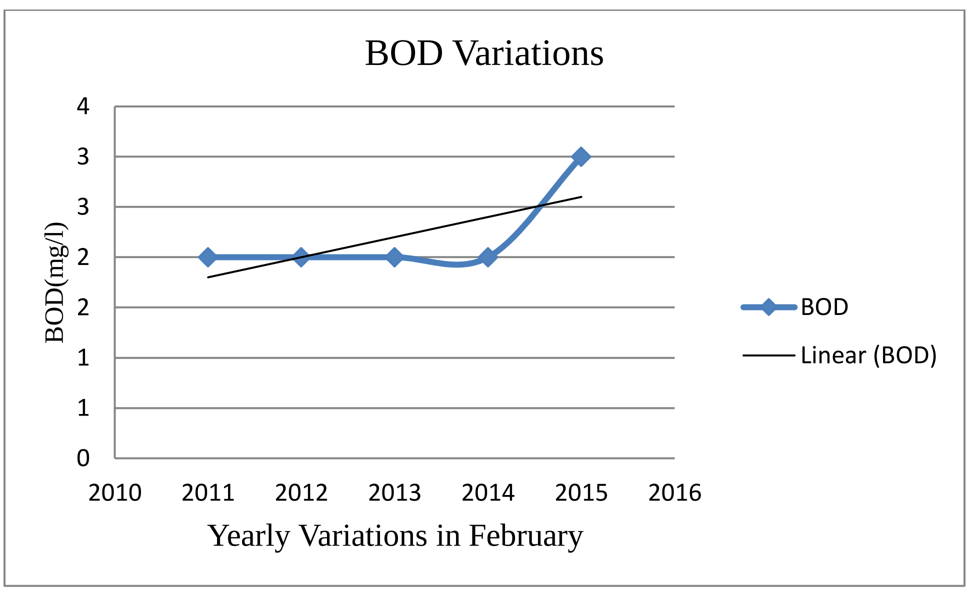

Figure 5.8- Variation of BOD in February

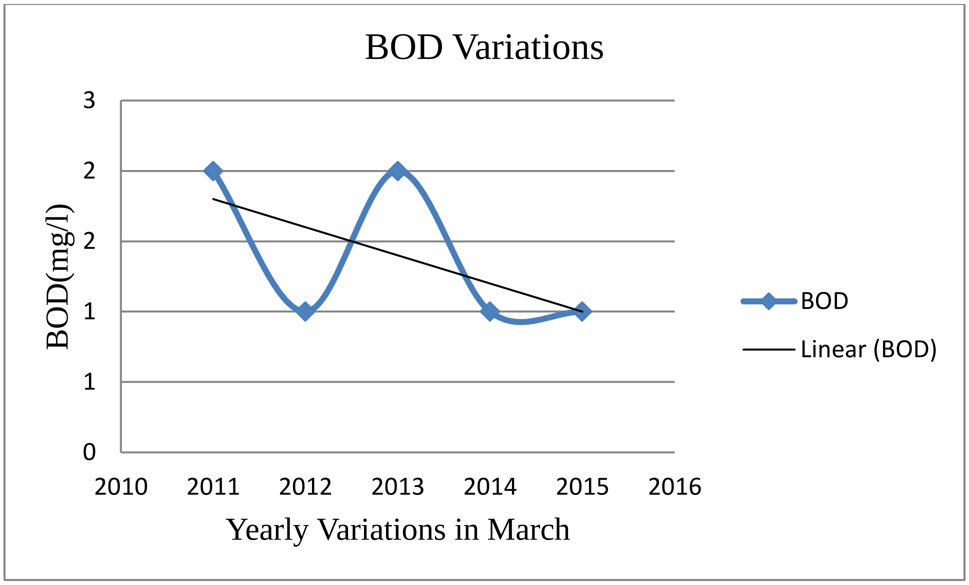

Figure 5.9- Variation of BOD in March

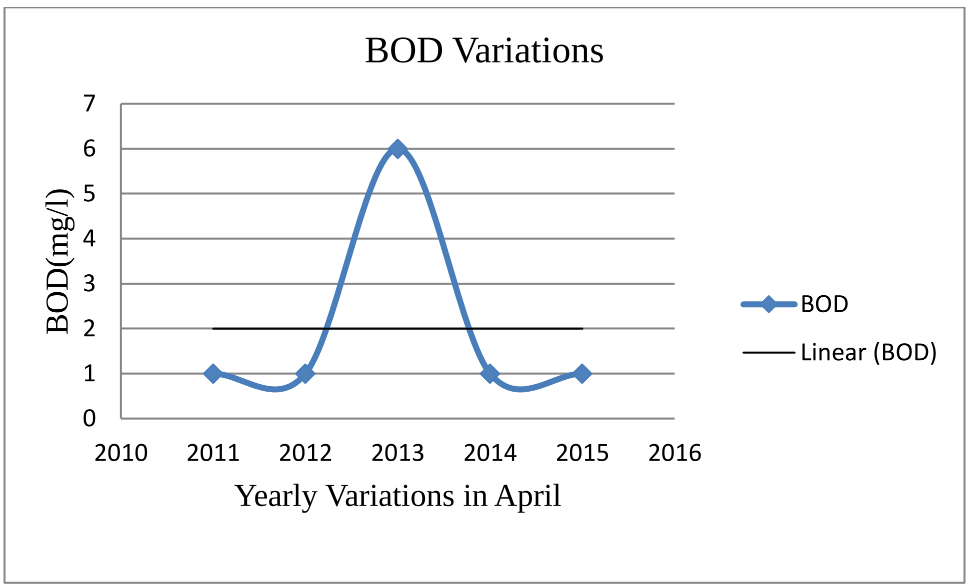

Figure 5.10- Variation of BOD in April

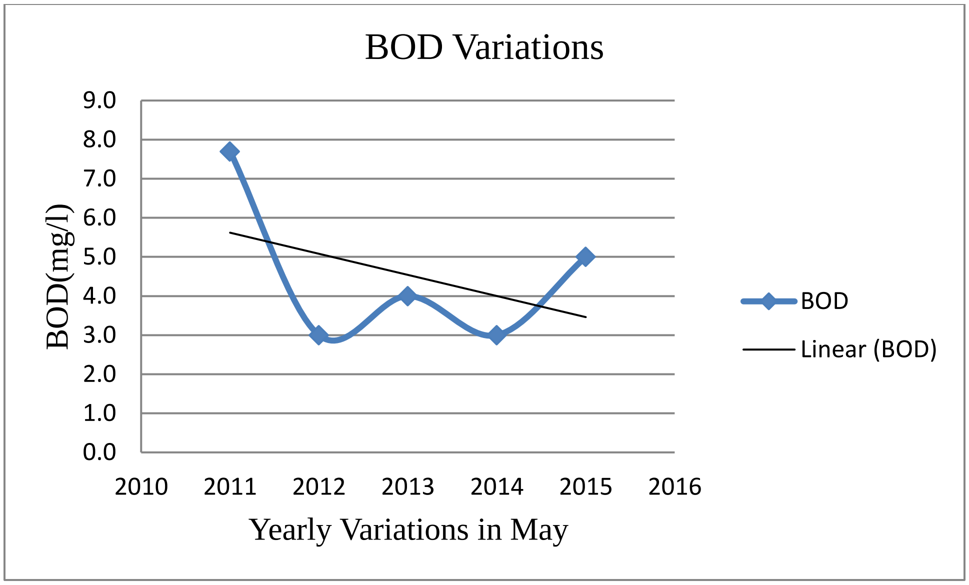

Figure 5.11- Variation of BOD in May

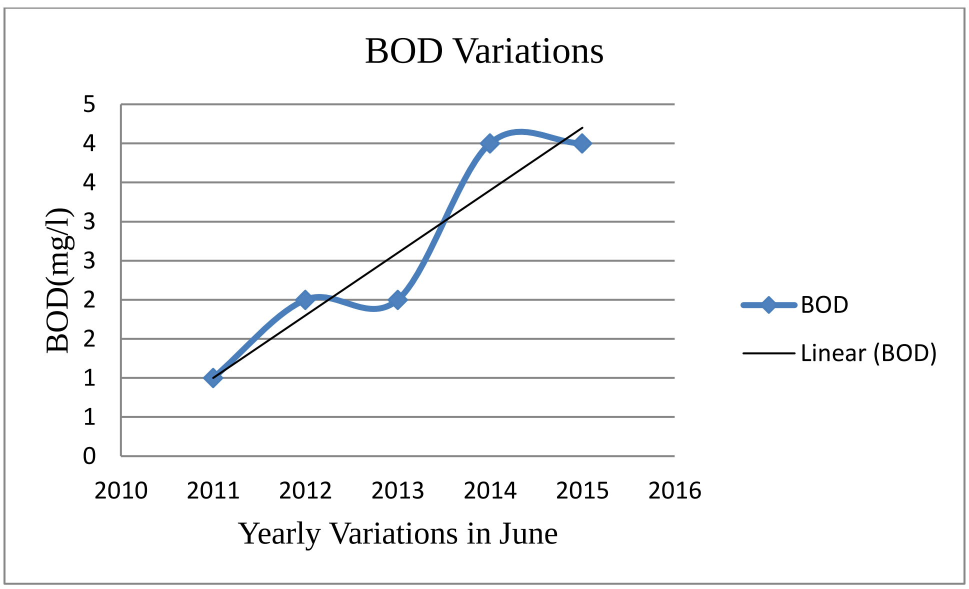

Figure 5.12- Variation of BOD in June

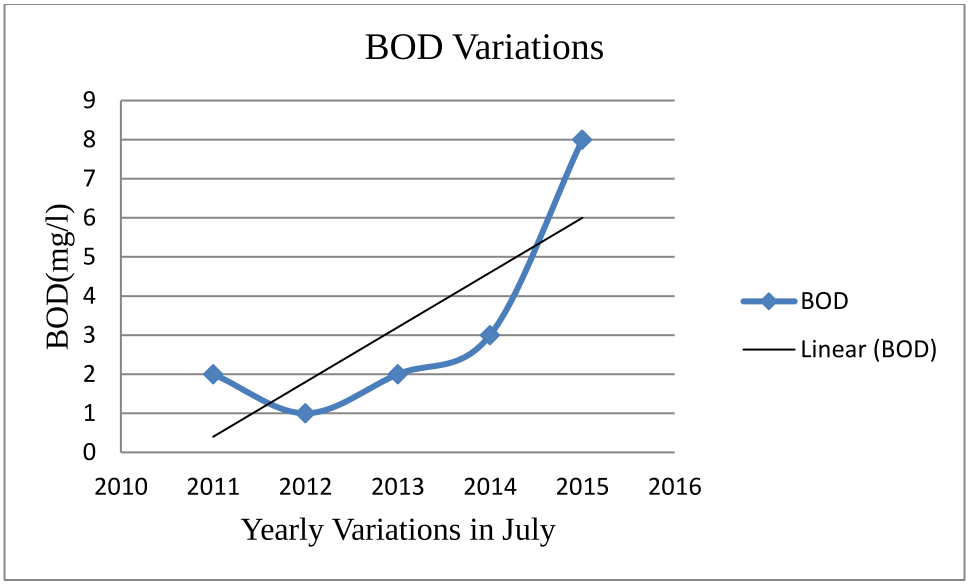

Figure 5.13- Variation of BOD in July

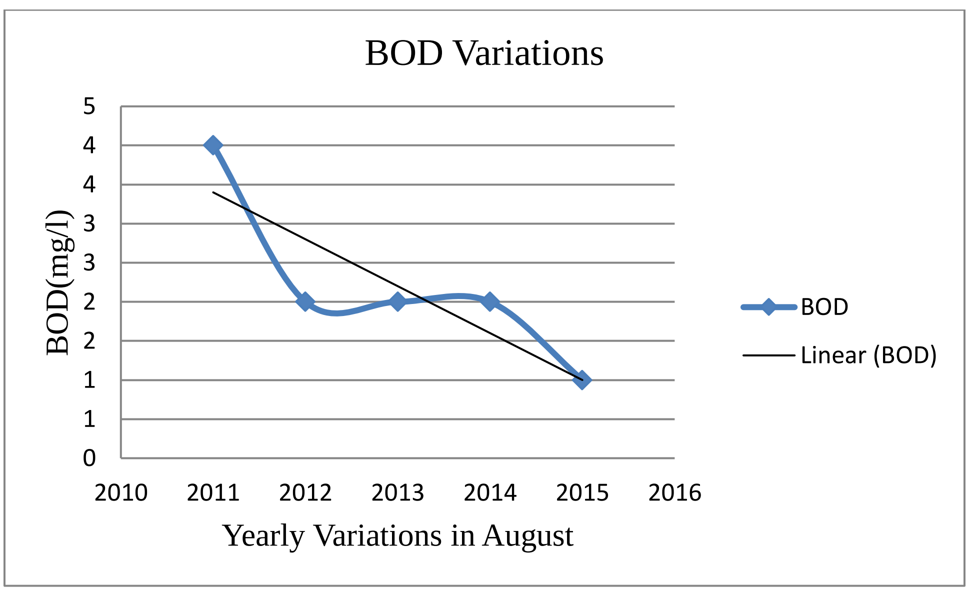

Figure 5.14- Variation of BOD in August

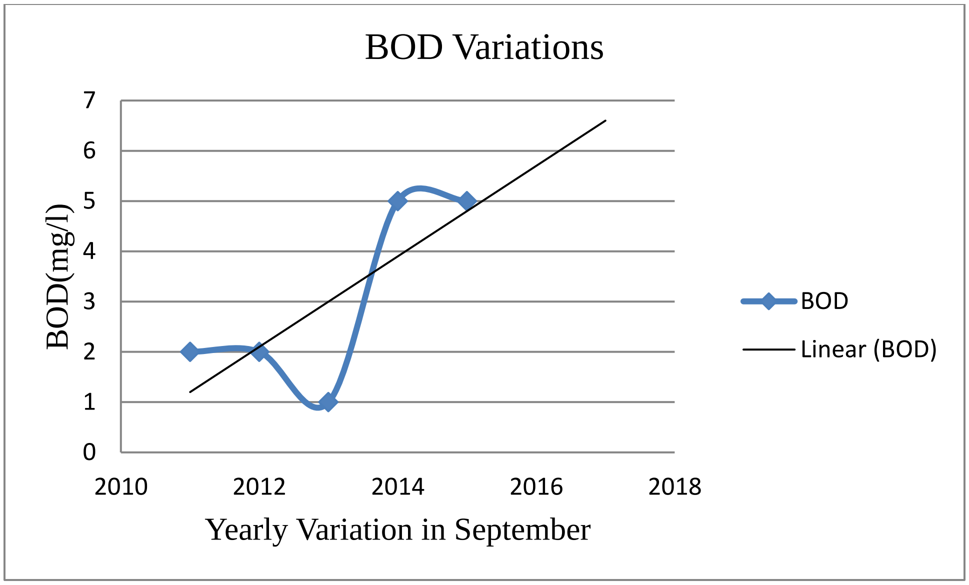

Figure 5.15 - Variation of BOD in September

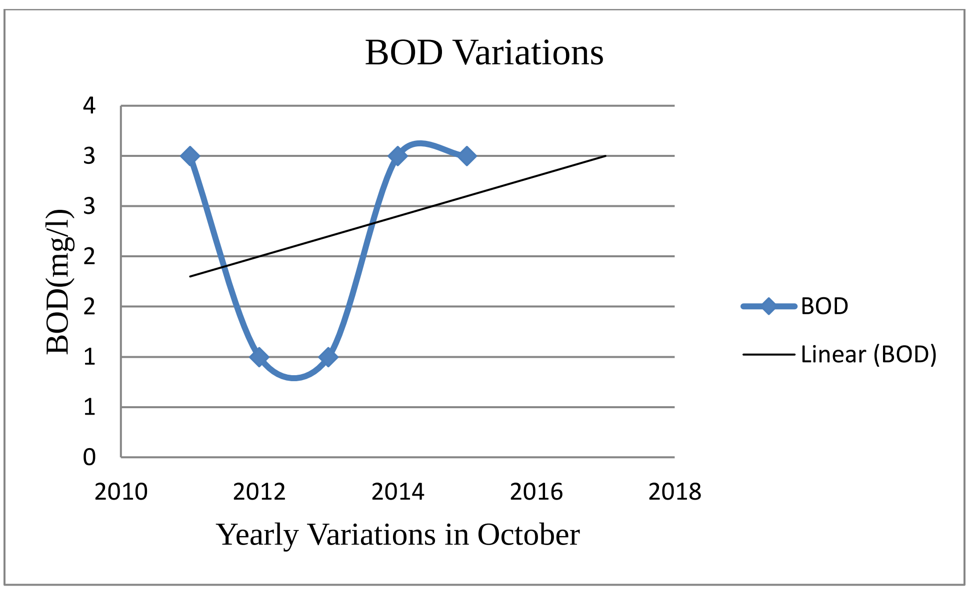

Figure 5.16 - Variation of BOD in October

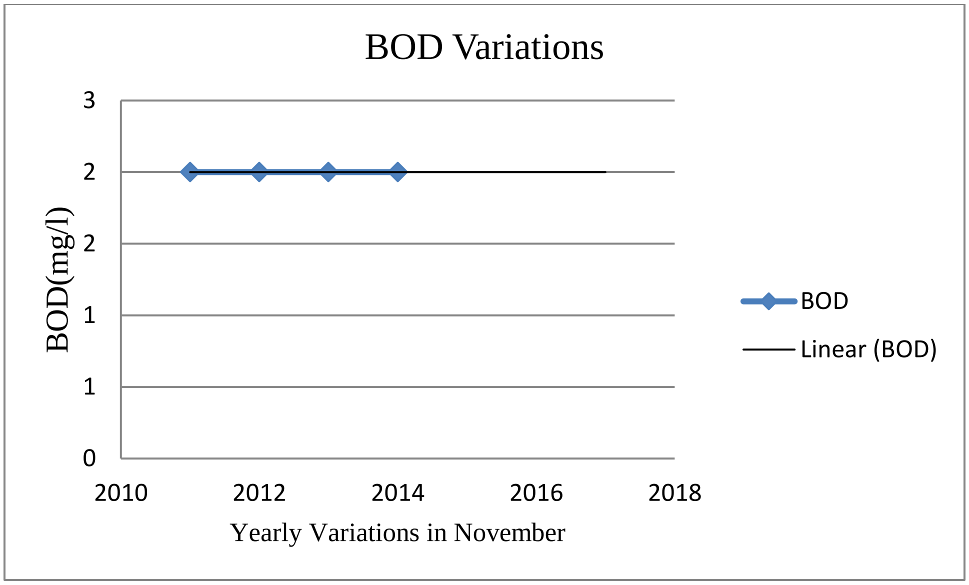

Figure 5.17 - Variation of BOD in November

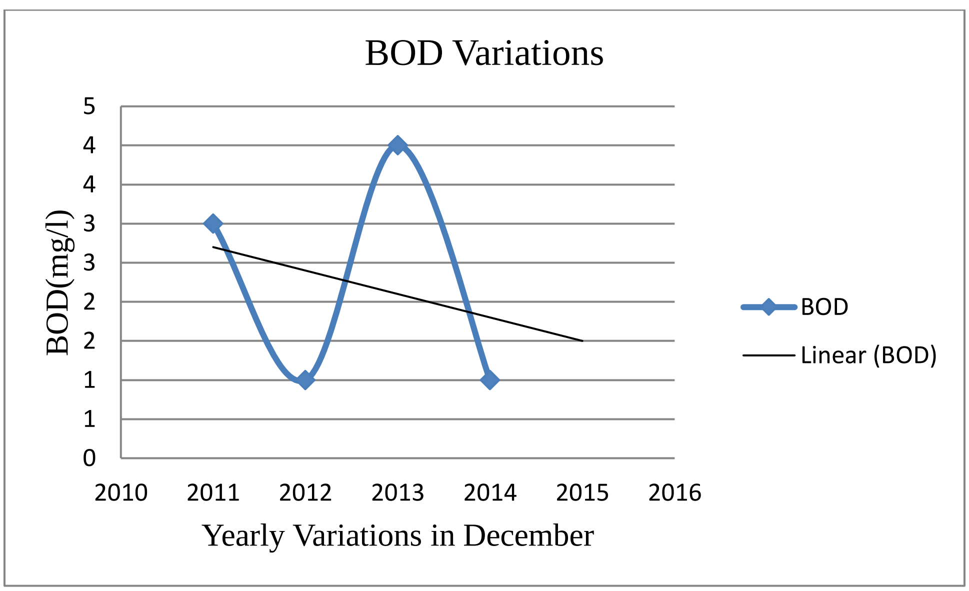

Figure 5.18 - Variation of BOD in December

5.4 YEARLY VARIATIONS OF pH PARAMETERS AT PALLA

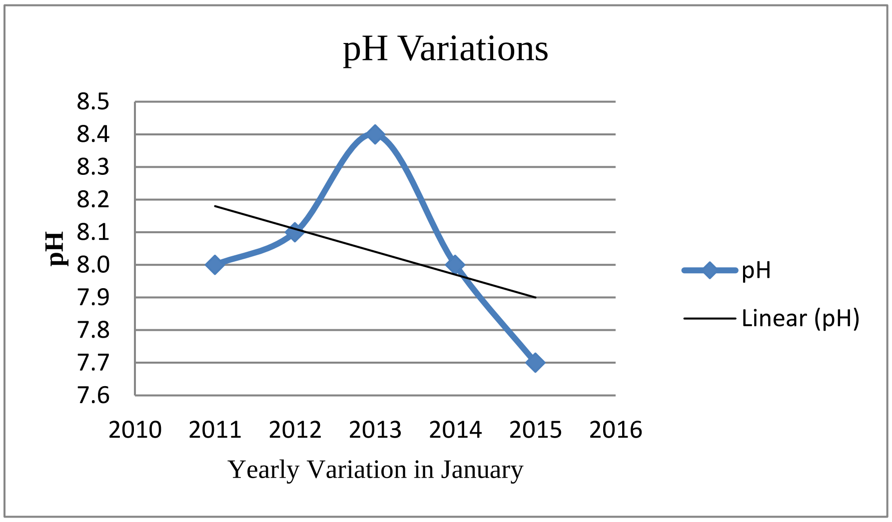

Figure 5.19 - Variation of pH in January

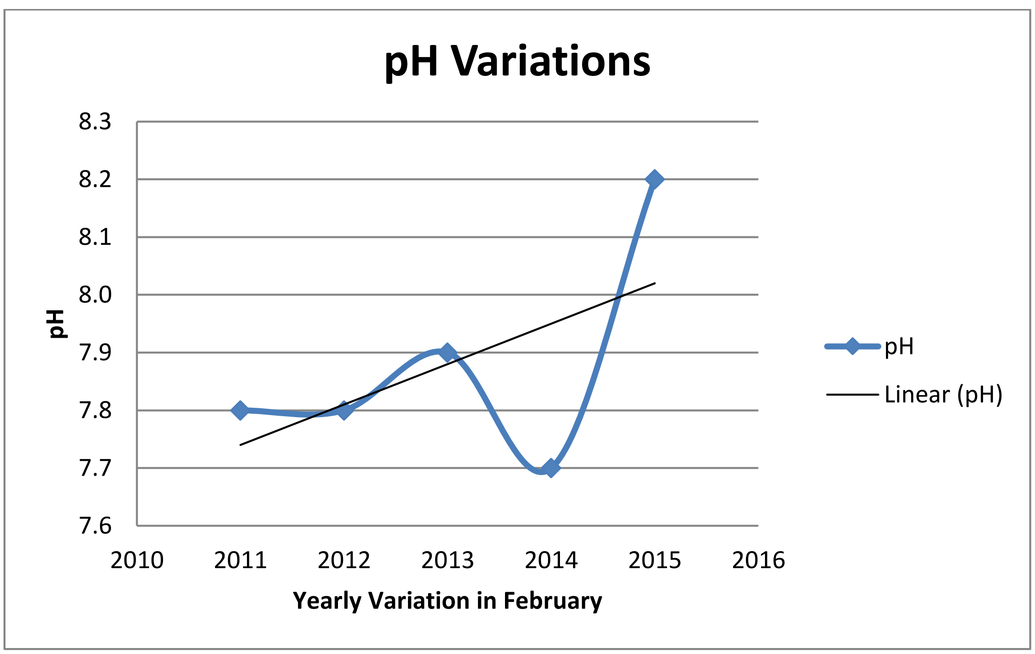

Figure 5.20 - Variation of pH in February

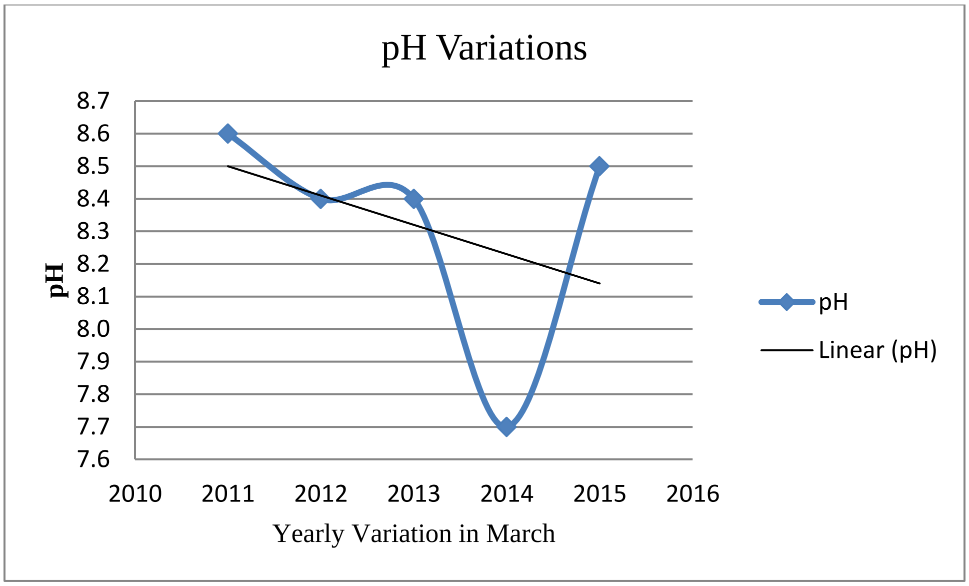

Figure 5.21 - Variation of pH in March

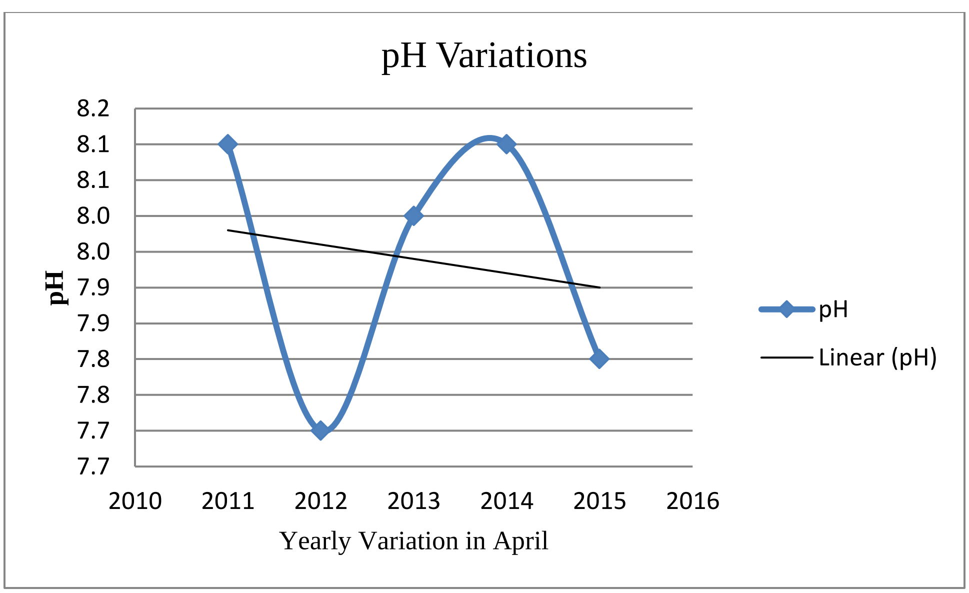

Figure 5.22 - Variation of pH in April

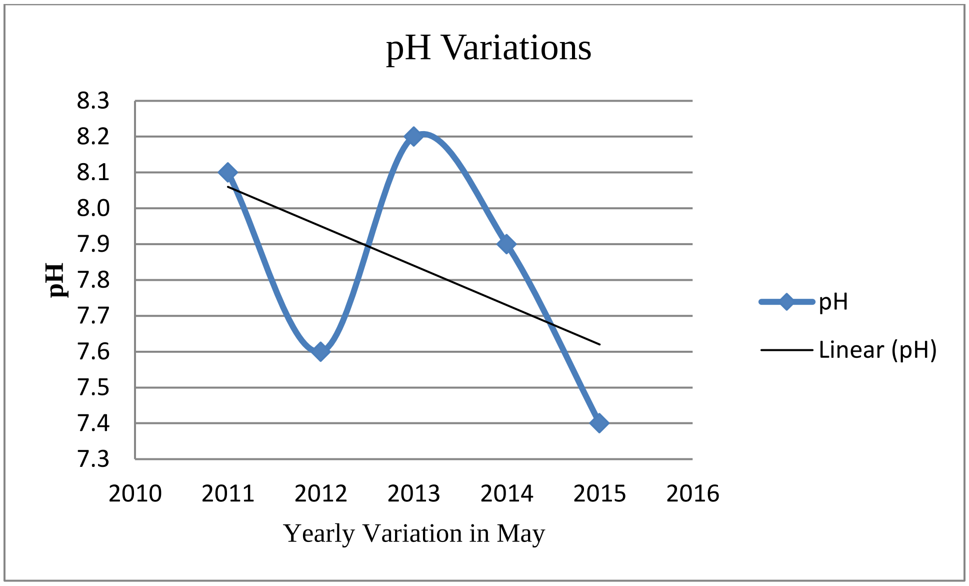

Figure 5.23 - Variation of pH in May

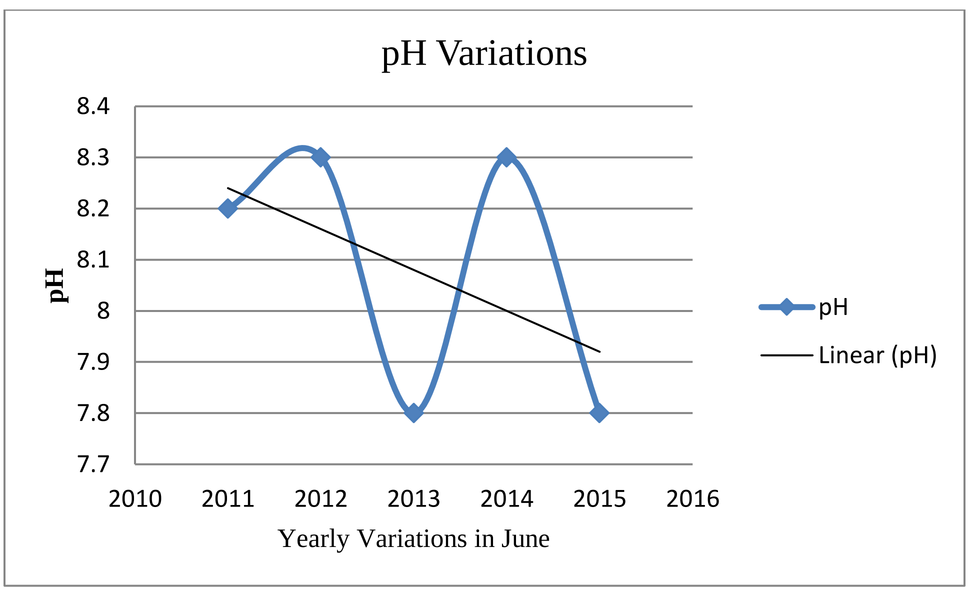

Figure 5.24 - Variation of pH in June

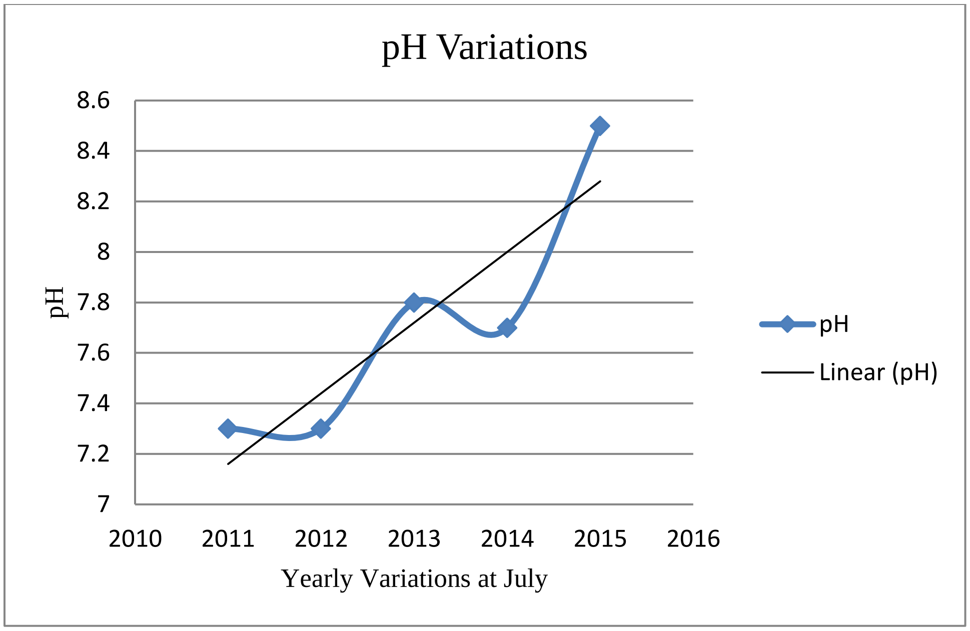

Figure 5.25- Variation of pH in July

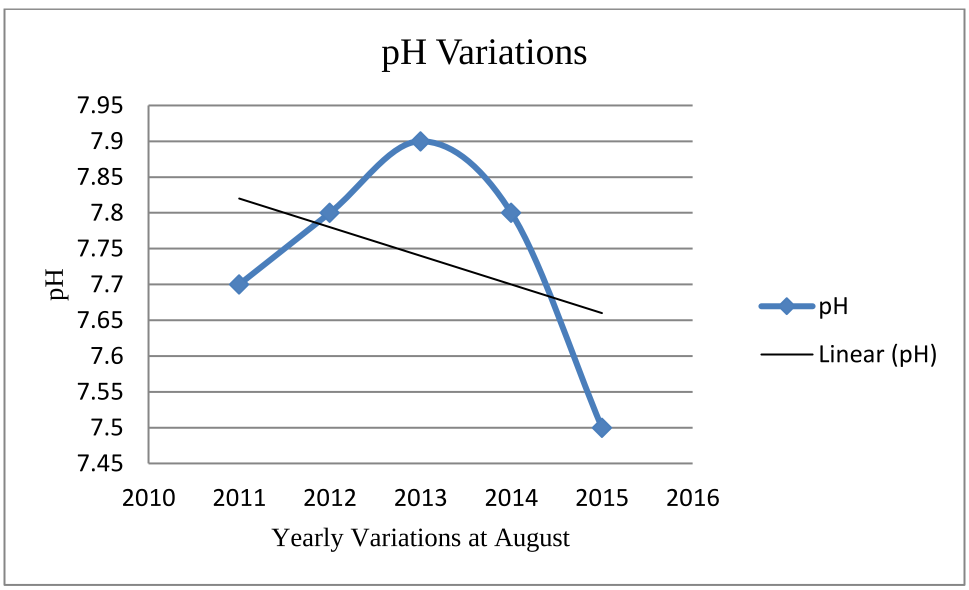

Figure 5.26- Variation of pH in August

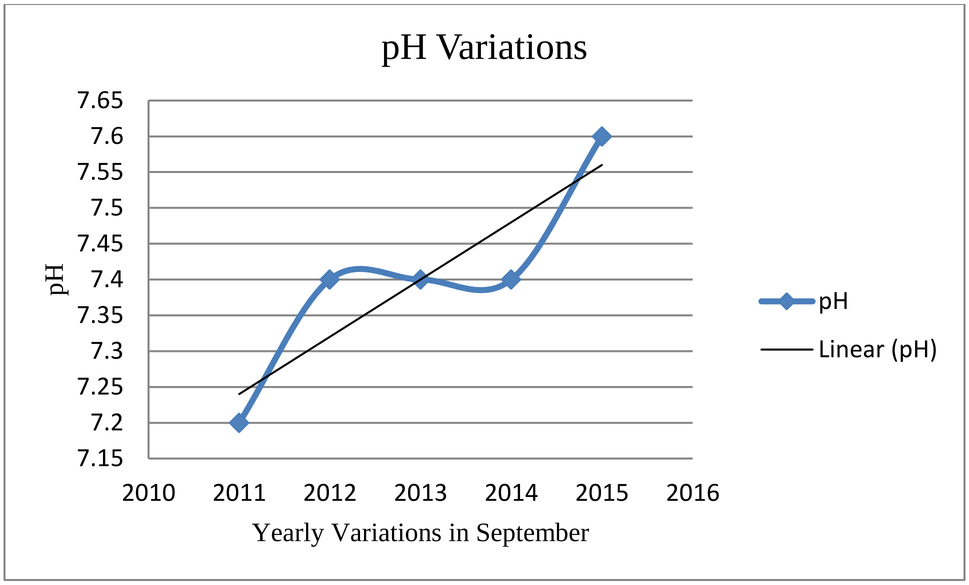

Figure 5.27- Variation of pH in September

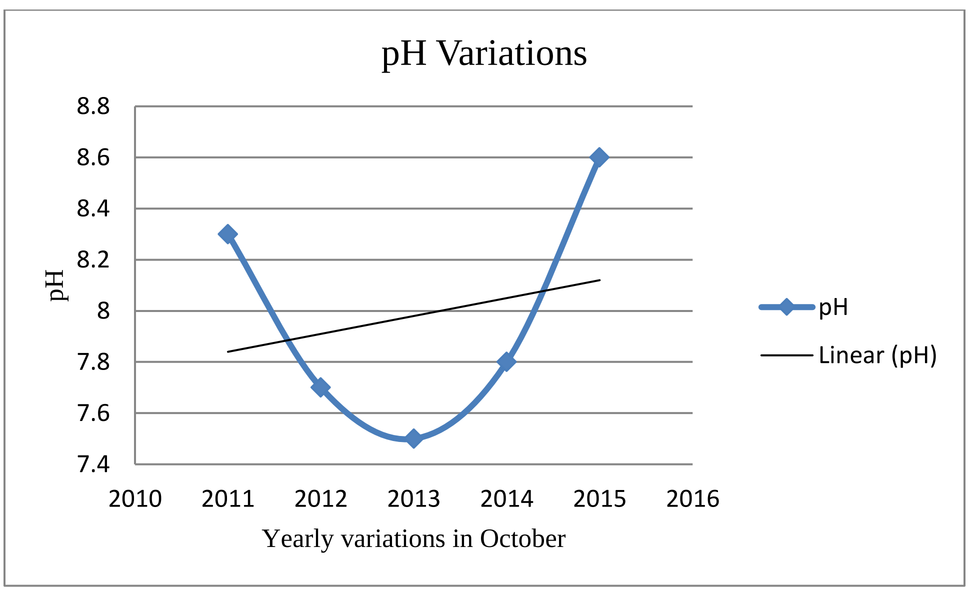

Figure 5.28- Variation of pH in October

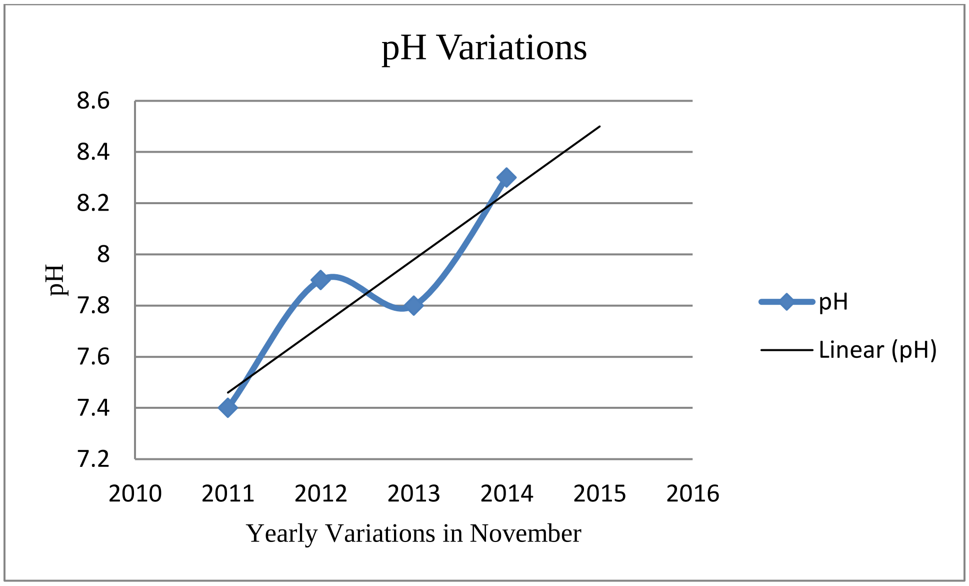

Figure 5.29- Variation of pH in November

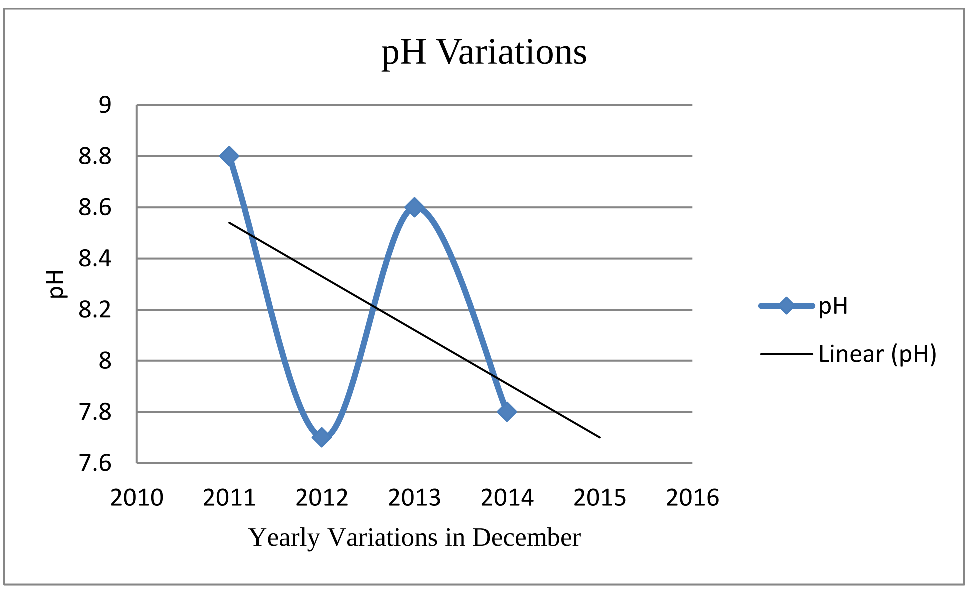

Figure 5.30- Variation of pH in December

5.5 YEARLY VARIATIONS OF DO PARAMETERS AT PALLA

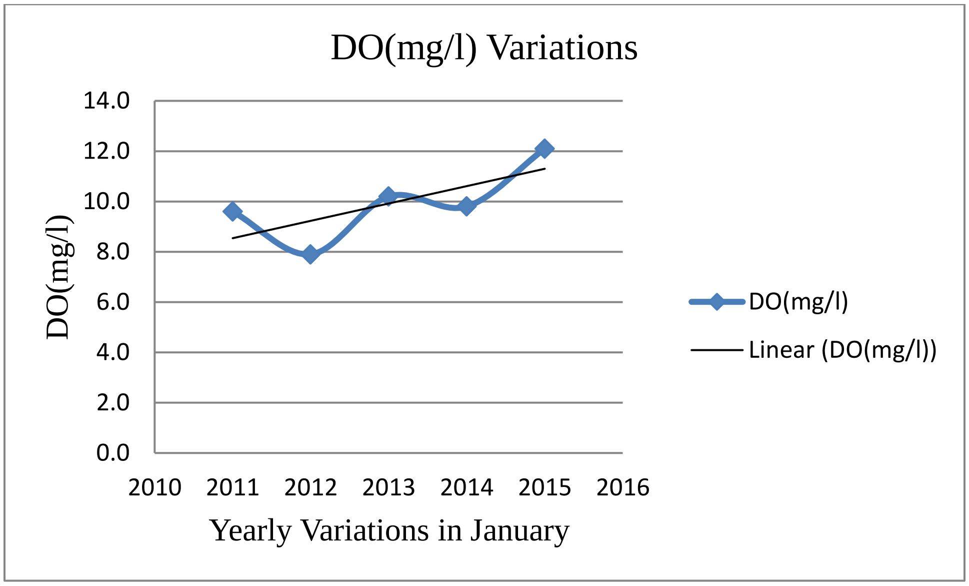

Figure 5.31- Variation of DO in January

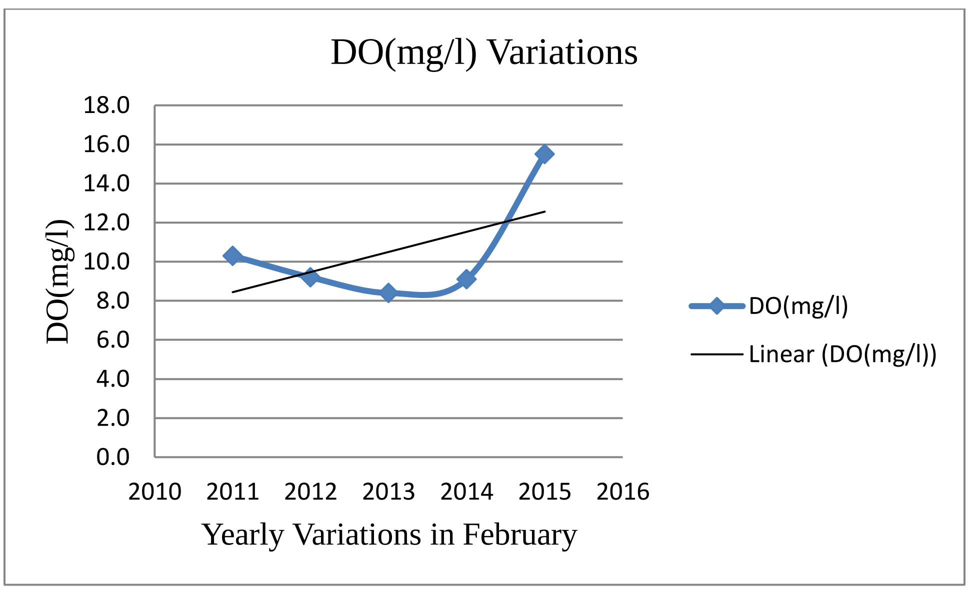

Figure 5.32- Variation of DO in February

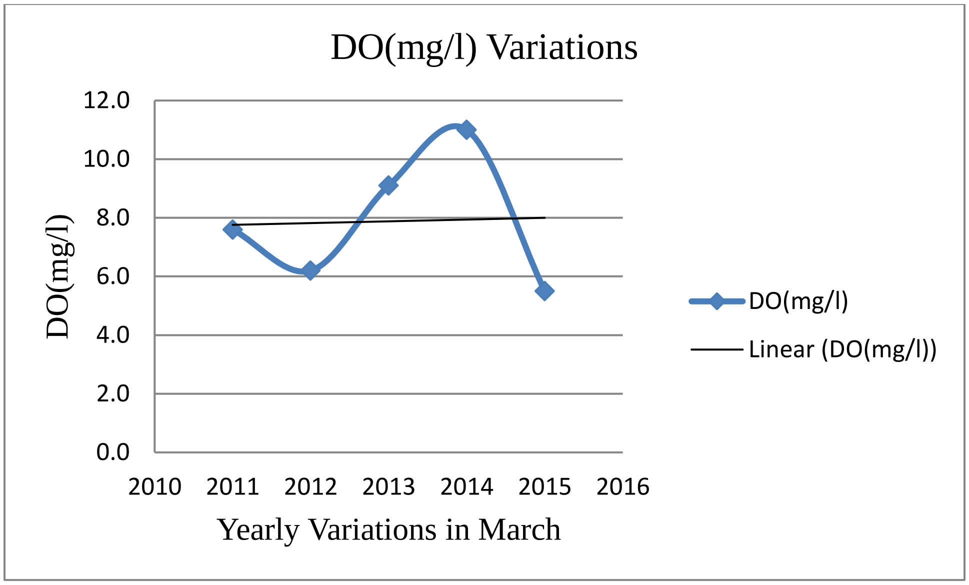

Figure 5.33- Variation of DO in March

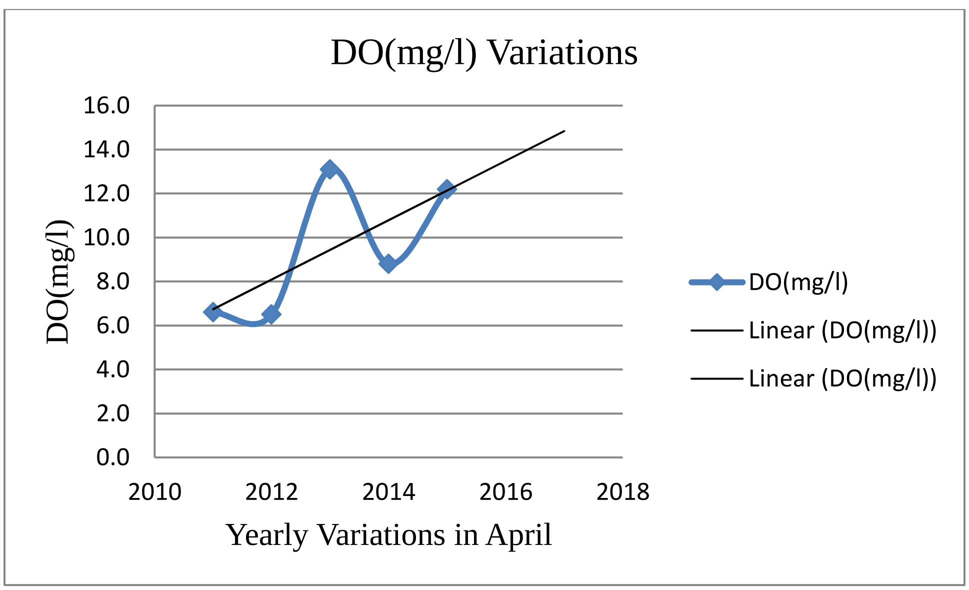

Figure 5.34- Variation of DO in April

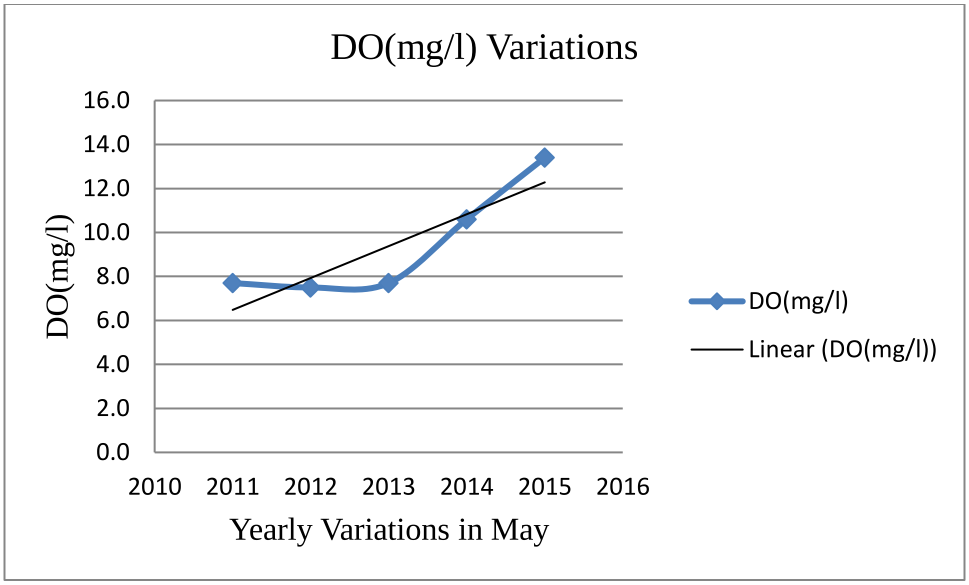

Figure 5.35- Variation of DO in May

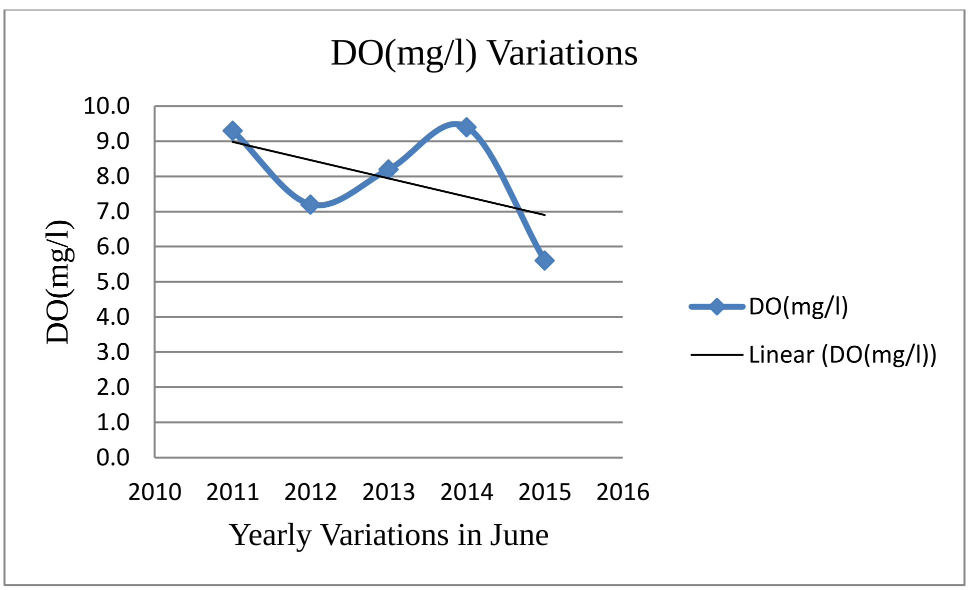

Figure 5.36- Variation of DO in June

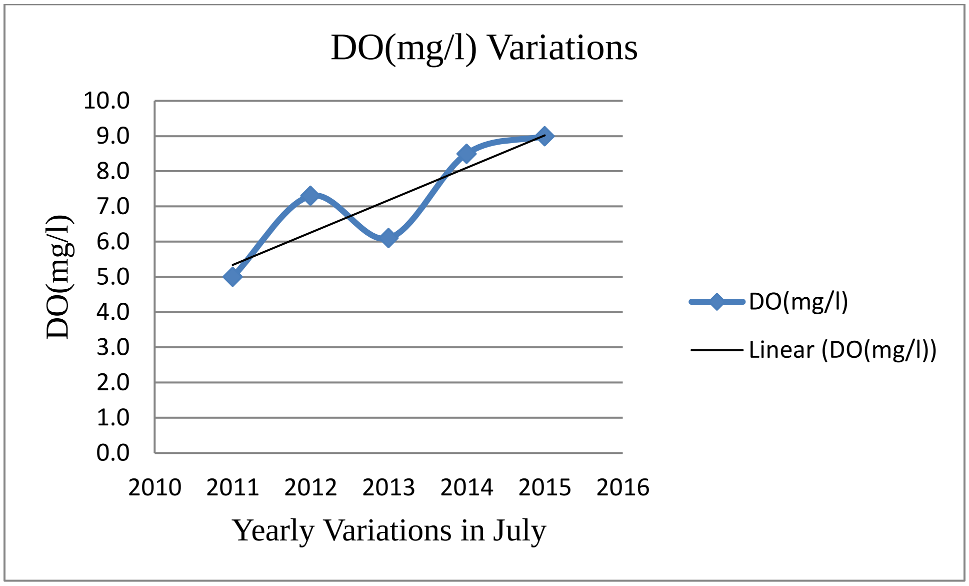

Figure 5.37- Variation of DO in July

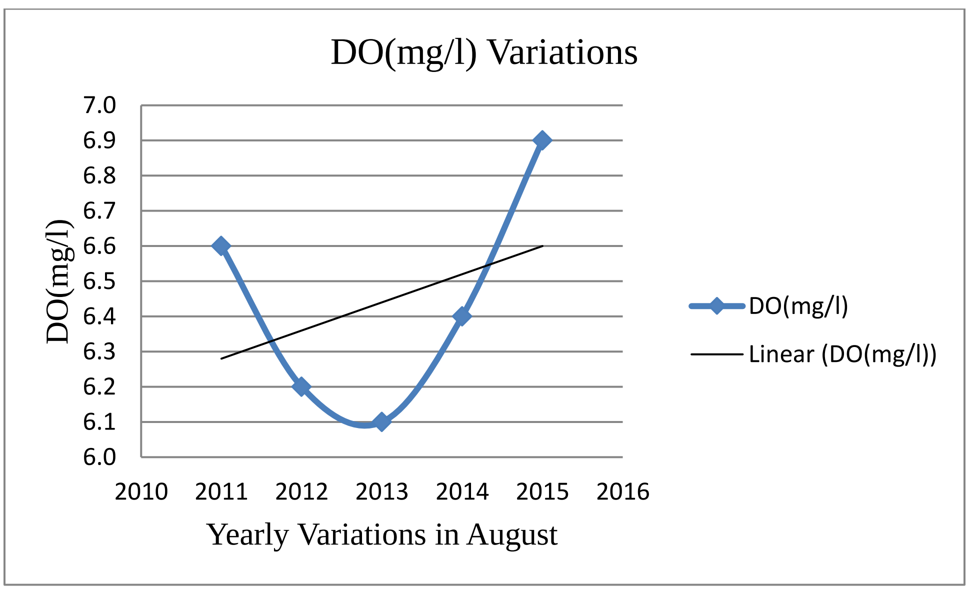

Figure 5.38- Variation of DO in August

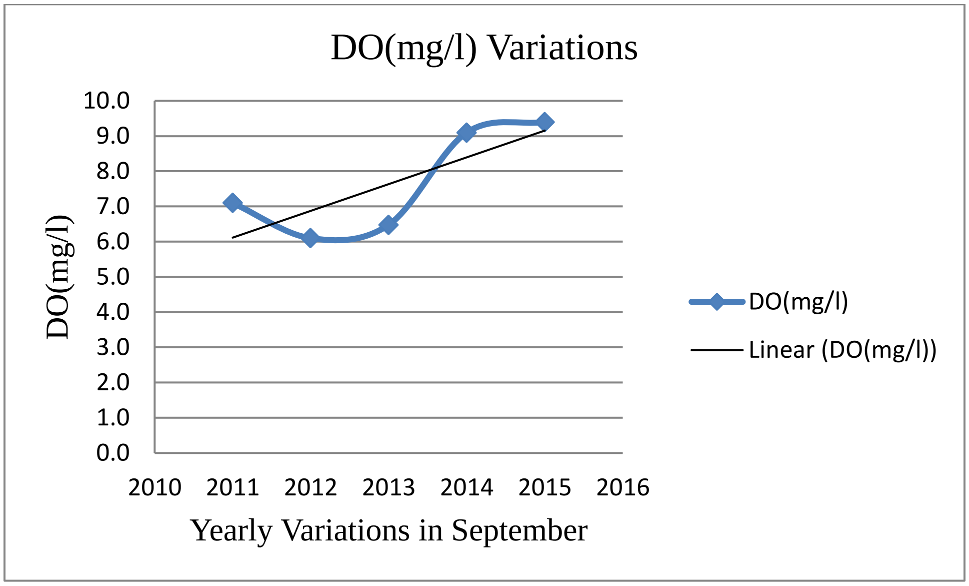

Figure 5.39- Variation of DO in September

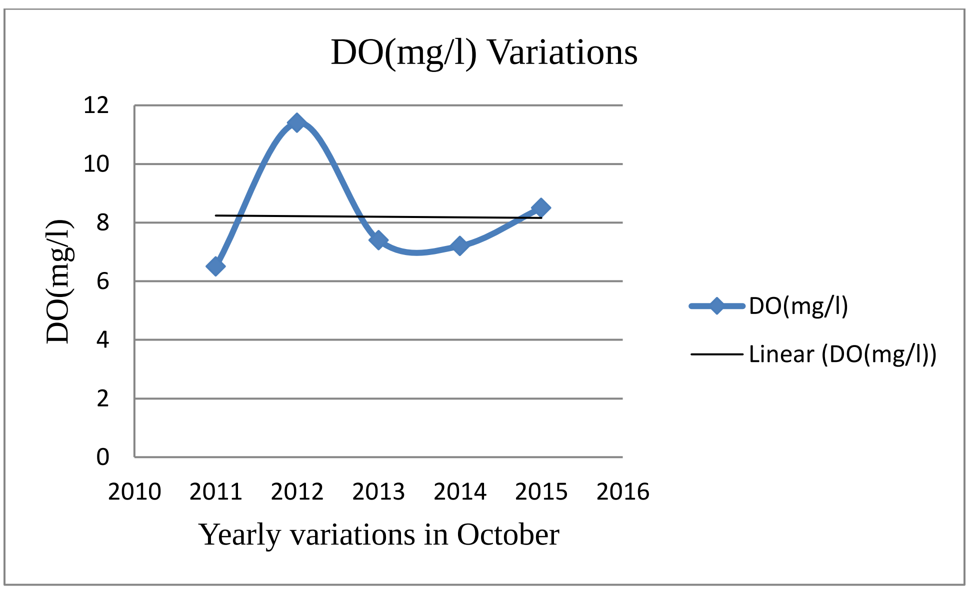

Figure 5.40- Variation of DO in October

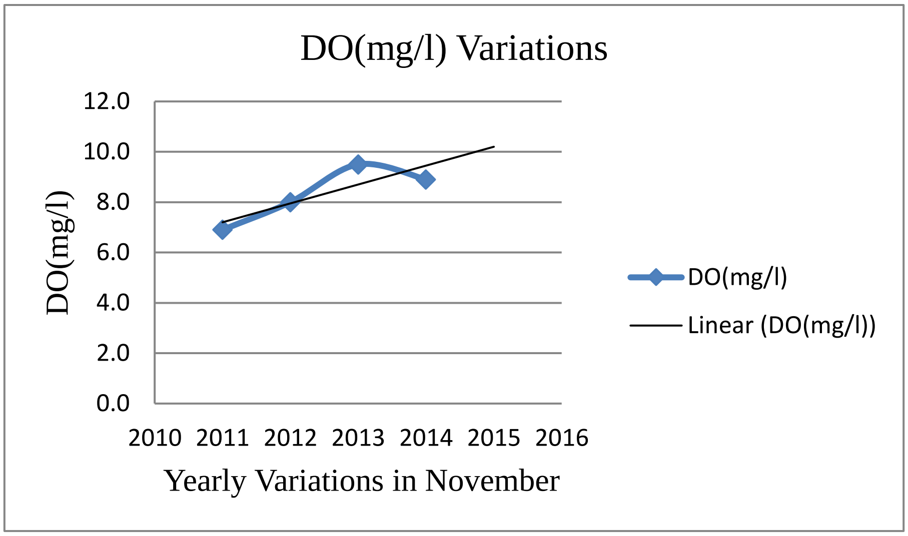

Figure 5.41- Variation of DO in November

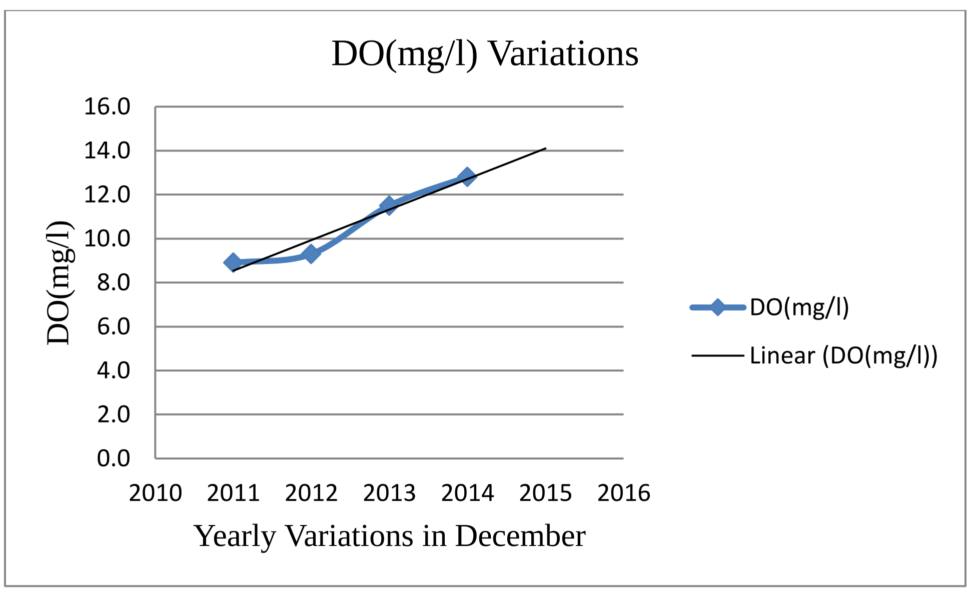

Figure 5.42- Variation of DO in December

5.6 MONTHLY VARIATIONS OF PARAMETERS AT PALLA

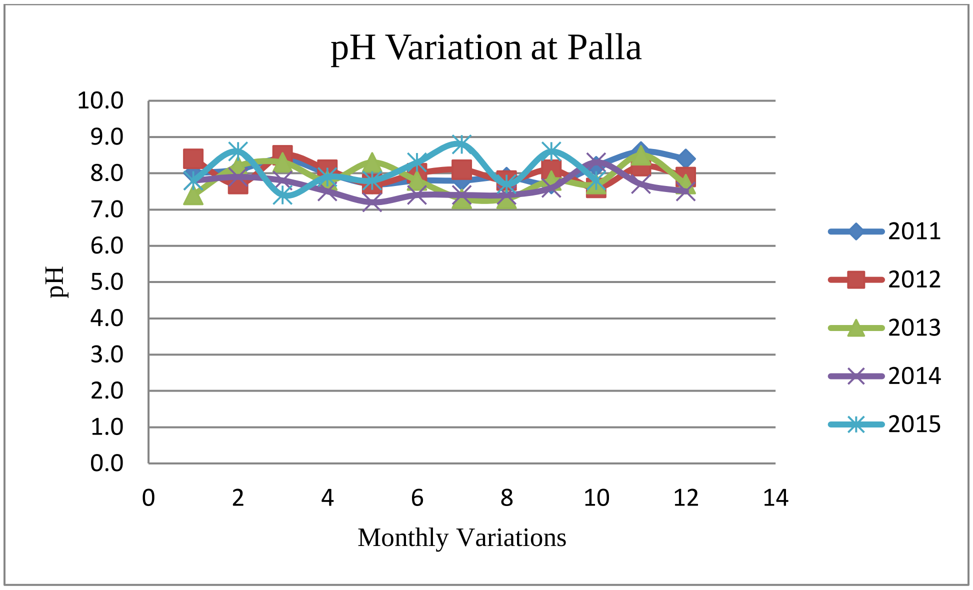

Figure 5.43- Monthly Variations of pH at Palla

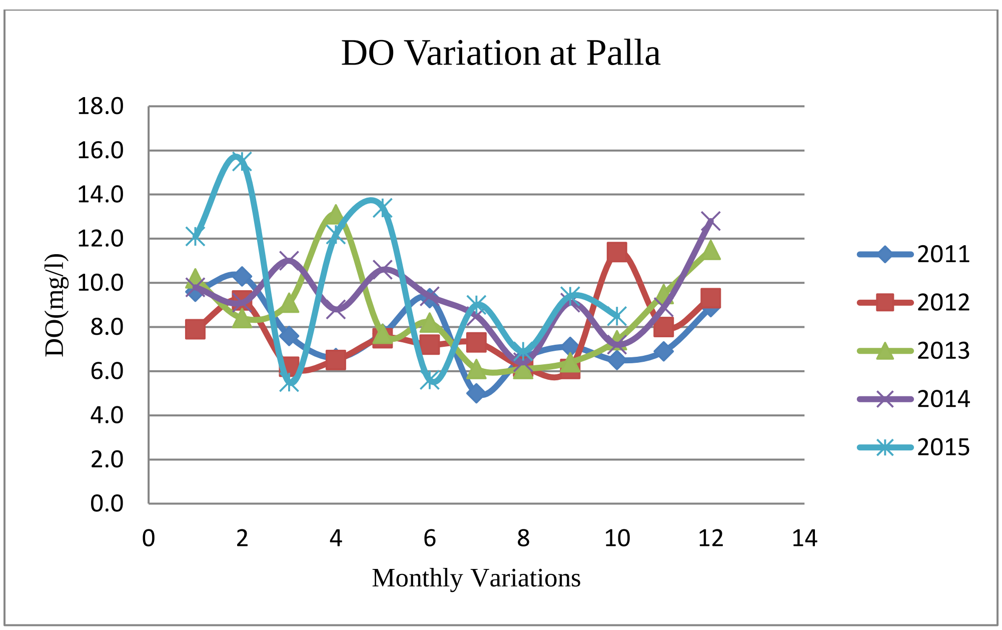

Figure 5.44- Monthly Variations of DO at Palla

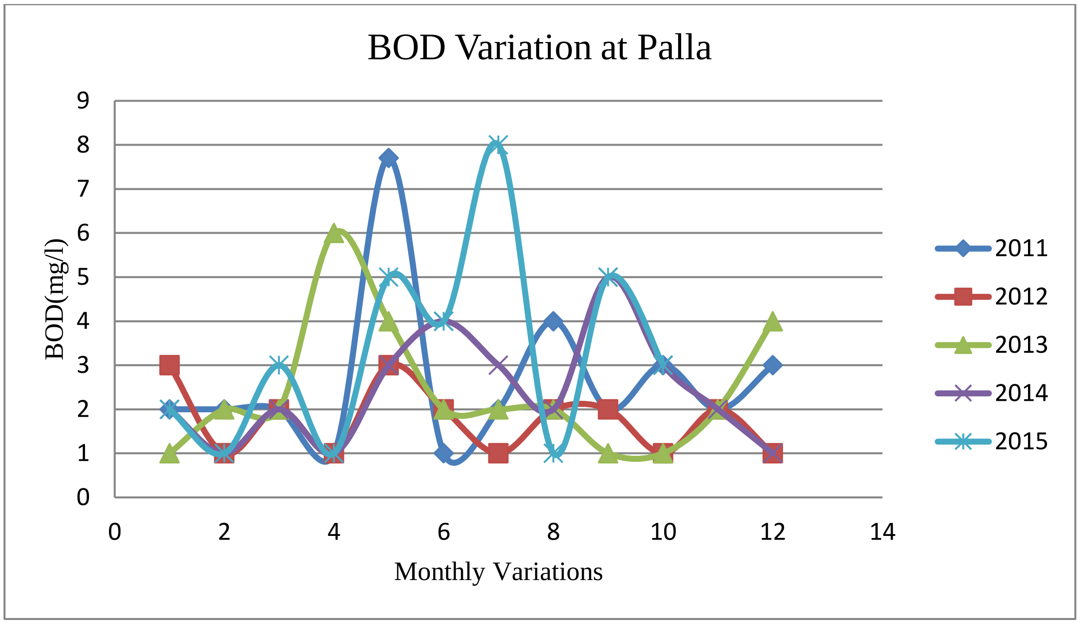

Figure 5.45- Monthly Variations of BOD at Palla

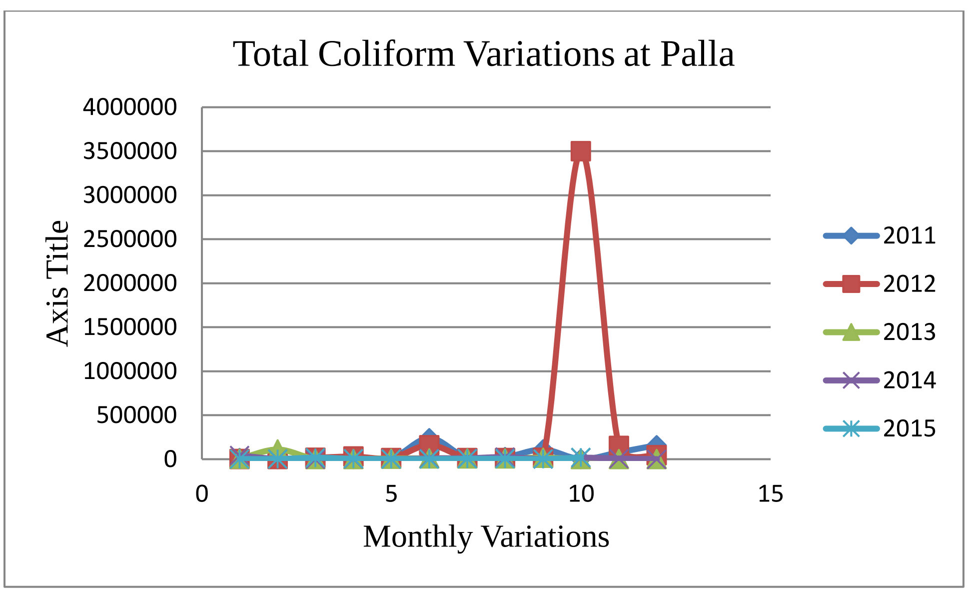

Figure 5.46- Monthly Variations of Total Coliform at Palla

5.7 MONTHLY VARIATIONS OF PARAMETERS AT NIZAMUDDIN

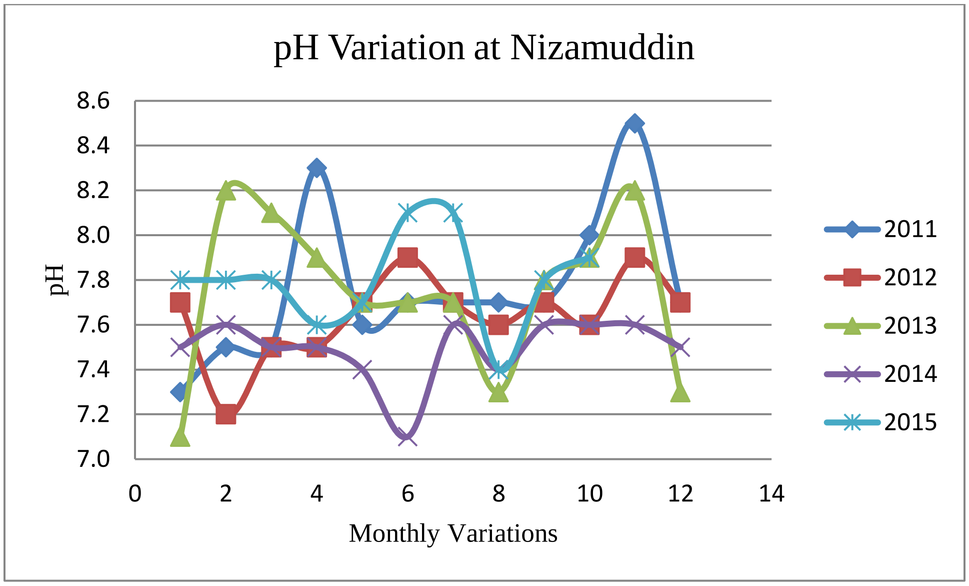

Figure 5.47- Monthly Variations of pH at Nizamuddin

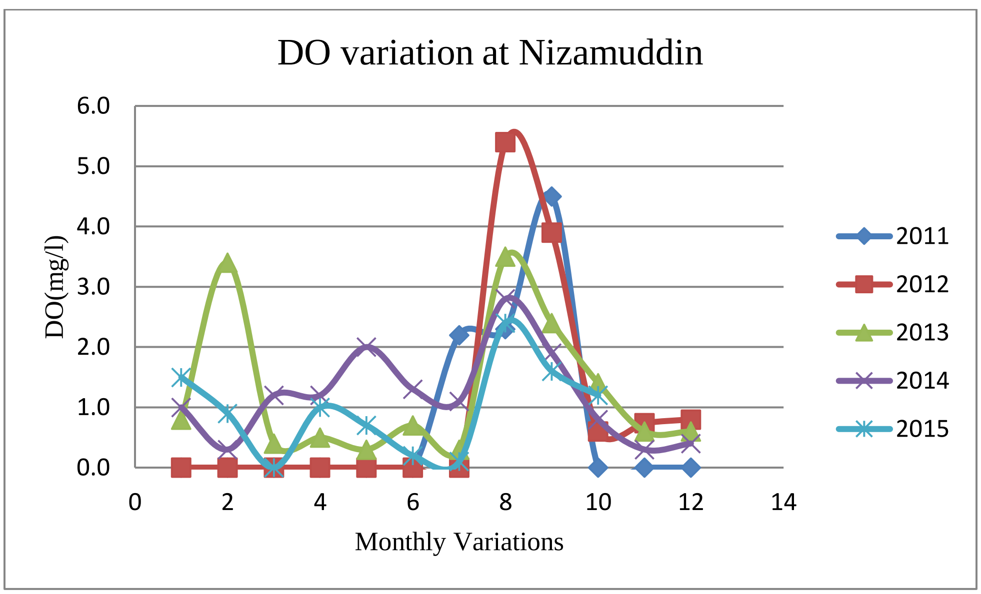

Figure 5.48- Monthly Variations of DO at Nizamuddin

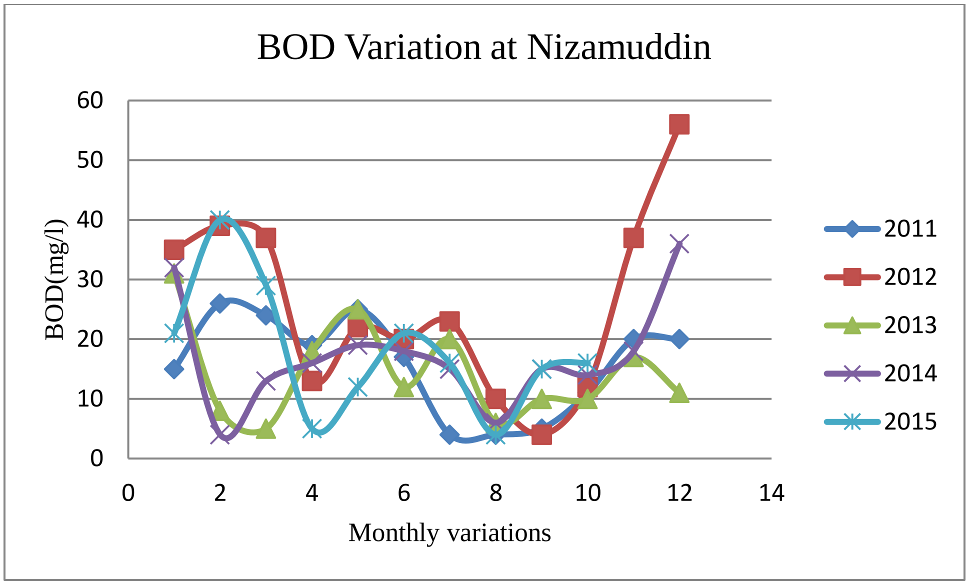

Figure 5.49- Monthly Variations of BOD at NIzamuddin

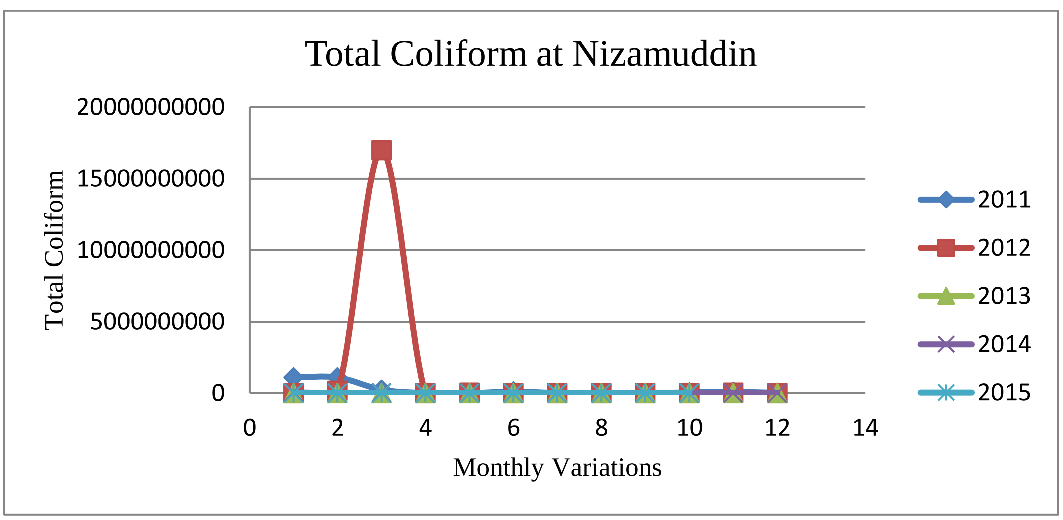

Figure 5.50- Monthly Variations of Total Coliform at Nizamuddin

5.8 MONTHLY VARIATIONS OF PARAMETERS AT AGRA CANAL (KALINIDI KUNJ)

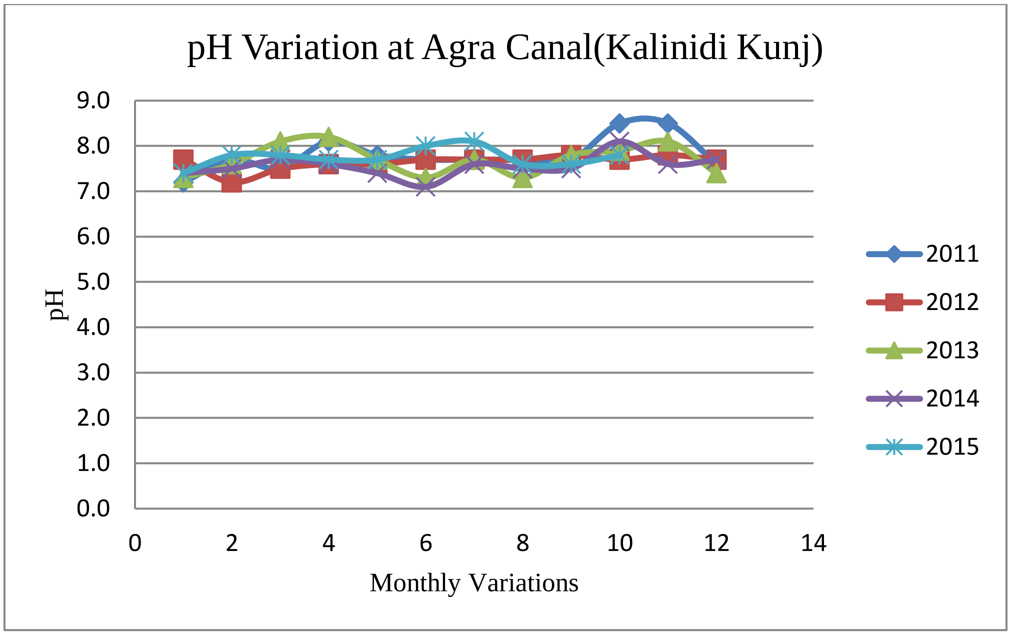

Figure 5.51- Monthly Variations of pH at Agra canal (Kalinidi Kunj)

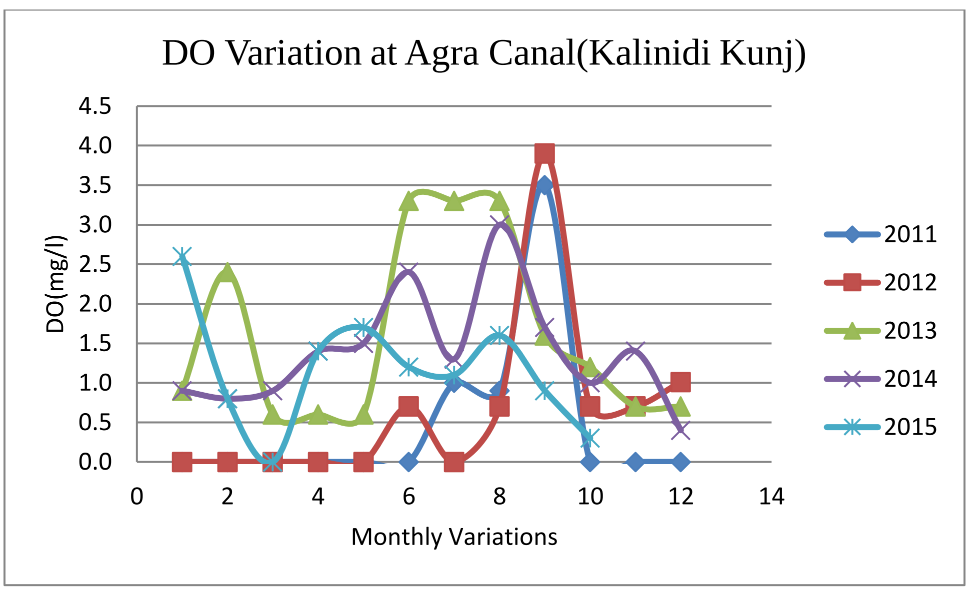

Figure 5.52- Monthly Variations of DO at Agra canal (Kalinidi Kunj)

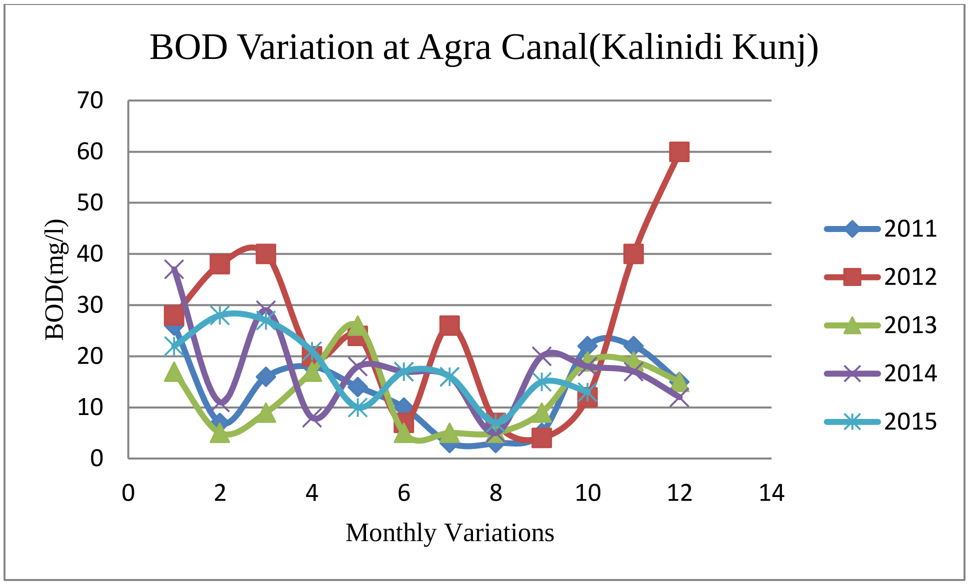

Figure 5.53- Monthly Variations of BOD at Agra canal (Kalinidi Kunj)

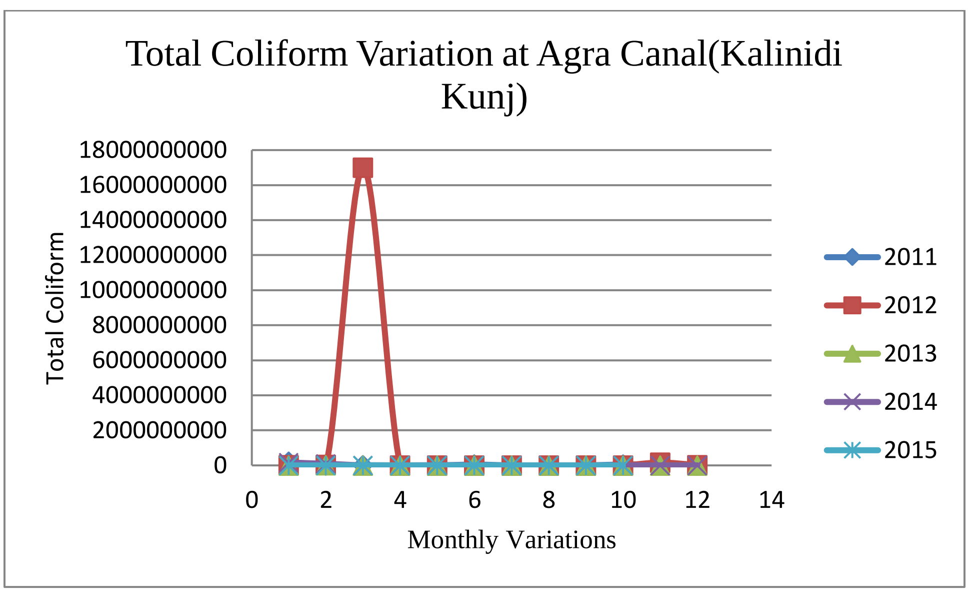

Figure 5.54- Monthly Variations of Total Coliform at Agra canal (Kalinidi Kunj)

5.9 MONTHLY VARIATIONS OF PARAMETERS AT OKHLA AFTER MEETING SHAHDARA DRAIN

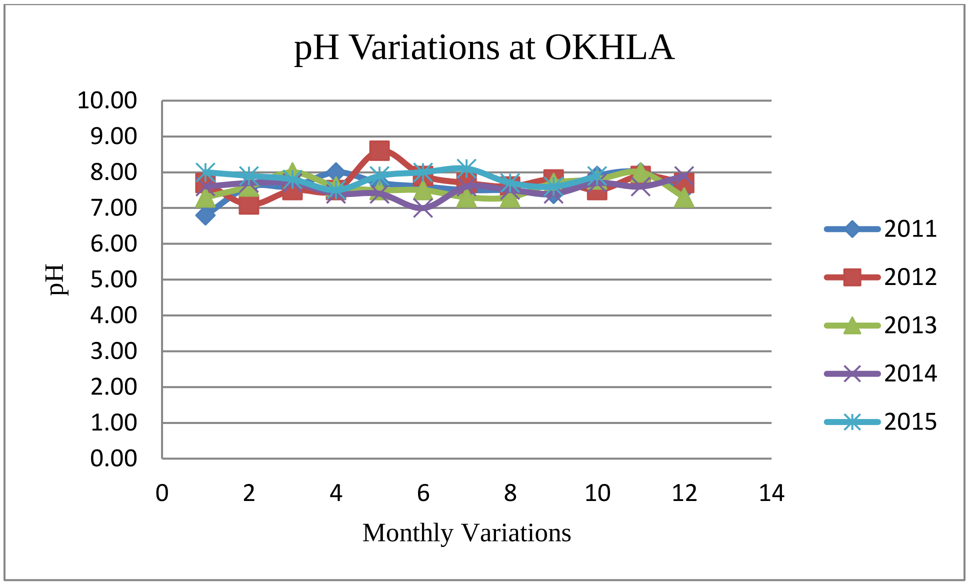

Figure 5.55- Monthly Variations of pH at OKHLA after meeting Shahdara Drain

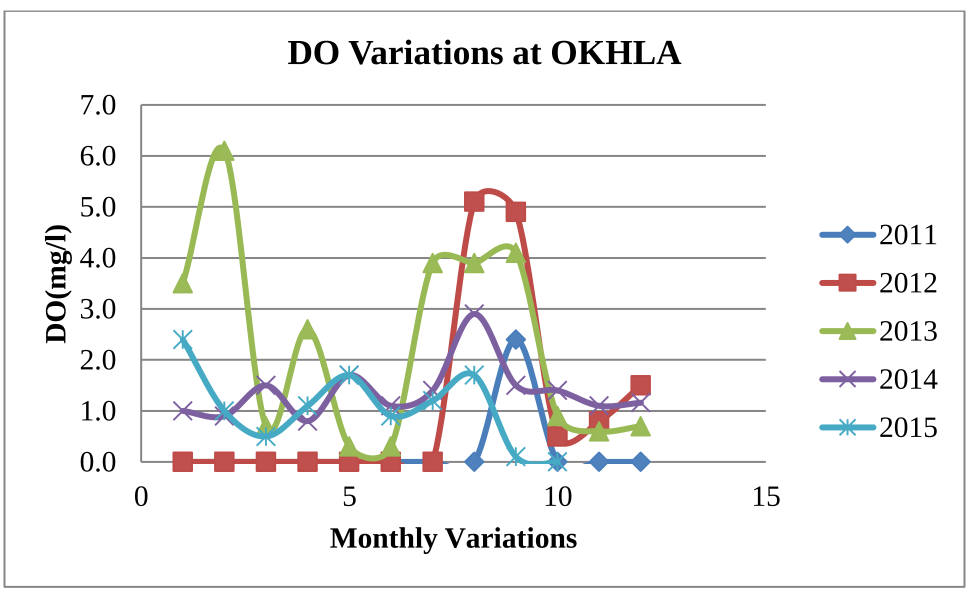

Figure 5.56- Monthly Variations of DO at OKHLA after meeting Shahdara Drain

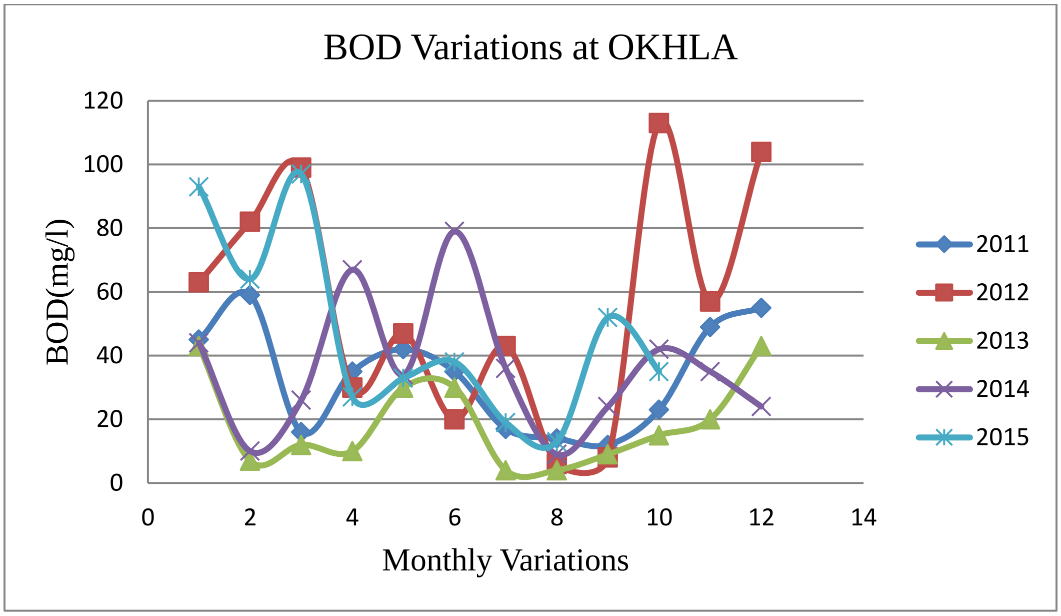

Figure 5.57- Monthly Variations of BOD at OKHLA after meeting Shahdara Drain

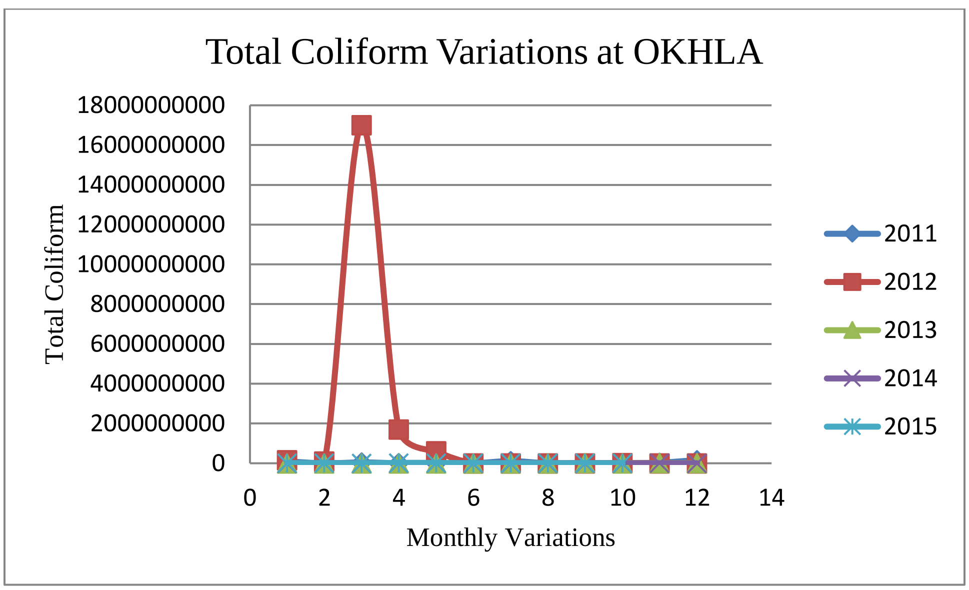

Figure 5.58- Monthly Variations of Total Coliform at OKHLA after meeting Shahdara Drain

5.10 MONTHLY VARIATIONS OF PARAMETERS AT AGRA CANAL (MADANPUR KHADAR)

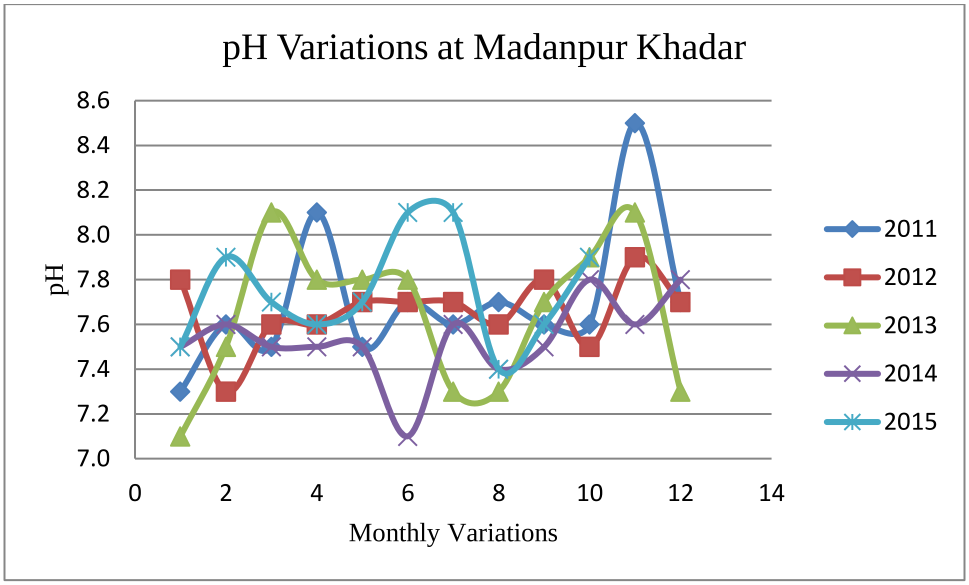

Figure 5.59- Monthly Variations of pH at Agra Canal(Madanpur Khadar)

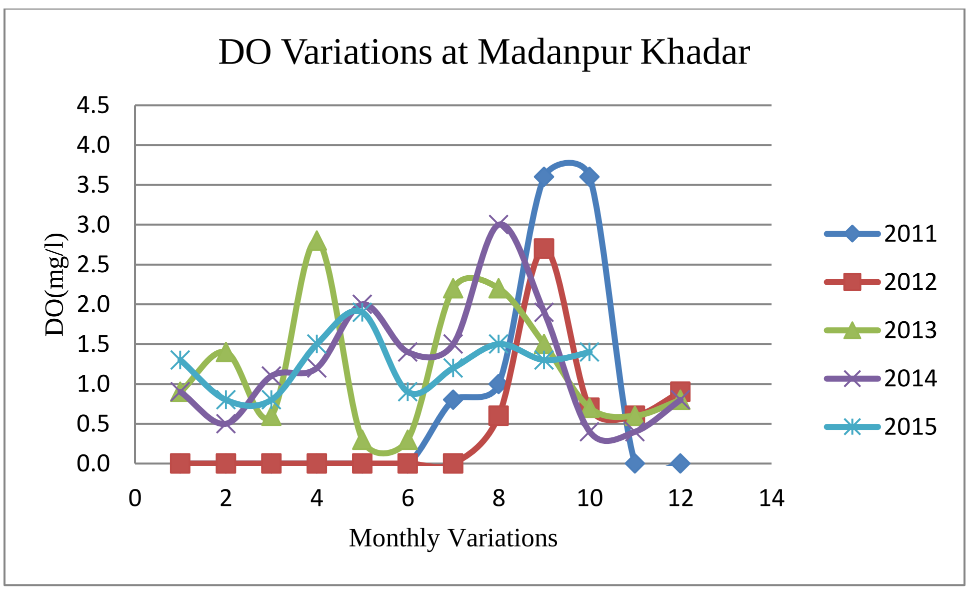

Figure 5.60- Monthly Variations of DO at Agra Canal(Madanpur Khadar)

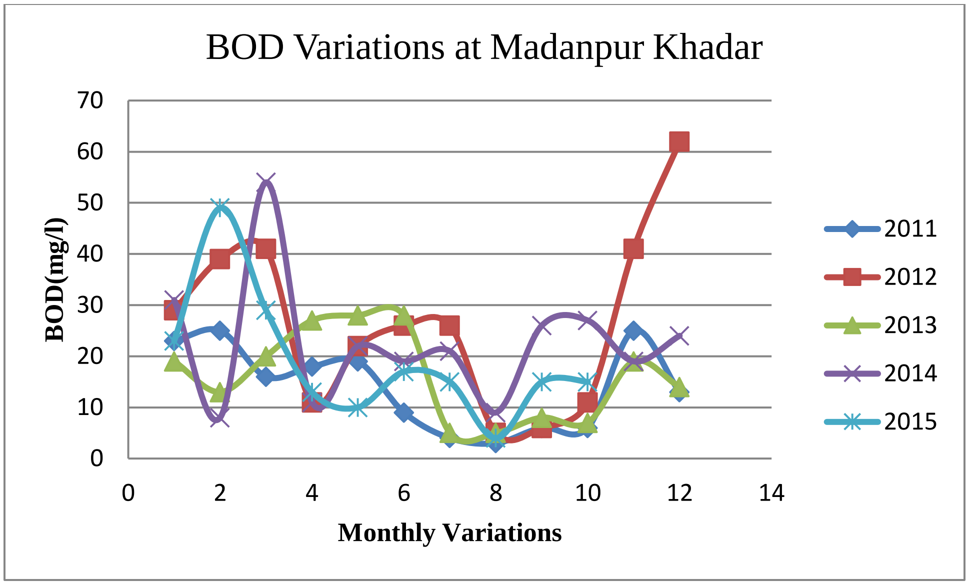

Figure 5.61- Monthly Variations of BOD at Agra Canal(Madanpur Khadar)

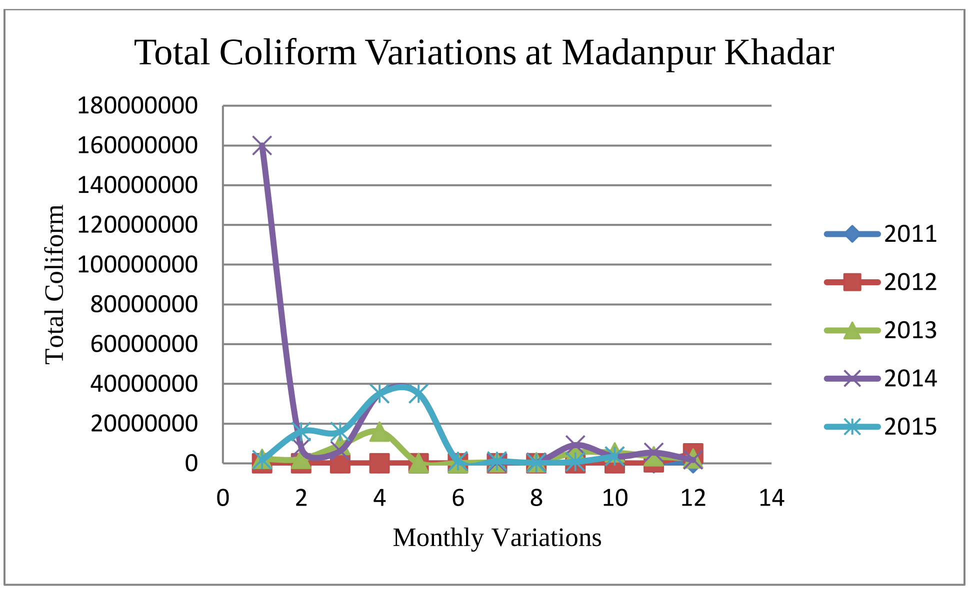

Figure 5.62- Monthly Variations of Total Coliform at Agra Canal (Madanpur Khadar)

CHAPTER – 6

RESULTS AND CONCLUSION

6. RESULTS AND CONCLUSION

In this study, a robust decision-making tool for river water management in the form of the FRHI is presented.

The fuzzy water quality index as derived from fuzzy logic tool box using graphical user interface showed good correlation when compared with the standard water quality index of National Sanitation Foundation. The correlation between FWQI and WQI by NSF at different sites are

6. The correlation between FWQI and NSF WQI at Palla is 0.82058
7. The correlation between FWQI and NSF WQI at Nizamuddin is 0.90838
8. The correlation between FWQI and NSF WQI at Agra Canal(Kalinidi kunj) is 0.893
9. The correlation between FWQI and NSF WQI at OKHLA is 0.902117
10. The correlation between FWQI and NSF WQI at Agra Canal(Madanpur Khadar) is 0.86459.

The value of correlation should be such that it lie between -1 and +1. The positive sign show positive correlation and negative sign show negative correlation. Positive correlation exists when r is close to 1 and r value of exactly 1 indicates a perfect positive fit. A correlation greater than 0.8 is generally described as strong, whereas a correlation less than 0.5 is described as weak but they can vary based on the type of data and scientific data generally require a stronger correlation. The correlation at different site shows that good correlation exists between them and therefore the performance of the fuzzy model is found to be excellent at an overall level . The new index is believed to assist decision makers in reporting the condition of river health and investigation of spatial and temporal changes in the river. The fuzzy logic concepts, if used logically, could be an effective tool for some of the environmental policy matters and integrated environmental management.

7. REFERENCES

1. W. Silvert, Ecological impact classification with fuzzy sets. Ecol. Mod. 96 (1997) 1–10.
2. P.W. Bolton, J.C. Currie, D.J. Tervet, W.T. Welsh, An index to improve water quality classification. Water Pollution Cont. 77 (1978) 271-284.
3. D.S. Bhargava, Use of a water quality index for river classification and zoning of Ganga River. Env. Pol. Ser. B: Che. Phy. 6 (1983) 51-67.
4. NSFWQI, National Sanitation Foundation International. (2007). Accessed on October of 2015, Available from:
5. V.K. Patki, S. Shrihari, B. Manu, P.C. Deka, Fuzzy system modeling for forecasting water quality index in municipal distribution system. Urb.Wat. J. 12 (2015) 89–110.
6. H. Gharibi,A.H. Mahvi, R. Nabizadeh, H. Arabalibeik, M. Yunesian, M.H. Sowlat, A novel approach in water quality assessment based on fuzzy logic. J. Env. Manag. 112 (2012) 87-95.
7. A. Lermontov, L. Yokoyama, M. Lermotov, M.M. Soares, River quality analysis using fuzzy water quality index: Ribeira do Iguape river watershed Brazil. Ecol. Ind. 9(2009) 1188-1197.
8. S.M. Lion, S.L. Lo, C.Y. Hu, Application of two stage Fuzzy set theory to river quality evaluation in Taiwan. Wat. Res. 37 (2003) 1406-1416.
9. I. Yilmaz, Fuzzy evaluation of water quality classification. Ecol. Ind. 7 (2007) 710-718.
10. W. Duque-Ocampo, N. Ferre-Huguet, J.L. Domingo, M. Schuhmacher, Assessing water quality in rivers with fuzzy logic inference systems: A case study. Env. Inter. 32 (2006) 733-742.
11. L.A. Zadeh, Fuzzy sets. Inf. Cont. 8 (1965) 338–353.
12. A. Nema, R. Rai, Fuzzy application to groundwater classification. Thesis (MTech). IIT, Delhi, India (2008).
13. R.V. Bai, R. Bouwmeester, S. Mohan, Fuzzy logic water quality index and importance of water quality parameters. Air, Soil and Wat. Res. 2 (2009) 51–59.
14. S.R.M.M. Roveda, A.P.M. Bondança, J.G.S. Silva, J.A.F. Roveda, A.H. Rosa, Development of a water quality index using a fuzzy logic: A case study for the Sorocaba river. IEEE World Congress on Computational Intelligence, WCCI 2010, Art. No. 5584172.
15. R.E. Carlson,Limnology and Oceanography. 25 (1980) 378-382.
16. P.P. Bonissone, Soft computing: the convergence of emerging reasoning technologies. Soft. Comput. 1 (1997) 6–18.

17. L. Zadeh, Outline of a new approach to the analysis of complex systems and decision processes. IEEE Trans. Syst. Man. Cybern. 3 (1973) 28-44.
18. A.Saffiotti, The uses of fuzzy logic in autonomous robot navigation. Soft. Comput. 1(1997) 180–197.
19. L.L. Di, A. Gisolfi, A. Albunia, G. Galardi, F. Meschi, A fuzzy-based methodology for the analysis of diabetic neuropathy. Fuzzy Sets Syst. 129 (2002) 203–228.
20. H.M. Lee, Applying fuzzy set theory to evaluate the rate of aggregative risk in software development. Fuz. Set. Syst. 79 (1996) 323–336.
21. R. Sadiq, Y. Kleiner, B. Rajani, Aggregative risk analysis for water quality failure in distribution networks. J. Water Supply: Res. Technol. Aqua 53 (2004)241-261.
22. A.K. Lohani, N. Goel, K. Bhatia, Takagi-Sugeno fuzzy inference system for modeling stage–discharge relationship. J. Hydrol. 331 (2006) 146–160.
23. Lohani, A., Kumar, R., Singh, R. Hydrological time series modeling: a comparison between adaptive neuro-fuzzy, neural network and autoregressive techniques. J. Hydrol. 442 (2012) 23–35.
24. A.K. Lohani, N. Goel, K. Bhatia, Improving real time flood forecasting using fuzzy inference system. J. Hydrol. 509 (2014) 25–41.
25. M. Kucukmehmetoglu, Z. Sen, M. Ozger, Coalition possibility of riparian countries via game theory and fuzzy logic models. Wat. Res. Res. 46 (2010) 1-20.
26. S.P. Rai, N. Sharma, A. K. Lohani,Risk assessment for Transboundary Rivers using fuzzy synthetic evaluation technique. J. Hydro. 519 (2014) 1551-1559.
27. K.W. Chau. A review on integration of artificial intelligence into water quality modelling. Mar. Poll. Bull. 52 (2006) 726-733.
28. T.J. Ross, Fuzzy Logic with Engineering Applications. John Wiley & Sons, New York, (2004).
29. R.R. Yager,On a general class of fuzzy connectives. Fuz. Set. Sys. 4 (1980) 235-242.
30. Zadeh, L.A., 1994. Soft.
31. Khan, F.I., Sadiq, R., 2005. Risk-based prioritization of air pollution monitoring using fuzzy synthetic evaluation technique. Environmental monitoring and assessment, 105(1-3): 261-283.