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RESEARCH ARTICLE

Assessment of Seasonal Variation in Water Quality Dynamics in River Varuna- A Major Tributary of River Ganga

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Abstract

Surface water samples from River Varuna flowing along Varanasi one of the oldest and most religious city of India were collected during January 2013 to December 2013. The collected samples were analyzed for various physico-chemical and microbiological parameters, with objective of assessing the changes occurring in various parameters during different seasons. The result obtained revealed that important indicator of pollution such as Biological oxygen demand (BOD) and Chemical oxygen demand (COD) were found to be lowest during monsoon period. Thus bringing out important role of natural flow in maintenance of homeostasis and reducing pollution in aquatic systems.

INTRODUCTION

Rivers as one of the basic resources of surface water and have Ecologic and notable economic value. The hydrochemical composition and the quality of water have always been influenced by natural (Geologic) and unnatural (Pollution) factors (Karbassi and Pazoki, 2015). A river's water quality is the composite of several interrelated compounds, which are subjected to local and temporal variations and also affected by the volume of water flow (Mandal et al. 2010). Surface water resources are more vulnerable to pollution than ground water resources (Ogubanjo and Rolajo, 2004), especially in developing countries where the heavy industrialization, increasing urbanization, and adaptation of modern agricultural practices play an important role in improving the living standard but at the same time cause severe environmental damage (Mulk et al., 2015), and declining quality of life for many people (D. W. Pearce and R. K. Turner, 1990). Therefore, constant monitoring of a river system is required to evaluate the effects of environmental factors on water quality for proper utilization and sustainable development of the resource (Cosmas et al., 2011). In cities where there is not an efficient sewage system, the domestic wastewater discharge is one of the main sources of pollution, stimulating the growth of bacteria and adding other microorganisms to the environment, including those found in fecal matter (Silva et al., 2010.). The main groups of bacteria used to indicate pollution levels in water are total coliform (CT) and Fecal Coliform, and more specifically Escherichia coli, has been indicated to evaluate the anthropogenic contamination of a wellspring (Plummer & Long, 2007; Silva et al., 2010). Pathogenic organisms are normal species of all ecosystems, but microbiological contamination with fecal bacteria is considered to be a crucial issue throughout the rivers (Hamuda & Patko 2012). Human and animal pathogens of enteric origin transmitted through the soil, agriculture, water and sediment, are considered important contaminants of the environment (Bonetta *et al*. 2011).

Analysis of physico-chemical and microbiological parameters of water is essential, to assess the quality of water for the best usage like irrigation, drinking, bathing, fishing, industrial processing and so on. Water quality deals with the physical, chemical and biological characteristics in relation to all other hydrological properties. The present study focuses on the River Varuna which originates at 25°27′N, 82°18′E, at a place called Malahan near Phulpur in Allahabad district and flows east-to-southeast for about 100 km, and joins the Ganga at 25°19′46″N, 83°02′40″E, just downstream of Varanasi city, one of the prominent Agricultural, industrial and oldest town of Uttar Pradesh state in India, catering to the needs of several millions of people. Varuna river has been selected for the study as it has undergone severe pollution and contribute to pollution of the river Ganga also when emphasis is being laid on cleaning the river Ganga it becomes imperative to make its tributaries pollution free to achieve the national objective of ensuring river Ganga free from pollution. The river is currently facing tremendous pressure due to encroachments, discharge of untreated domestic and industrial waste, dumping of solid waste and illegal diversion of water. However, the river remains less examined with regard to important base-line information. This paper focuses on the present pollution status of river Varuna which is determined by analyzing the physicochemical and microbiological parameters and the seasonal variation in pollution level.

1 Material and Method

1.1 Study Area

The study was performed for one year at selected sites along a 32 km long stretch of River Varuna at Varanasi from January 2013 to December 2013. The climate of the region is tropical monsoonal. The year is divisible into a hot and dry summer (Pre-Monsoon), a humid rainy season (Monsoon) and a cold winter season (Post-Monsoon). The ambient mean temperature was lowest in December (9.9 to 26.1 °C) and highest in May-June (27.8 to 40.9 °C). The rainy months remained warm and wet, with humidity reaching close to saturation. The day length is recorded as longest in June (about 14 hours) and shortest in December (about 10 hours). Wind direction shifts predominantly westerly and south - westerly in October through April and easterly and north - westerly in remaining months. Ten sampling stations were selected along the thirty two kilometers long stretch of Varuna River and one sites were selected at each station. These study sites is divided in to three stretches from upstream to downstream. A summary of these stretches is given in Table 1. Locations of these sampling sites are shown in figure 1 and their details are listed in table 2.

1.2 Method

After a vigorous survey of the river Varuna ten sampling sites were selected along the stretch of the river for the assessment of water quality These samples were collected in Summer (pre-monsoon), a humid rainy season (monsoon) and cold winter season (post-monsoon), 2013 to monitor changes caused by Agriculture runoff, urban discharge, laundry, heap of municipal solid waste, Industrial effluent and anthropogenic as well as natural sources. Sampling, preserving, and transportation of the water samples to the laboratory were done as per the standard methods (APHA 2001, Table 3 and 4). Composite Sampling was done at each site. Samples were qualitatively analyzed for different physiochemical and microbiological parameters and were tabulated in Table 5. The pH, temperature, electrical conductivity (EC), total dissolved sold (TDS), salinity and dissolve oxygen (DO) were determined immediately at the collection site by a portable multi parameter (EUTECH PCD650 and PCSTestr 35) , to minimize errors with time due to biological and chemical reactions between the atmosphere and the sample (Hutton 1983).

2 Results and Discussion

Samples collected from River Varuna and tested are clearly indicative of the deteriorating condition of river water quality and impact of untreated effluent recklessly being discharged through drains. These variations were mainly due to degree of discharge of untreated domestic and industrial effluent, agricultural runoff and activities of neighboring population like bathing, washing of clothes, dumping of wastes on the bank of river varuna. The result obtained from the univariate data analysis is shown Table 4 for all the location in terms of mean and standard deviation.

2.1 **Temperature:** Water Temperature is an important water quality parameter, which regulates the biogeochemical activities in the aquatic environment and relatively easy to measure in water bodies which naturally show change in temperature seasonally. The temperature of River Varuna ranges between 37.0 to 15.9 ^{0}C (Figure 2). The maximum temperature 37 ^{0}C was observed at S4 during Pre Monsoon sampling, whereas, minimum 15.9 ^{0}C was recorded at S8 and S9 during Post monsoon period. High quantum discharge of sewage, agricultural runoff and leachate from heap of municipal solid waste along the river bank may be a significant cause of change of river water temperature

2.2 Turbidity: Turbidity of water is the expression of optical property in which the light is scattered by the particles present in the water (Verma et al.,2012). High turbidity shows presence of large amount of suspended solids. Turbidity is the condition resulting from suspended solids in the water, including silts, clays, industrial wastes, sewage and plankton. Turbidity in River Varuna recorded ranges between 99.05 NTU to 17.17 NTU (Figure-3). The maximum turbidity in water was recorded during monsoon season at S10 whereas minimum turbidity was recorded during Pre- monsoon season at S4. Soil erosion, huge agricultural runoff, discharges, and Stirred bottom sediment may be cause of significant changes in river water turbidity.

2.3 pH: p^H of a water body is very important in determination of water quality since it affects other chemical reactions such as solubility and metal toxicity. The fluctuation in optimum pH ranges may lead to an increase or decrease the toxicity of poisons in water bodies (Ali, 1991) The pH value recorded ranges between 8.86 to 7.18 (Figure 4). The maximum pH was recorded during pre-monsoon season at S1 and the minimum pH was recorded during pre-monsoon season at S4. Washing station, discharge of industrial and domestic waste and leachate from heap of municipal solid waste along the river bank may be a significant cause of change in river water pH.,

2.4 Electrical Conductance: EC is a measure of water capability to transmit electric current and also it is a tool to assess the purity of water (Murugesan et al., 2006). Electrical conductivity recorded in River Varuna ranges between 1194 μS/cm to 286 μS/cm (Figure 5). The high value of conductivity was recorded during the pre-monsoon at S4 were as low value was recorded during monsoon season at S2. A number of ions enter in to the river through point and nonpoint sources in the form of dissolved salt and inorganic material such as alkalis, chloride, sulfides and carbonate compound may be a significant cause in changing EC of river water.

2.5 Free CO_2: Carbon Dioxide is present in water in the form of a dissolved and influences the acidity of water and thus can cause corrosion in the distribution system. Carbon Dioxide is present in *water* in the form of a dissolved gas. The concentration of free CO_2 in water increases due to increasing algal blooms which creates a barriers between atmosphere and river water gaseous exchange (Dwivedi and Pandey, 2002). The amount of free CO_2 recorded in the water of River Varuna ranges between 1034 mg/l to 39.6 mg/l (Figure-6). The minimum amount of free CO_2 in the water of river Varuna was recorded during monsoon season at S2, whereas the maximum amount of free CO_2 in water was recorded during monsoon season at S6. Degrading organic waste, agricultural runoff and nutrient richness may a cause in increasing free CO_2 in river water.

2.6 Total Dissolved Solid: Water with a high TDS indicates more ionic concentration, which is of inferior palatability and induce an unfavorable physicochemical reaction in the consumers. Kataria et al., (1996) reported that increase in value of TDS indicate pollution by extraneous Sources. The amount of TDS recorded in the water of River Varuna ranges between 846 mg/l to 203 Mg/l (Figure-7). The minimum amount of TDS in the water of river Varuna was recorded during monsoon season at S2, whereas the maximum amount of TDS in water was recorded during Pre-monsoon season at S4. A number of dissociate electrolyte as well as dissolved organic matter enter into the river water through a number point and non point sources may be a cause to increasing TDS in a river water.

2.7 Total Solid: The amount of TS recorded in the water of River Varuna ranges between 1880 mg/l to 248 Mg/l (Figure-8). The minimum amount of TS in the water of river Varuna was recorded during post monsoon season at S1, whereas the maximum amount of TS in water was recorded during monsoon season at S10. Soil erosion, huge agricultural runoff, discharges, and Stirred bottom sediment may be cause of significant changes in TS of river water.

2.8 Total Suspended Solid: The amount of TSS recorded in the water of River Varuna ranges between 1630 mg/l to 23 Mg/l (Figure-9). The minimum amount of TSS in the water of river Varuna was recorded during post monsoon season at S4, whereas the maximum amount of TSS in water was recorded during monsoon season at S10. Degrading organic waste increase the water temperature and Organic particles from decomposing materials may contribute in changing the TSS in river water.

2.9 Acidity: The amount of acidity recorded in the water of River Varuna ranges between 66 mg/l to 6.4 Mg/l (Figure-10). The minimum amount of acidity in the water of river Varuna was recorded during monsoon season at S1, whereas the maximum amount of Acidity in water was recorded during post monsoon season at S6. human-induced air pollution, *acid* rain and industrial discharge may be a significant cause in fluctuation in acidity of river water.

2.10 Alkalinity: Alkalinity of Water is its capacity to neutralize a strong acid and it is normally due to the presence of bicarbonate, carbonate and hydroxide compound of calcium, sodium, and potassium. (Murhekar Gopalkrushna H., 2011). The amount of Alkalinity recorded in the water of River Varuna ranges between 686 mg/l to 178 Mg/l (Figure-11). The minimum amount of Alkalinity in the water of river Varuna was recorded during post monsoon season at S8, whereas the maximum amount of alkalinity in water was recorded during post monsoon season at S5. Disposal of dead bodies of animals, Clothe washing station and urban discharge through open drains in water bodies may be considered as a significant cause for increasing the value of phenolphthalein Alkalinity.

2.11 Chloride: The chlorides concentration serves as an indicator of pollution by sewage. People accustomed to higher chloride in water are subjected to laxative effects. The amount of chloride recorded in the water of River

Varuna ranges between 142 mg/l to 3.55 mg/l (Figure-12). The minimum amount of chloride in the water of river Varuna was recorded during monsoon season at S2 and s3, whereas the maximum amount of chloride in water was recorded during pre monsoon season at S3. Increasing trend of chloride in river water may be due to increasing loadings from point and nonpoint source of discharges, degrading animal dead bodies and industrial operations. Chloride concentration in water indicates the presence of organic waste in water, primarily of animal origin (Thresh et al., 1949).

2.12 Hardness: Hardness is the parameter of water quality used to describe the effect of dissolved minerals (mostly Ca and Mg), determining suitability of water for domestic, industrial, and drinking purpose attributed to presence of bicarbonates, Sulphate, chlorides and Nitrates of calcium and Magnesium. (Taylor, E.W, 1949). The amount of Hardness recorded in the water of River Varuna ranges between 394 mg/l to 80 mg/l (Figure-13). The minimum amount of Hardness in the water of river Varuna was recorded during monsoon season at S10, whereas the maximum amount of Hardness in water was recorded during pre monsoon season at S5. Agriculture runoff, urban discharge, Industrial effluent and Clothe washing station through open drains in water bodies may be a significant cause for increasing the value of hardness in river water bodies.

2.13 Sulphate: Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals. (Shrinivasa Rao B and Venkateswaralu P, 2000) Discharge of industrial wastes and domestic sewage tends to increase its concentration (Murhekar Gopalkrushna H., 2011). The amount of Sulphate recorded in the water of River Varuna ranges between 78 mg/l to7.9 mg/l (Figure-14). The minimum amount of Sulphate in the water of river Varuna was recorded during Pre monsoon season at S8, whereas the maximum amount of Sulphate in water was recorded during monsoon season at S9. Discharge of industrial effluent and agricultural runoff may be a significant cause in changing the concentration of sulphate in river water.

2.14 Nitrate: Nitrates are contributed to freshwater through discharge of sewage and industrial wastes and run off from agricultural fields (Verma et al., 2012) .The amount of nitrate recorded in the water of River Varuna ranges between 820 mg/l to30 mg/l (Figure-15). The minimum amount of nitrate in the water of river Varuna was recorded during monsoon season at S1, S6 and S9, whereas the maximum amount of nitrate in water was recorded during post monsoon season at S5 and S6. Increasing trend of Nitrate in river water bodies may be due to increasing loadings of organic waste disposal from point and nonpoint sources.

2.15 Phosphate: Phosphate is one of the limiting factors for phytoplankton productivity because of geochemical shortage of phosphate in drainage basin. The amount of nitrate recorded in the water of River Varuna ranges between 157 mg/l to2 mg/l (Figure-16). The minimum amount of phosphate in the water of river Varuna was recorded during post monsoon season at S10, whereas the maximum amount of phosphate in water was recorded during post monsoon season at S5. The washing of large amount of clothes by dhobis and laundry worker, as well as continuous entry of domestic sewage in some area can be held responsible for increase in amount of phosphate.

2.16 Dissolved Oxygen: Dissolve Oxygen is one of the important parameter in water quality assessment. Its presence is essential to maintain variety of forms of life in the water and the effect of waste discharge in a water body are largely determined by the oxygen balance of system. It can be rapidly depleted from waste water by discharge of oxygen demanding waste. Inorganic reducing agent such as H_2S, Ammonia, Nitrite, ferrous iron and certain oxidizable substance also tend to decrease DO in Water (Verma et al., 2010). The amount of dissolve oxygen recorded in the water of River Varuna ranges between 10.9 mg/l to0.8 mg/l (Figure-17). The minimum amount of DO in the water of river Varuna was recorded during post monsoon season at S6, whereas the maximum amount of DO in water was recorded during pre monsoon season at S1. Increasing dissolved solids especially organic material from the sewage effluent and degrading organic matter that increase the water temperature may a significant cause of current trend of depleting unacceptable level of DO in river water bodies. Inorganic reducing agents such as hydrogen sulphide, ammonia, nitrite, ferrous iron and certain oxidizable substances also tend to decrease dissolved oxygen in water (Tarzwell, 1957)

2.17 Biological Oxygen Demand: BOD determination is still the best available single test for assessing organic pollution (Verma et al., 2010). Singh and Rai (1999) observed BOD of water samples value was indication for entry of organic waste in the river Ganga at Varanasi and showed that high value are indication of organic pollution. The amount of BOD recorded in the water of River Varuna ranges between 218 mg/l to 22.4 mg/l (Figure-18). The minimum amount of BOD in the water of river Varuna was recorded during monsoon season at S10, whereas the maximum amount of BOD in water was recorded during pre monsoon season at S5. Depleting DO, increasing the TDS, high quantum discharge and lack of adequate water flow may a significant cause to increasing BOD in river water bodies. Permissible limit of BOD for aquatic system is 6 mg/l.

2.18 Chemical Oxygen Demand: COD test is quite useful in assessment of pollution strength of industrial waste and domestic sewage. COD as is the amount of O_2 required for a sample to oxidize at its organic and inorganic matter. The amount of COD recorded in the water of River Varuna ranges between 536 mg/l to 58 mg/l (Figure-19).

The minimum amount of COD in the water of river Varuna was recorded during post monsoon season at S1, whereas the maximum amount of COD in water was recorded during pre monsoon season at S5. The increase in COD concentration was found in the bottom water where organic matter is more (Prasad & Qayyum, 1976). Discharge of industries located at bank of river Varuna and leachate from the heap of municipal solid waste disposed along the bank can be considered as sizeable contributor to inorganic and organic carbon to raise COD.

2.19 Total Organic Carbon: Anthropogenic activities can have a profound effect on the organic carbon budgets of aquatic systems (Schepers and Francis 1982; France 1995a,b; France and Peters 1995). The amount of TOC recorded in the water of River Varuna ranges between 213 mg/l to 25.4 mg/l (Figure-20). The minimum amount of TOC in the water of river Varuna was recorded during monsoon season at S10, whereas the maximum amount of TOC in water was recorded during pre monsoon season at S5. Runoff from agricultural lands, municipal and industrial wastewater discharges, and degradation of dead animal can lead to substantial increases in the levels of total and dissolved organic carbon in river water bodies. Schepers and Francis (1982), for example, found that grazing livestock increased total organic carbon by 11% in runoff waters as a result of increased soil erosion and production of animal wastes.

2.20 Total Coliform, E. coli, and Fecal Coliform: Total coliform ,E.coli and Faecal coliform were studied as microbiological pollution indicators. Figure 21, 22, 23 shows that Pre monsoon samples analyzed revealed maximum presence of total coliform at S8, whereas S6 recorded maximum. E.Coli and Fecal Coliform. During Monsoon maximum total coliform was recorded atS8. Maximum E.coli and Faecal coliform were recorded at S3. In the post monsoon period S8 recorded maximum total coliform and S6 maximum E. coli and Faecal coliform. Discharge of domestic sewage and municipal waste, decaying of organic material, increasing the river water temperature and depletion of DO may contribute a significant elevation of Total coliform ,E.coli and Faecal coliform contamination in river water bodies.

3 Conclusion: The present study took into account of a seasonal variation throughout the one years so as to make the necessary conclusions. The data for different sampling sites collected across the aforementioned time period successfully and effort to discuss the pollution level of River Varuna. Over the year of time, river has been subjected to human interference regularly and water quality was to be getting deteriorated profoundly. Major Anthropogenic activities practiced in and around the stretch: Agricultural, obstraction of water for irrigation and drinking, washing cloth and utensils, discharging of sewage waste, sand dredging and religious ritual activities along the stretch were generating serious threat to biota by altering the physico-chemical and biological concentration of river system. Moreover, this analysis will help in future water control management program as it has outlined the parameters contributing to pollution for every site (Singh et al., 2015). It is therefore, needful, to develop a comprehensive river water quality monitoring program all over the world (Sharma and Kansal 2011).

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Table - 1: Characteristics of the research sites of Varuna river

Characters	**First Stretch (S1, S2, S3, S4)**	**Second Stretch (S5, S6, S7, S8)**	**Third Stretch (S9, S10)**
Location	Rameshwar - Nadesar bridge	Nadesar bridge- NH29 bridge (Sarnath Rajpath road bridge)	NH29 bridge (Sarnath Rajpath road bridge)-Adi keshav Ghat
Important Source pollution	Agricultural runoff	Small Scale Battery industry Automobile service station Small Scale Saree dyeing industries	Small Scale Saree dyeing industries
Number of marked and allied industrial unit	22	703	164
Nala pouring in the river	Razabajar nala, Nala opposite kashiram Aawas	Baghwa nala, Chaukaghat nala	Narokhar nala, konighat sever line
Amount of effluent pouring in the river	1.3 mld	3.68 mld	5.45 mld

Figure 1: Names and Location of different sampling sites at river Varuna

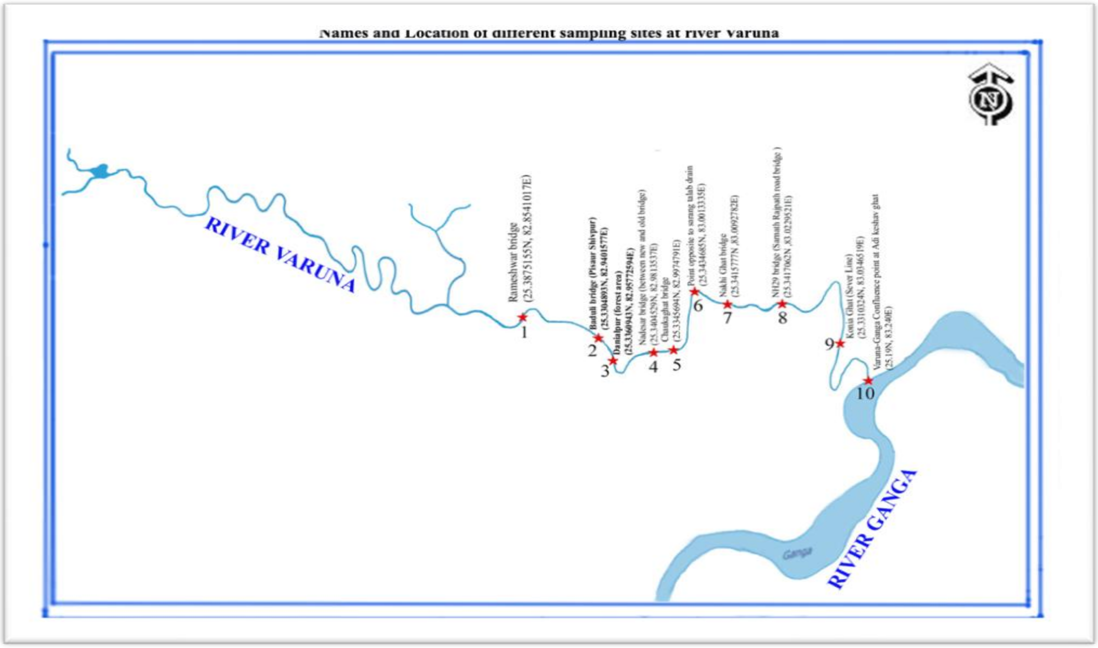

Table 2: Names and Location of different sampling sites at river Varuna

Name	Grid Reference
Rameshwar bridge – S1	25.3875155N, 82.8541017E
Baduli bridge (Pisaur Shivpur) –S2	25.3304893N, 82.9401577E
Danialpur (Forest area) – S3	25.3360943N, 82.95772594E
Nadesar bridge (between new and old bridge)-S4	25.3404529N, 82.9813537E
Chaukaghat bridge –S5	25.3345694N, 82.9974791E
Point opposite to Sarang talab drain –S6	25.3434685N, 83.0013335E
Nakhi Ghat bridge- S7	25.3415777N ,83.0092782E

NH29 bridge (Sarnath Rajpath road bridge) – S8	25.3417062N ,83.0229521E
Konia Ghat (Sever Line) S9	25.3310324N, 83.0346519E
Varuna-Ganga Confluence point at Adi keshav Ghat – S10	25.19N, 83.240E

Table 3: Preservation techniques of the water samples for chemical analysis

Sr. No.	Tests/Properties Measurements'	Recommended sample volume(ml)	Type of container	Preservation	Allowable holding time
1	Temperature	100	P,G	Determined at site	NA
2	p^H Value	100	P,G	Determined at site	NA
3	Turbidity	100	P,G	Determined at site	NA
4	Salinity	100	P.G	Determined at site	NA
5	Conductivity	100	P,G	Determined at site	NA
6	Acidity	100	P,G	Refrigerate -4^{0}C	24hr
7	Alkalinity	100	P,G	Refrigerate -4^{0}C	24hr
8	Hardness	100	P,G	Refrigerate -4^{0}C	7days
9	Total Solids	100	P,G	Refrigerate -4^{0}C	7days
10	TDS	100	P,G	Determined at site	NA
11	TSS	100	P,G	Refrigerate -4^{0}C	7days
12	Elemental Analysis	200	P,G	Refrigerate -4^{0}C, HNO3 to pH<2	6 months
13	CO2 (Free)	100	P,G	Refrigerate -4^{0}C	No holding
14	Chloride	50	P,G	Not required	7days
15	BOD	1000	P,G	Refrigerate -4^{0}C	24hr
16	DO	100	P,G	Determined at site	NA
17	COD	50	P,G	H_2SO_4 to pH >2	7days
18	TOC	50	P,G	Refrigerate -4^{0}C	24hr
19	Sulphate	50	P,G	Refrigerate -4^{0}C	7 days
20	Nitrate	100	P,G	Refrigerate -4^{0}C, H_2SO_4 to pH<2	24 hr
21	Phosphate	50	P,G	Refrigerate -4^{0}C	24 hr
22	Faecal Coliform	100	P,G	Refrigerate -4^{0}C	6hr
	E Coli	100	P,G	Refrigerate -4^{0}C	6hr

Table 4: Water and Waste water Test (APHA Methods are based On 20th Edition: 2001)

Sr. No.	Tests/Properties Measurements'	Std. Method/Techniques	Reference
1.	P^H Value	Electrometric Method	APHA 4500 B
2.	Turbidity	Nephelometric Method	APHA 2130B
3.	Color	Spectrophotometric Method	APHA 2120C
4.	Taste	Flavor Threshold Test	APHA 2160B
5.	Acidity	Titration Method	APHA 2310B
6.	Alkalinity	Titration Method	APHA 2320B
7.	Hardness	EDTA Titrimetric Method	APHA 2340C
8.	Conductivity	Laboratory Method	APHA 2510B
9.	Total Solids	Total solids Dried at 103-105^0 C Method	APHA 2540B

10.	TDS	Total Dissolved solids Dried at 180^0C Method	APHA 2540C
11.	TSS	TSS Dried at 103-105^0 C Method	APHA 2540D
12.	Elemental Analysis	Flame Atomic Absorption Spectrometry	APHA 3120B
13.	CO2 (Free)	Titrimetric Method	APHA 4500 CO2C
14.	Chloride	Amperometric Titration Method	APHA 4500 Cl B
15.	DO	Winkler's Iodometric method	4500-O B
16.	BOD	5-Day BOD Test Method	APHA 5210B
17.	COD	Open Reflux Method	APHA 5220B
18.	TOC	Wet-Oxidation Method	5310 D
19.	Sulphate	Turbidimetric Method	4500 SO_4^{2-}E
20	Nitrate	Ultraviolet Spectrophotometric Screening Method	4500-NO_3^- B
21	Phosphate	Stannous Chloride Method	4500-PD
22	Faecal Coliform	Fecal Coliform Filter Procedure	APHA 9211D
23	E Coli	Methyl Red test Method	APHA9225

Table 5: Statistical summary of Physico-Chemical and Microbiological characteristics of River Varuna Recorded during the year 2013

Sr. No.	Parameters	Pre-monsoon ± S.D.	Monsoon± S.D.	Post-Monsoon± S.D.	Standard	
					BIS (**IS:10500-91, 2004)**	ICMR
1	Temperature, ^{0}C	33.51±2.306	30.63±1.661	16.98±1.090	_	_
2	Turbidity, NTU	42.780±45.304	43.178±22.746	47.507±31.790	5	5
3	P^H Value	8.243±0.450	8.016±0.240	8.68±0.373	6.5 to 8.5	7.0 - 8.5
4	Electrical Conductance , µS/cm	977.6±179.676	337.9±47.301	543.1±211.145	-	-
5	CO2 (Free), mg/L	114.88±60.240	159.28±307.629	96.36±49.842	-	-
6	TDS, mg/L	689.9±126.762	238.8±33.809	378.7±145.712	500	500
7	Total Solids, mg/L	1204.6±243.096	709.036±427.807	476.4±225.159	-	-
8	TSS, mg/L	515.9±167.801	470.2±422.042	97.7±86.607	-	-
9	Acidity, mg/L	40.3±10.944	11±3.508	31.8±17.974	100	
10	Alkalinity, mg/L	431.5±87.751	209.4±25.648	335.8±189.512	200	-
11	Chloride, mg/L	74.55±35.302	8.52±3.816	9.282±0.7959	250	200
12	Hardness, mg/L	240.8±83.741	92.2±7.208	212.2±84.823	300	300
13	Sulphate, mg/L	20.59±14.623	62.38±14.711	50.37±13.438	200	200
14	Nitrate, mg/L	515.3±37.768	135.9±91.635	320.9±300.243	45	20
15	Phosphate, mg/L	47.7±21.57	14.1±15.14	53.8±55.028		-
16	DO, mg/L	7.27±1.522	8.02±1.020	3.856±3.340	6	-
17	BOD, mg/L	153.4±29.62	59.012±26.103	60.9± 37.005	6	-
18	COD, mg/L	295.4±92.222	150.6±60.251	112±148.174	_	-
19	TOC, mg/L	117.854±36.636	59.444±23.378	44.5±58.808	-	-
20	Total Bacteria, cell/ml	4428±2410.570	2175.9±1402.794	3746.5±2112.274	0	-
21	E.coli, cell/ml	409±230.880	120±63.81	290.8±185.720	0	-
22	Fecal Coliform, cell/ml	236±160.759	48.9±30.956	180.3±148.546	0	-

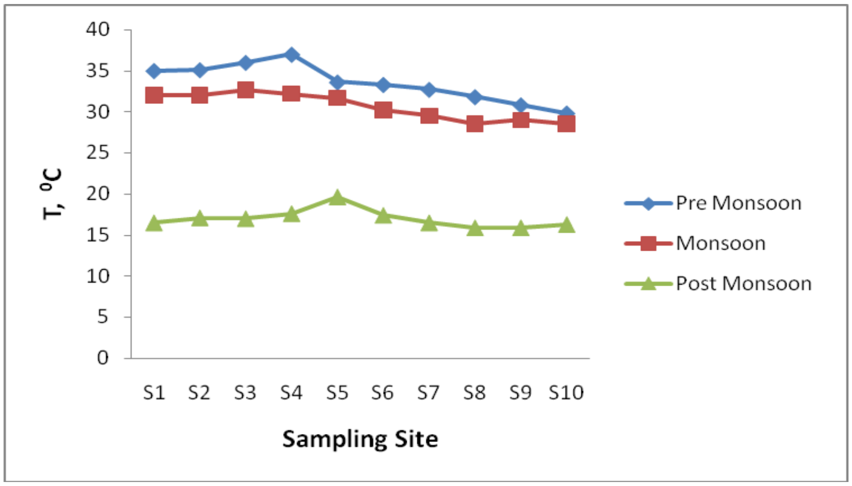

Figure 2: Variation of Temperature during Pre-monsoon, Monsoon and Post Monsoon period

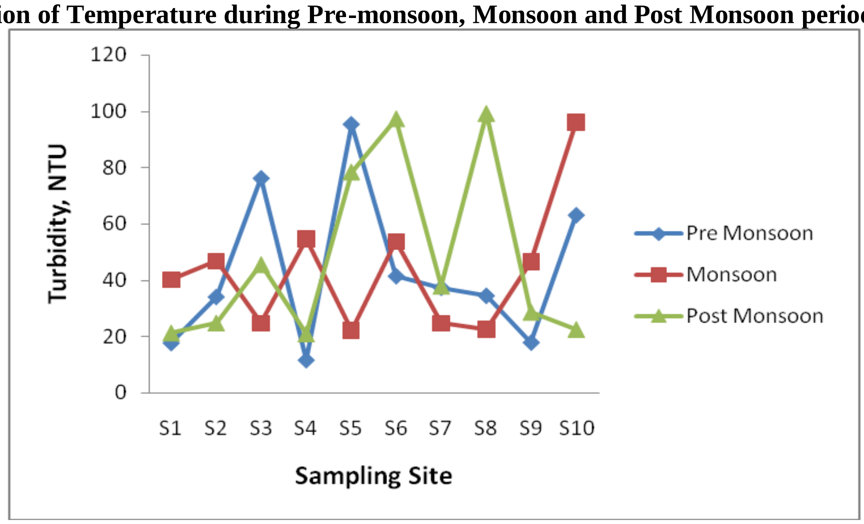

Figure 3: Variation in Turbidity during Pre-monsoon, Monsoon and Post Monsoon

.

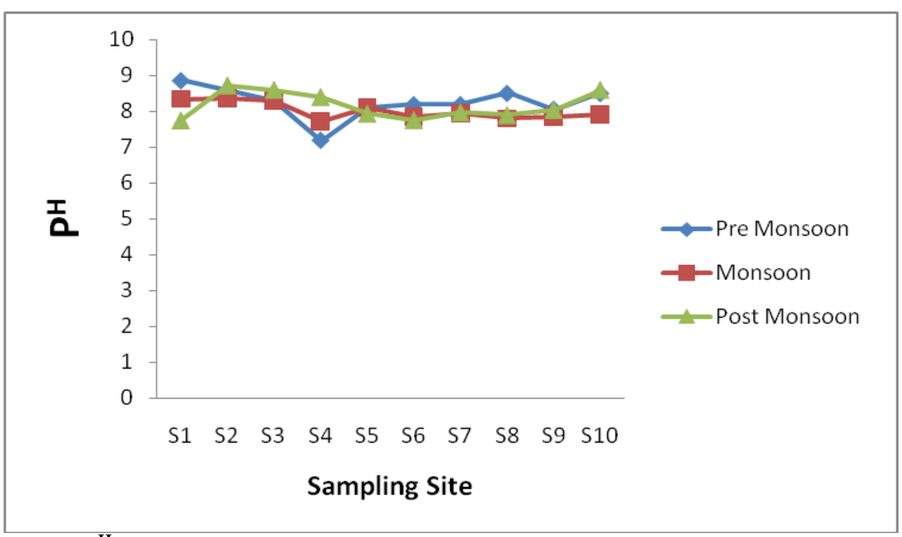

Figure 4: Variation of p^H during Pre-monsoon, Monsoon and Post Monsoon

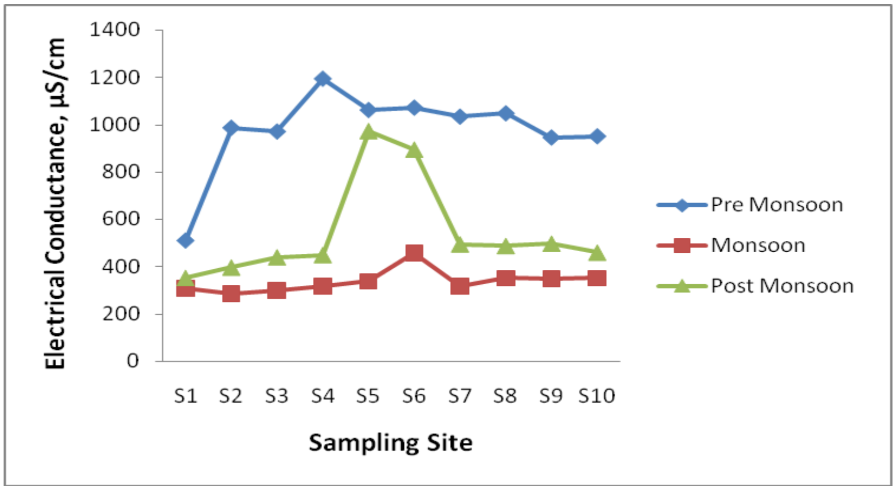

Figure 5: Variation of EC during Pre-monsoon, Monsoon and Post Monsoon

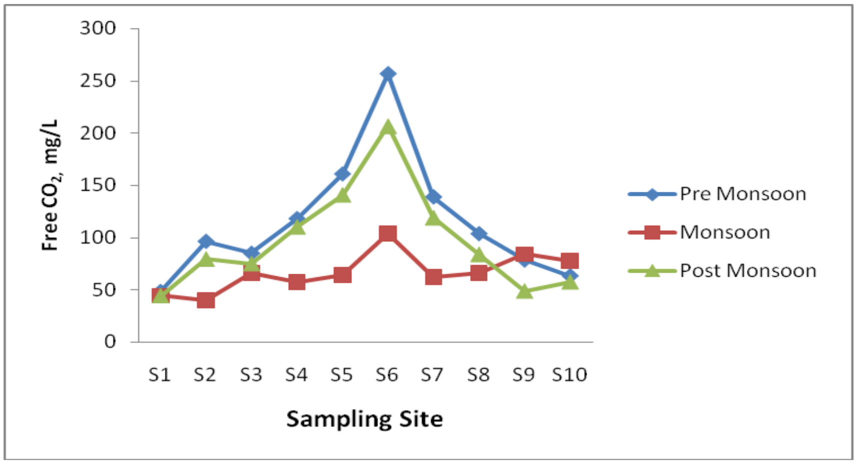

Figure 6: Variation of free CO_2 during Pre-monsoon, Monsoon and Post Monsoon

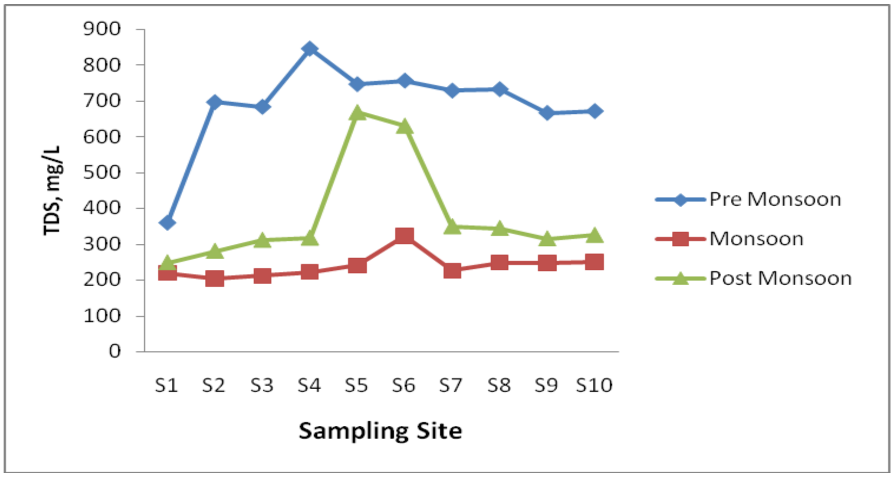

Figure 7: Variation of TDS during Pre-monsoon, Monsoon and Post Monsoon

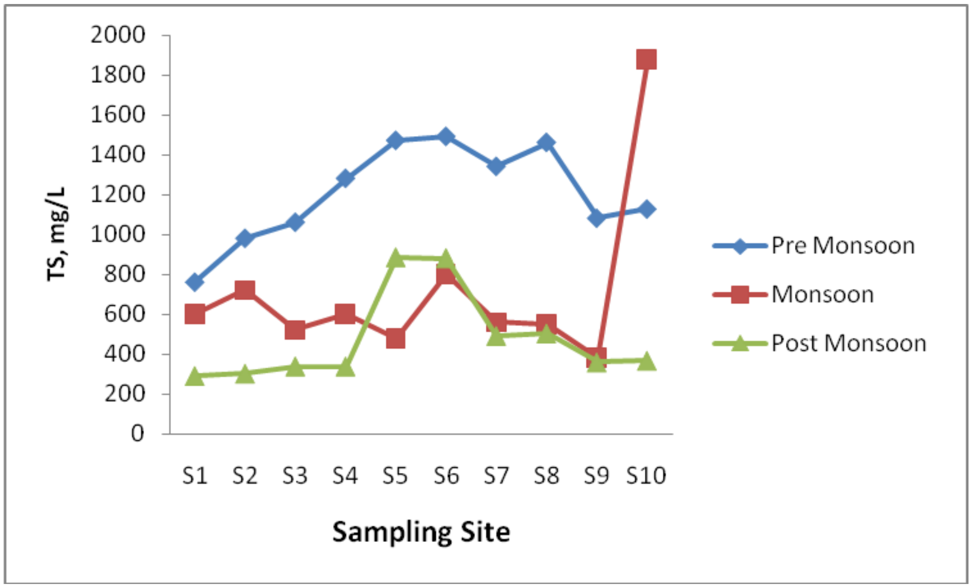

Figure 8: Variation of TS during Pre-monsoon, Monsoon and Post Monsoon

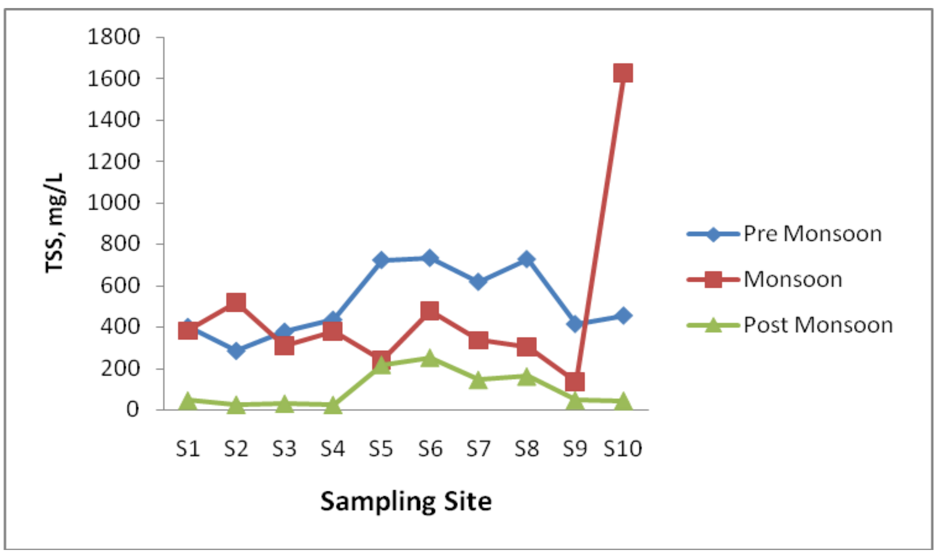

Figure 9: Variation of TSS during Pre-monsoon, Monsoon and Post Monsoon

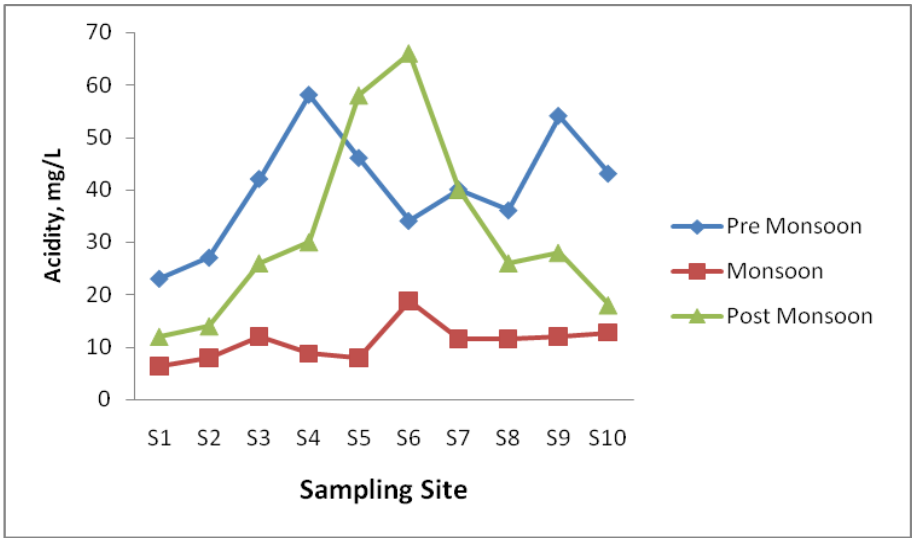

Figure 10: Variation of Acidity during Pre-monsoon, Monsoon and Post Monsoon

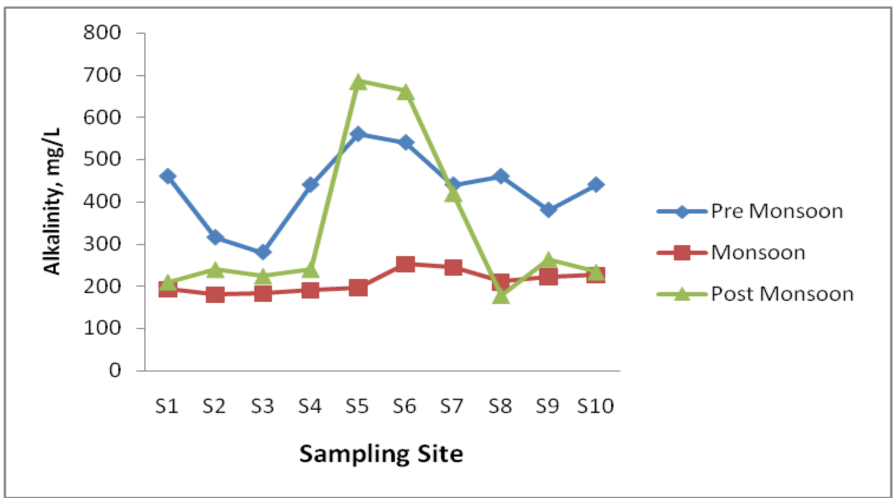

Figure 11: Variation of Alkalinity during Pre-monsoon, Monsoon and Post Monsoon

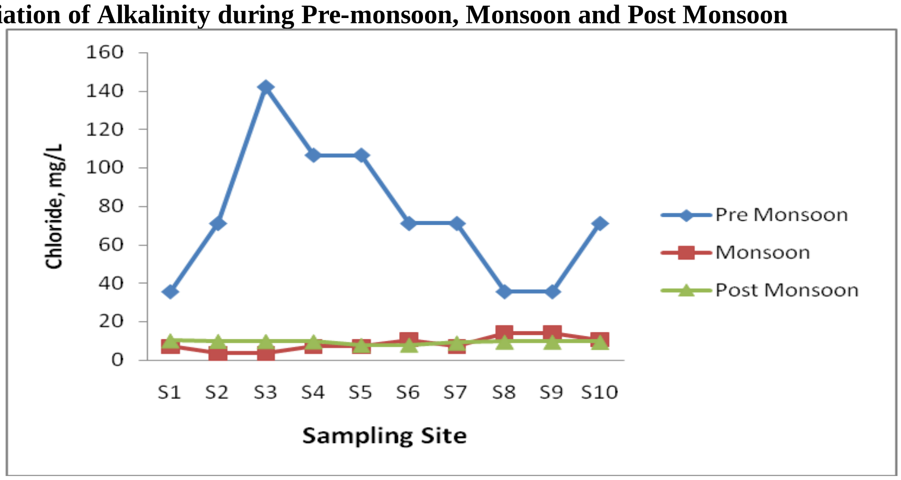

Figure 12: Variation of Chloride during Pre-monsoon, Monsoon and Post Monsoon

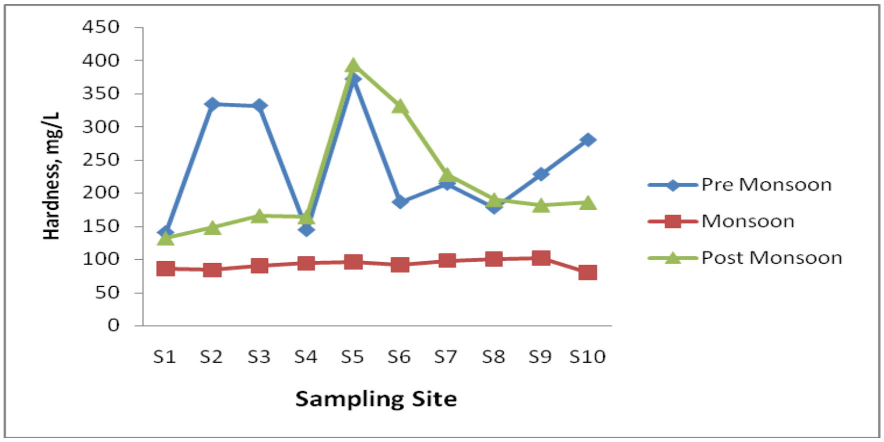

Figure 13: Variation of Hardness during Pre-monsoon, Monsoon and Post Monsoon

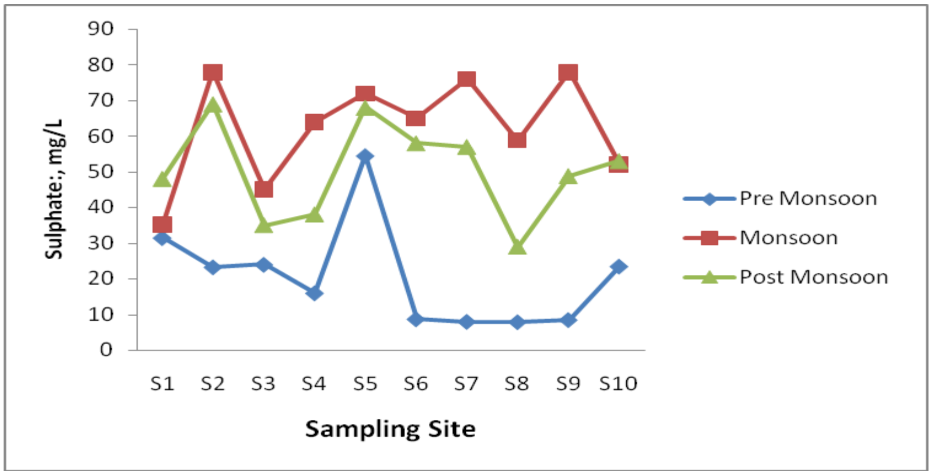

Figure 14: Variation of Sulphate during Pre-monsoon, Monsoon and Post Monsoon

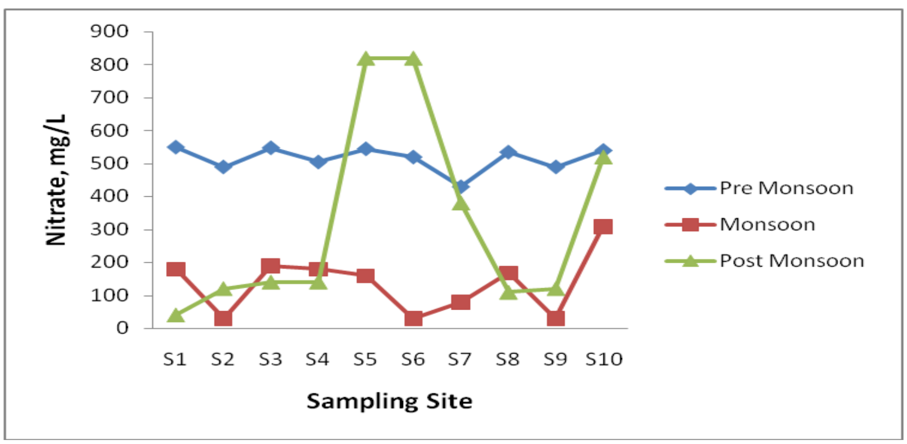

Figure 15: Variation of Nitrate during Pre-monsoon, Monsoon and Post Monsoon

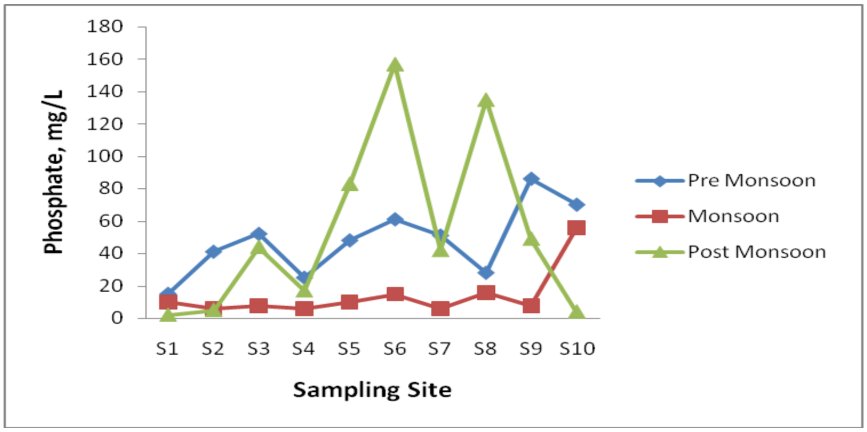

Figure 16: Variation of Phosphate during Pre-monsoon, Monsoon and Post Monsoon

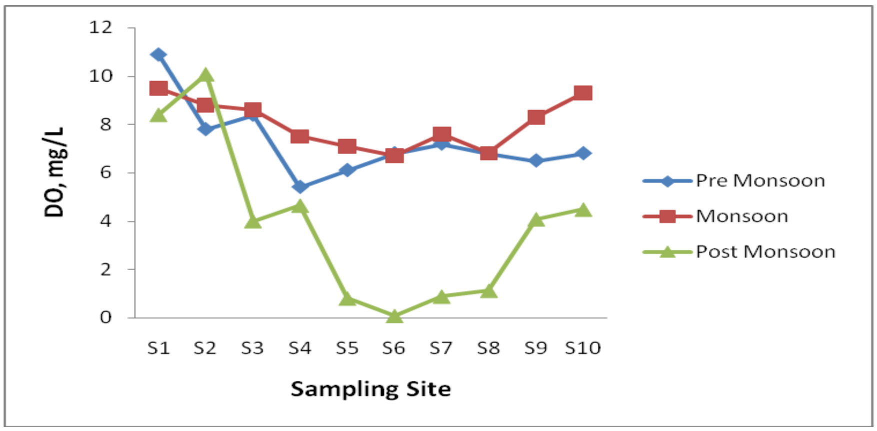

Figure 17: Variation of DO during Pre-monsoon, Monsoon and Post Monsoon

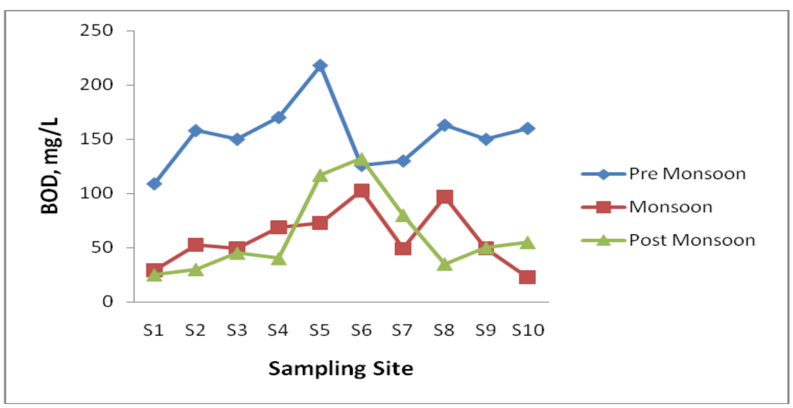

Figure 18: Variation of BOD during Pre-monsoon, Monsoon and Post Monsoon

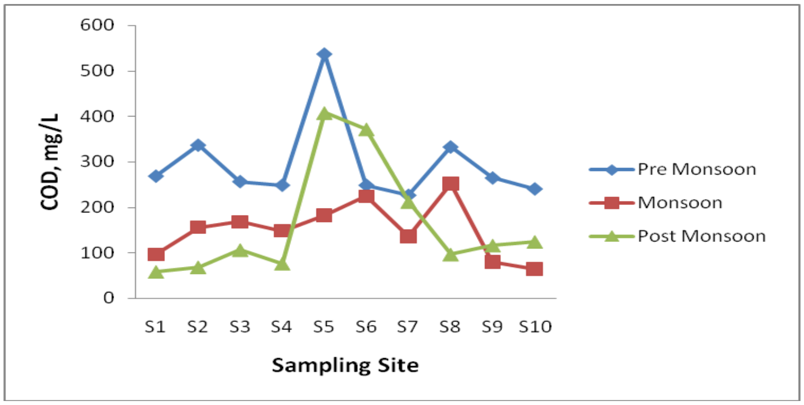

Figure 19: Variation of COD during Pre-monsoon, Monsoon and Post Monsoon

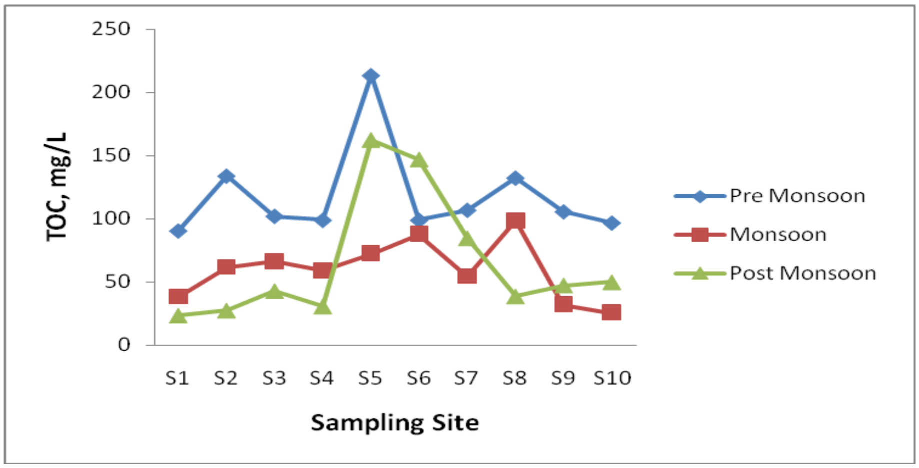

Figure 20: Variation of TOC during Pre-monsoon, Monsoon and Post Monsoon

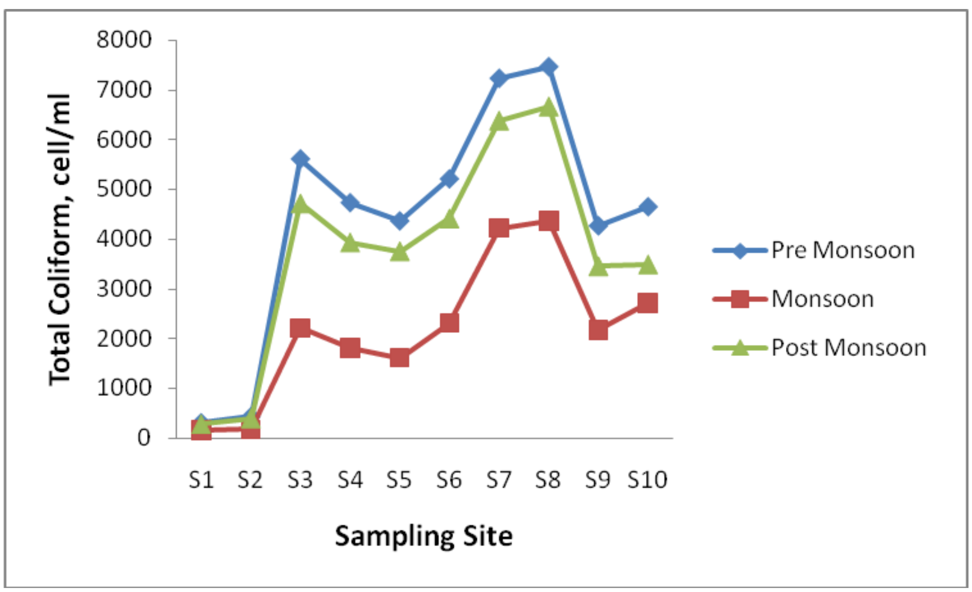

Figure 21: Variation of Total Coliform during Pre-monsoon, Monsoon and Post Monsoon

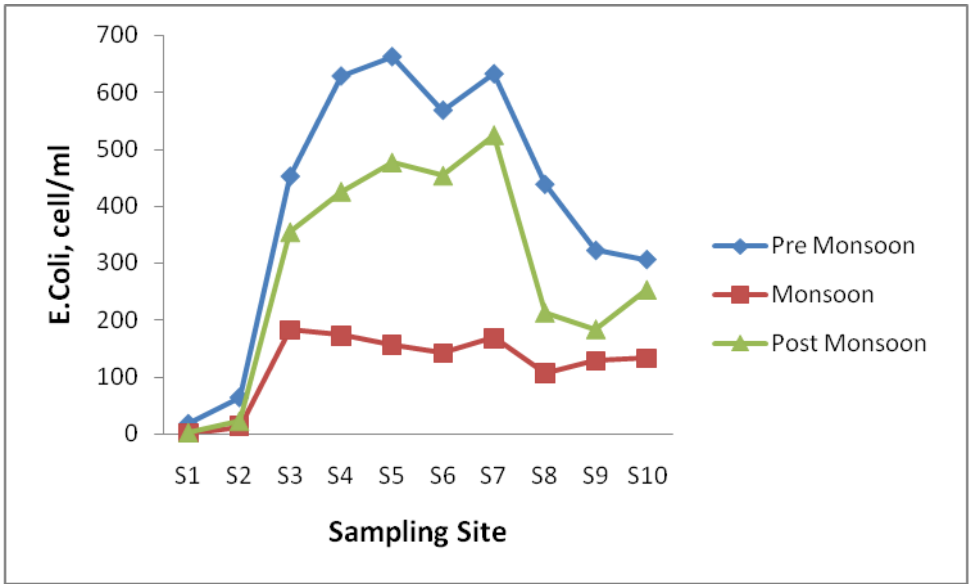

Figure 22: Variation of E. Coli during Pre-monsoon, Monsoon and Post Monsoon

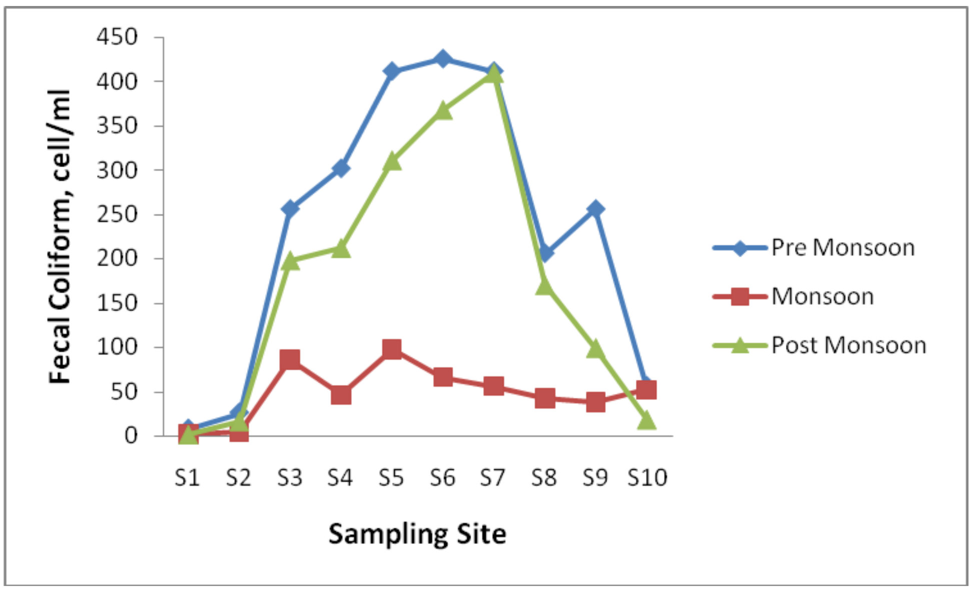

Figure 23: Variation of E. Coli during Pre-monsoon, Monsoon and Post Monsoon

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