Chapter – 2

Spatial and Seasonal Pattern of Geochemical Properties of Water

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2.1 INTRODUCTION

Water is a vital resource which is essential for activities like agriculture, industries and domestic purposes. Looking to its importance, its proper utilisation and conservation is essential. The assessment of water quality can be done through the determination of various water parameters. Their presence is essential but the deviation from the permissible as well as desirable limit affects human health (Kanchan and Roy, 2009). In the present study, *total dissolved solids* (*TDS), pH, electrical conductivity (EC), iron* and *nitrite* were analysed for both the pre and post-monsoon season of surface and sub-surface water for the three years (2011-2013). *TDS, pH, EC, iron, magnesium, calcium, sodium, potassium* and *nitrite* were analysed for pre-monsoon, monsoon and post-monsoon only for surface water (2013-2014). *TDS* indicates the combined content of all inorganic and organic substances contained in a solution (Upadhyay et al., 2013). Carbonates, bicarbonates, *chlorides, phosphates, nitrates, calcium, magnesium, sodium, potassium, manganese,* organic matter, salt and other particles are the different elements which form *TDS* (Mahananda et al., 2010). The high concentration of this component (*TDS*) causes undesirable taste and gastro-intestinal problems (Upadhyay et al., 2013). *pH* determines the level of acidity or

alkalinity of an aqueous solution. The *pH* <7 is said to be acidic and alkaline when >7. The *pH* level affects many of the chemical and bio-chemical reactions (Manjare et al., 2010). The *pH* of water affects solubility of many toxic chemicals and when acidity increases most of the metals become more soluble and toxic (Vaishali and Punita, 2013). Nausea, skin infection, headache, fever, osteoporosis are the some of the problems which are caused due to the drinking of water with lower level of *pH* (Kanchan et al., 2012). *Iron* commonly exists in both surface and sub-surface waters (Casey, 2009). Individually, *iron (Fe),* does not create any issue regarding the quality of water but excess amount can change its colour and taste (Haman and Bottcher, 1986). It is an essential element in human nutrition, but presence of excess of *iron* may lead to tissue damage (Lieu et al., 2011). *Nitrate* and *nitrite* are the naturally occurring ions and the toxicity of *nitrate* in humans is mainly attributed to its reduction of *nitrite* (WHO, 2011).When nitrate is converted into *nitrite*, toxic effects are encountered (Thomas et al., 2011). *Nitrite* (NO_2) disturbs the water quality even if they are present in a trace amount (Ghosh and Kanchan, 2014). High *nitrite* level causes methaemoglobinaemia and gastrointestinal infections (WHO, 2011). The presence of *nitrite* on the surface of the tongue is a major cause of dental caries (Addisscott, 2004). *Magnesium* plays a significant role in prevention of cardiovascular diseases (Gobbo et al., 2013). However, excessive amount of magnesium in the blood causes hypermagnesinia. Other health problems related to high intake of *magnesium* are nausea, vomiting, muscle weakness, respiratory distress and low blood pressure (Schaefer, 2015). *Calcium* perform an important function of keeping the bone healthy. But high level of *calcium* in the human body causes hypercalcemia, decreased appetite, nausea, constipation, depression and vomiting (Delgado, 2016). Excessive intake of *sodium* results in muscular twitching, nausea, pulmonary oedema and vomiting **(**Elton, 1963; Department of National Health Welfare, Canada, 1992). It also aggravates chronic congestive heart failure (He,et al 2002). The *potassium* toxicity has been studied in relation to the use of high doses of salt substitutes. The health problems resulting from high doses of potassium are chest tightness, nausea and

vomiting, diarrhoea, hyperkalaemia, shortness of breath and heart failure (WHO, 2009).

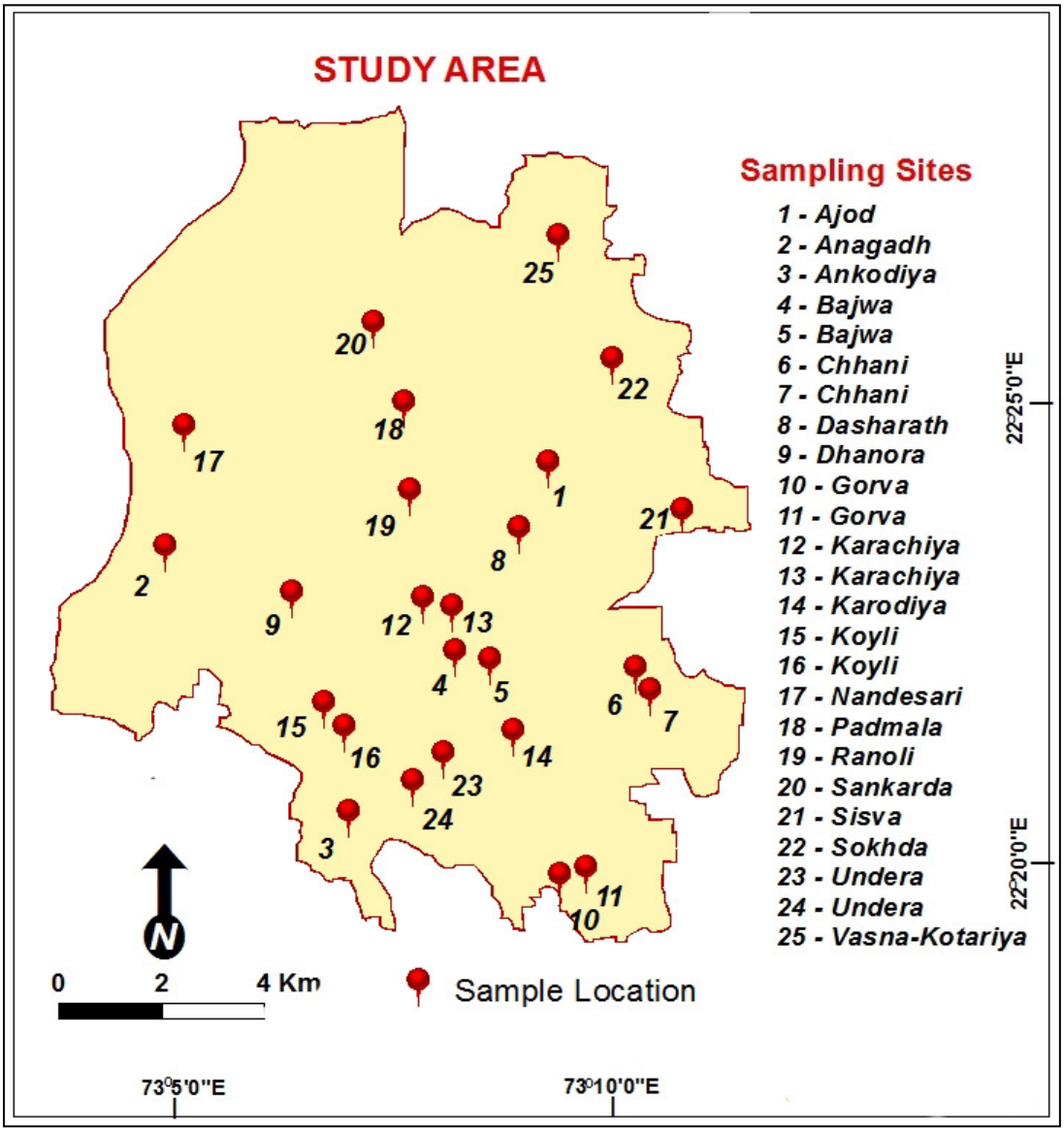

Fig.2.1: Surface Water Sampling Location

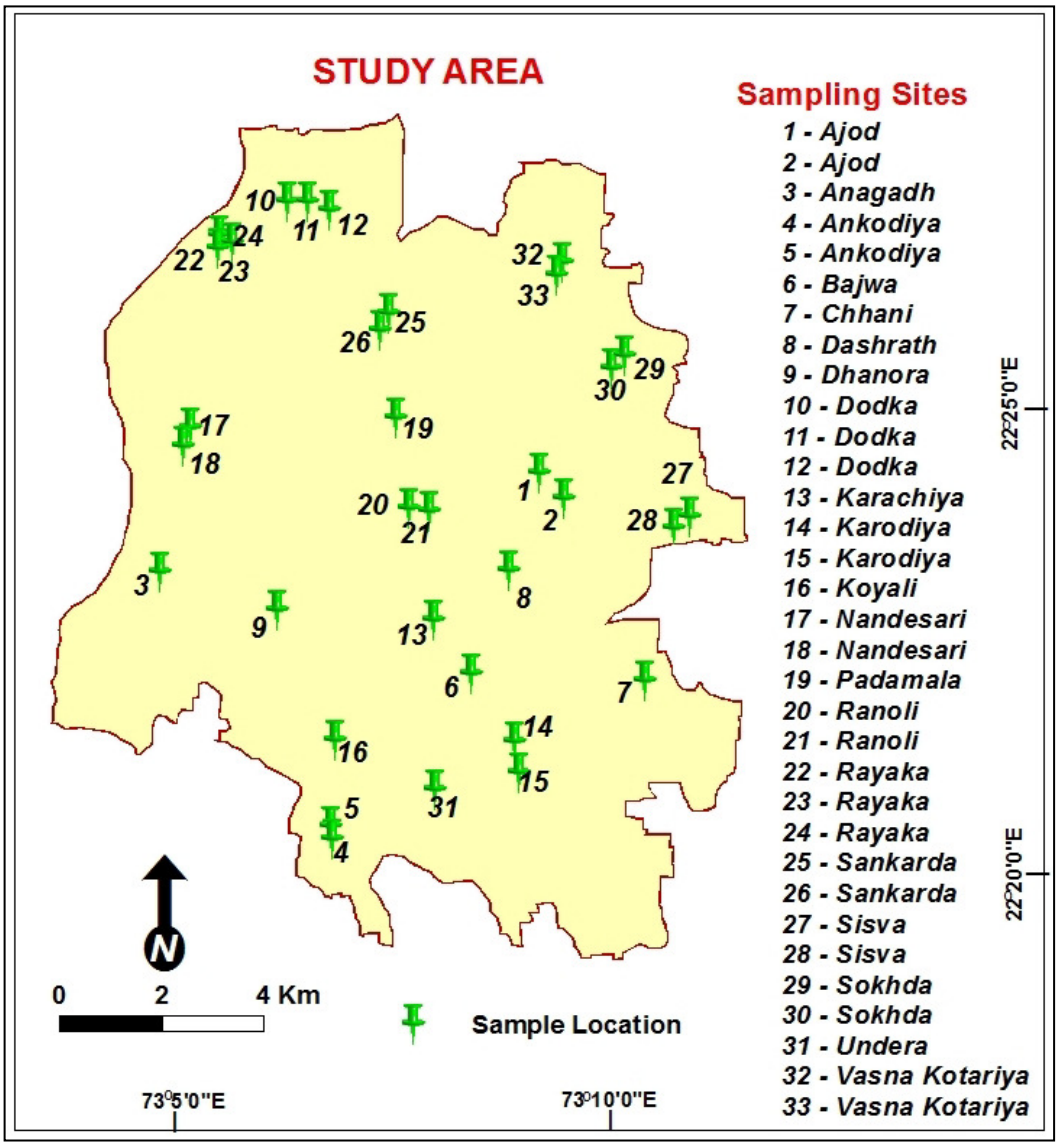

Fig.2.2: Sub-surface Water Sampling Location

2.2 CHARACTERISTICS OF SURFACE AND SUB-SURFACE WATER

2.2.1 Concentration of *TDS* in Surface Water

During pre-monsoon, the concentration of *TDS* in surface water gradually increased from 2011 to 2013 (Table 2.1). The maximum concentration (2910.00 mg/l) was noted in 2011 at *Undera*. While the minimum (357.00 mg/l) was noted at *Ankodiya* in the same year. *Dashrath* (2688.00 mg/l and 2760.00 mg/l) and *Gorwa* (294.40 mg/l and 422.40 mg/l) had the highest and lowest concentration during 2012 to 2013 respectively. The mean in the consecutive three years that is 2011, 2012 and 2013 was 1388.44 mg/l, 15529.53 mg/l and 1538.86 mg/l respectively. The deviation from the mean was high in all the three years indicating the spatial variation of

concentration in the surface water. The value was highest in 2012 (642.08) and comparatively lower in 2013.

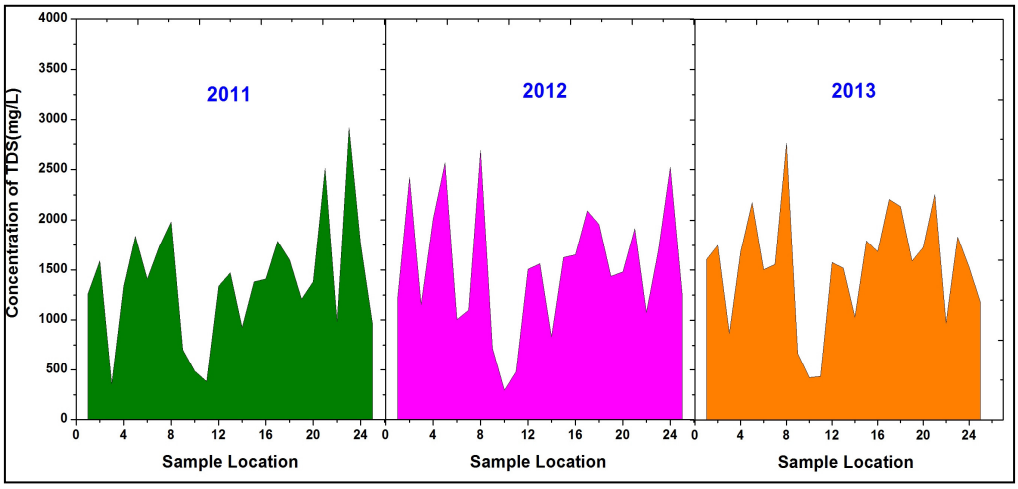

Fig. 2.3: Concentration of *TDS* in Surface Water during Pre-Monsoon

The overall concentration of *total dissolved solids* decreased during post-monsoon season, except for 2013 when relatively higher concentration was observed. The maximum concentration of *TDS* in 2011 was noted at *Bajwa* which is adjacent to the *GSFC*. In 2012 and 2013 the highest concentration was observed in *Nandesari*. *Gorva* village had the lowest concentration throughout the time period (Fig.2.4). The mean was almost same in 2011 (1031.25 mg/l) and 2012 (1030.43 mg/l) and it increased in 2013 (1078.72 mg/l). The standard deviation was lowest in post-monsoon 2011 and highest in 2013 (Table 2.1).

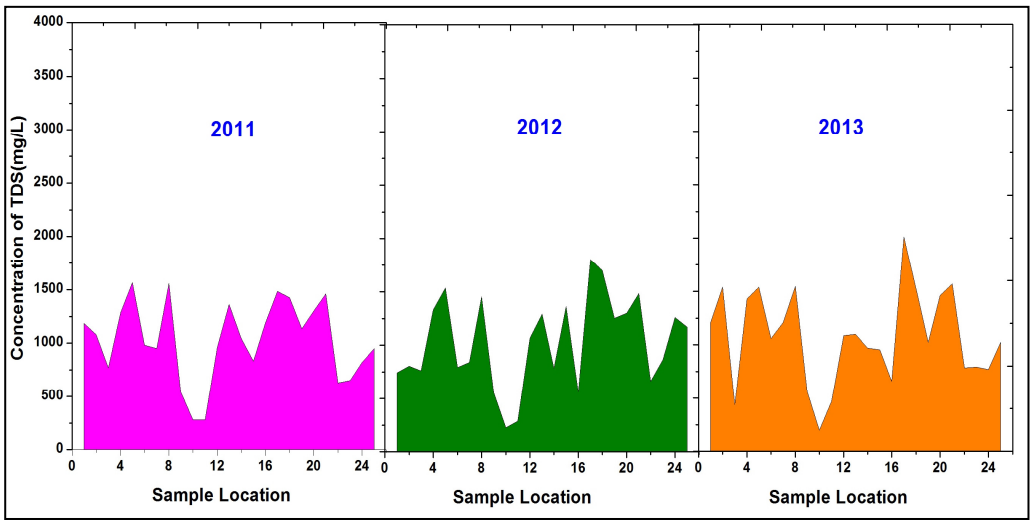

Fig.2.4: Concentration of *TDS* in Surface Water during Post-Monsoon

Table 2.1: *TDS*: Surface Water (2011-13)					
Season	**N**	**Average**	**Minimum**	**Maximum**	**Std. Deviation**
Pre-Monsoon (2011)	25	1388.44	357	2910	598.89
Pre-Monsoon (2012)	25	1529.53	294.4	2688	642.08
Pre-Monsoon (2013)	25	1538.86	422.4	2760	572.82
Post-monsoon (2011)	25	1031.25	279.15	1567.57	368.58
Post-monsoon (2012)	25	1030.43	224	1804	424.17
Post-monsoon (2013)	25	1078.72	198.4	2013	435.72
The unit of total dissolved solids is in mg/l					
Source: Computed					

2.2.2 Concentration of *TDS* in Sub-Surface Water

In sub-surface water, the highest concentration of *TDS* in pre-monsoon 2011 (3540.00 mg/l) and 2013 (2571.20 mg/l) was observed at *Nandesari*. While in 2012, it was noted in *Sisva* village. The lowest level was at *Dodka* in 2011 (384.00 mg/l), *Rayaka* in 2012 (460.80 mg/l) and 2013 (780.80 mg/l). The average level of concentration steadily increased (Table 2.2) while the standard deviation reduced from 693.18 to 508.41 in the three years.

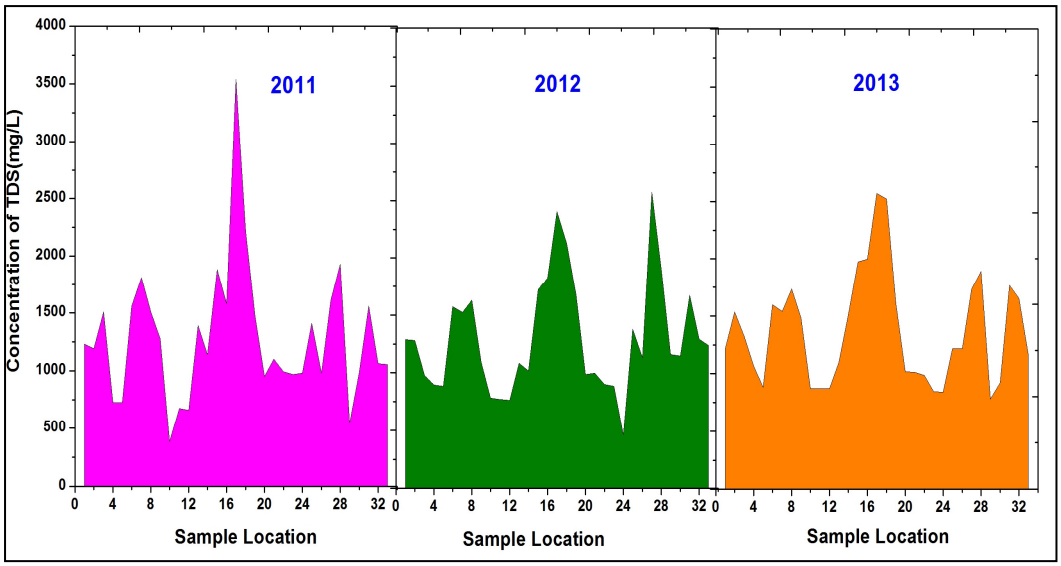

Fig.2.5: Concentration of *TDS* in Sub-Surface Water during Pre-Monsoon

In the post-monsoon season, the maximum concentration of in sub-surface water was noted at *Nandesari* consecutively for three years. The concentration was highest in 2011(2051.46 mg/l). Lowest dilution of *TDS* was in *Rayaka* (339.00 mg/l in

2012 and 532.00 mg/l in 2013) and *Dhanora* (384.00 mg/l in 2012). For the mean and standard deviation, the pattern was identical in pre-monsoon season (Table 2.6).

Table 2.2: *TDS*: Sub-surface Water (2011-13)

Season	N	Average	Minimum	Maximum	Std. Deviation
Pre-Monsoon (2011)	33	1290.33	384	3540	693.18
Pre-Monsoon (2012)	33	1303.73	460.8	2572.8	532.94
Pre-Monsoon (2013)	33	1372.7	780.8	2571.2	508.41
Post-monsoon (2011)	33	999.33	339.11	2051.46	416.17
Post-monsoon (2012)	33	1070.78	384	1951.2	401.89
Post-monsoon (2013)	33	1091.89	532	1982	396.37

The unit of the parameters is in mg/l

Source: Computed

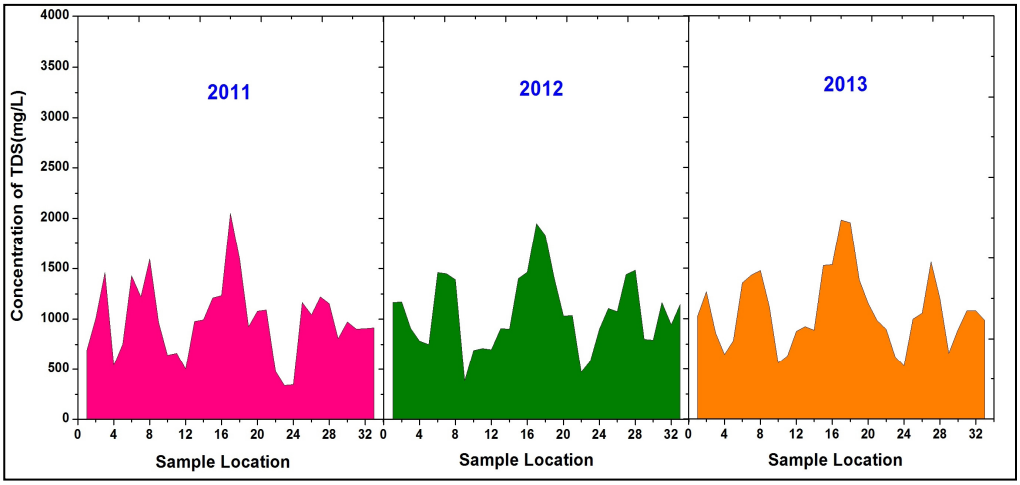

Fig.2.6: Concentration of *TDS* in Sub-Surface Water during Post-Monsoon

2.2.3 *pH* Level in Surface Water

During pre-monsoon, the *pH* in surface water ranged between normal to alkaline condition. The maximum *pH* value in the first two years was noted at *Undera* (9.45 and 5.50) depicting the alkaline condition of water. In 2013, the maximum *pH* level (8.00) was observed in many parts of the study area (*Anagadh, Gorwa, Koyli, Padmala, Ranoli* and *Undera*). *Bajwa* had the lowest *pH* level 7.38 in 2011. In 2012 and 2013, the minimum value was observed at *Dasharath* (7.00). Both the mean and standard deviation reduced in 2013 (Table 2.1). The low deviation indicated less variation of *pH*.

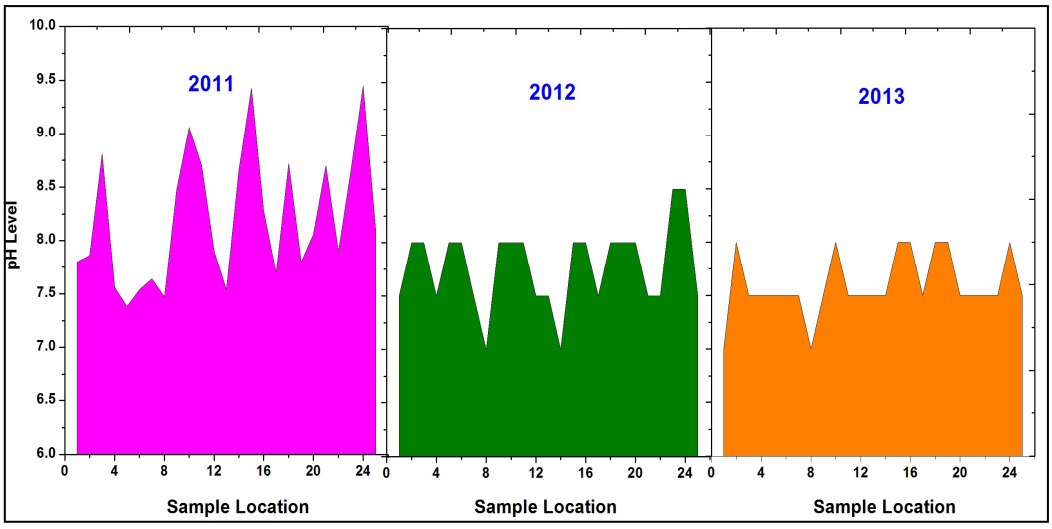

Fig.2.7: Level of *pH* in Surface Water during Pre-Monsoon

After the monsoon the *pH* level decreased throughout the space. *Undera* had the highest level (8.00) in 2011 while in 2012 the maximum value (7.50) was noted at *Undera* and *Sisva*. In 2013, high level of *pH* was observed at *Koyli*, *Padmala, Ranoli, Gorva* and *Ajod*. The lowest *pH* level (6.50) was same in all the years although observed at different sites of the study area. But *Dasharath* had this minimum level all

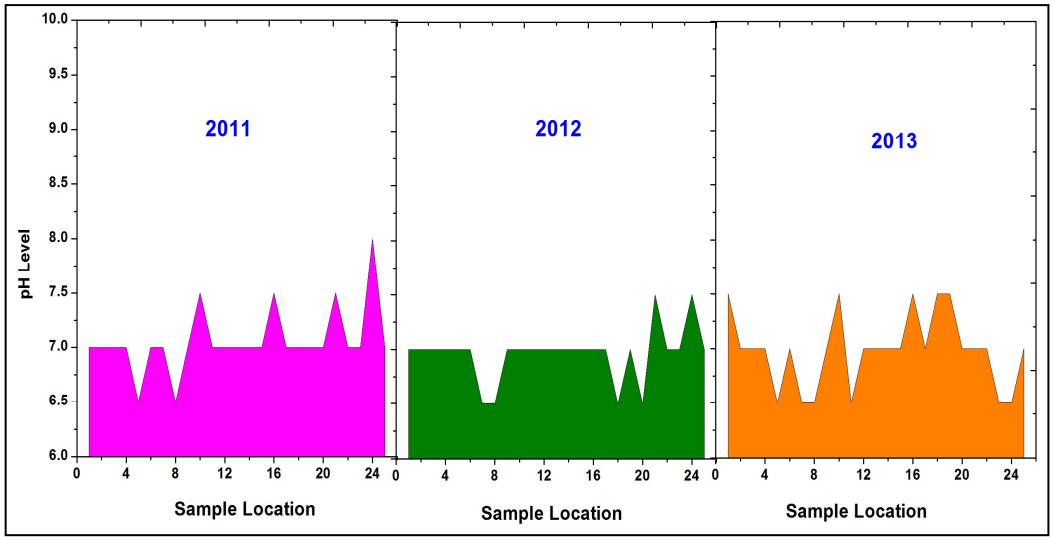

Fig.2.8: Level of *pH* in Surface Water during Post-Monsoon

the time. 7.06 was the mean in 2011, which reduced in 2012 and 2013 (Table 2.3). 0.30, 0.25 and 0.34 were the standard deviation in 2011, 2012 and 2013 respectively.

Table 2.3: *pH*: Surface Water (2011-13)

Season	N	Average	Minimum	Maximum	Std. Deviation
Pre-Monsoon (2011)	25	8.21	7.38	9.45	0.62
Pre-Monsoon (2012)	25	7.78	7	8.5	0.38
Pre-Monsoon (2013)	25	7.6	7	8	0.29
Post-monsoon (2011)	25	7.06	6.5	8	0.3
Post-monsoon (2012)	25	6.96	6.5	7.5	0.25
Post-monsoon (2013)	25	6.98	6.5	7.5	0.34

The unit of the parameters is in mg/l

Source: Computed

2.2.4 *pH* Level in Sub-Surface Water

During the pre-monsoon, the highest *pH* value in sub-surface water was observed at *Sisva* (8.13) while the lowest was noted in *Nandesari* (6.79) in the year

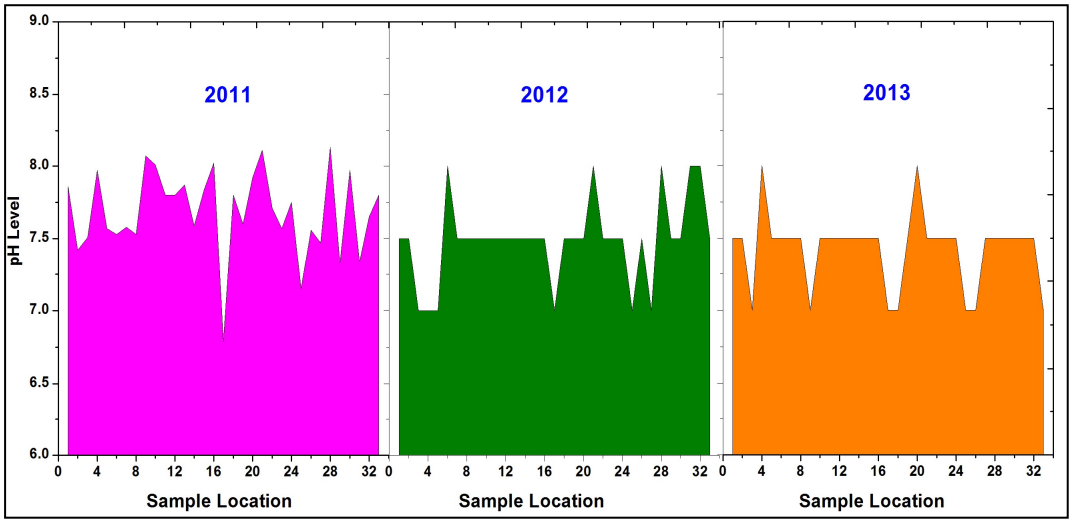

Fig. 2.9: Level of *pH* in Sub-surface Water during Pre-monsoon

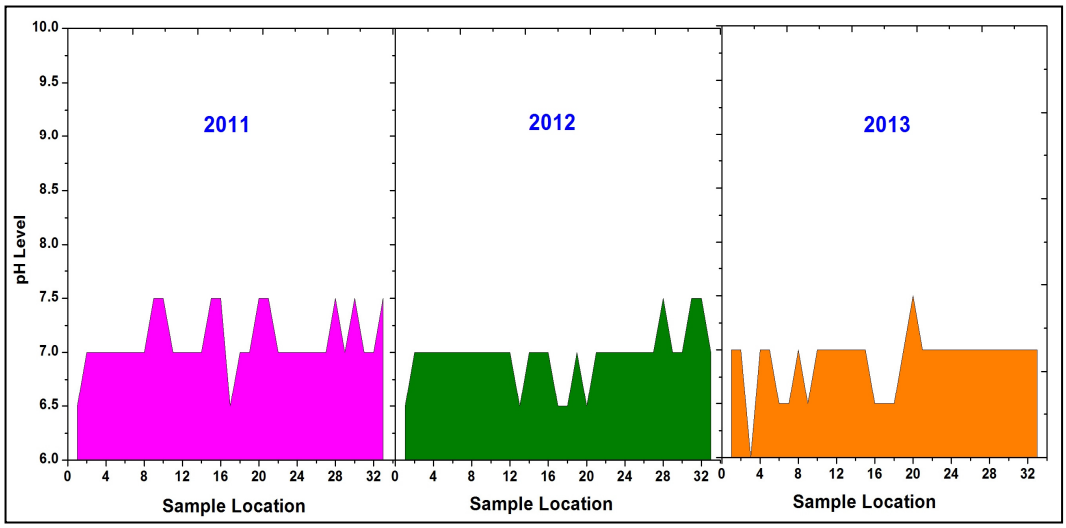

Fig.2.10: Level of *pH* in Sub-surface Water during Post-monsoon

2011. The maximum and minimum level in 2012 and 2013 was same (Table 2.4). The maximum (7.50) was found in –*Vasna-Kotariya, Undera, Sisva, Ranoli* and *Bajwa* (2012) and *Ankodiya* and *Ranoli* (2013) while the minimum (6.50) was noted at *Anagadh, Nandesari and Sankarda* . 7.69, 7.48 and 7.42 were the mean with the low standard deviation (Table 2.4).

After the rains, the maximum level of *pH* was same (7.50) in the three consecutive years. In 2011 and 2012, the highest and lowest value (6.50) was noted in different sites. In 2013, the highest value was found in *Ranoli* whereas the lowest was noted in *Anagadh*. The average value showed a decreased *pH* level in the entire region. The low standard deviation signified less variation of pH level.

Table 2.4: *pH* : Sub-surface Water (2011-13)

Season	N	Average	Minimum	Maximum	Std. Deviation
Pre-Monsoon (2011)	33	7.69	6.79	8.13	0.33
Pre-Monsoon (2012)	33	7.48	7	8	0.3
Pre-Monsoon (2013)	33	7.42	7	8	0.27
Post-monsoon (2011)	33	7.09	6.5	7.5	0.29
Post-monsoon (2012)	33	6.97	6.5	7.5	0.27
Post-monsoon (2013)	33	6.89	6	7.5	0.32

The unit of the parameters is in mg/l

Source: Computed

2.2.4 Concentration of *EC* in Surface Water

In surface water the average level of *EC* (electrical conductivity) increased from 2011 to 2013 (Table 2.5). The maximum level 4.55s/cm^{-1}x 10^{-3} was observed at *Undera* while in 2012 and 2013 it was noted at *Dasharath* (4.20 s/cm^{-1}x 10^{-3} and 4.31s/cm^{-1}x 10^{-3}). *Ankodiya* had the lowest level in 2011 (0.56s/cm^{-1}x 10^{-3}). Whereas in 2012 and 2013, the minimum level was observed at *Gorva* (0.46s/cm^{-1}x 10^{-3} and 0.66s/cm^{-1}x 10^{-3}) respectively. Less variation in the standard deviation was noted during this season.

In the post-monsoon season, the *EC* value decreased (Table 2.6). The maximum level was found at *Bajwa* in 2011. While in 2013, it was observed at *Nandesari* (2.82s/cm^{-1}x 10^{-3} in 2012 and 3.15s/cm^{-1}x 10^{-3} in 2013). *Gorva* had the

lowest level throughout the year (Table 2.5). 0.58 was the deviation from the mean in 2011. The standard deviation in 2012 and 2013 were 0.66 and 0.68 respectively.

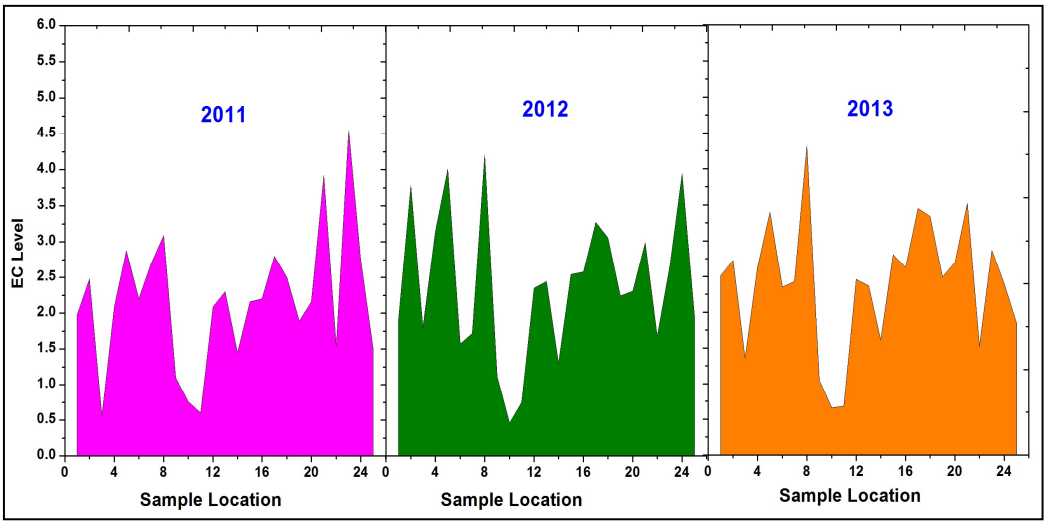

Fig.2.11: Concentration of *EC* in Surface Water during Pre-Monsoon

Table 2.5: *EC*: Surface Water (2011-13)

Season	N	Average	Minimum	Maximum	Std. Deviation
Pre-Monsoon (2011)	25	2.17	0.56	4.55	0.94
Pre-Monsoon (2012)	25	2.39	0.46	4.2	1
Pre-Monsoon (2013)	25	2.4	0.66	4.31	0.9
Post-monsoon (2011)	25	1.61	0.44	2.45	0.58
Post-monsoon (2012)	25	1.62	0.35	2.82	0.66
Post-monsoon (2013)	25	1.68	0.31	3.15	0.68

The unit of the parameters is in s/cm-1x 10-3

Source: Computed

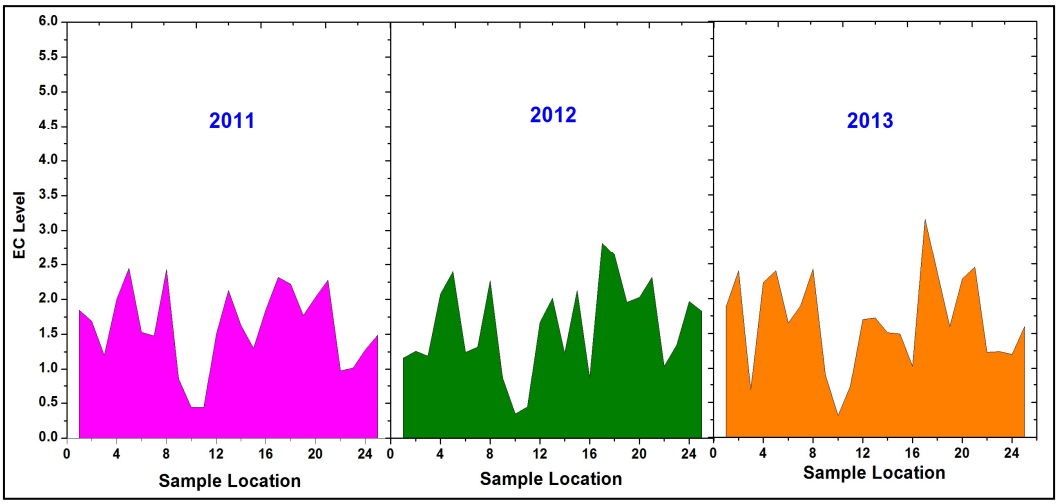

Fig.2.12: Concentration of *EC* in Surface Water during Post-monsoon

2.4.6 Concentration of *EC* in Sub-Surface Water

In sub-surface water, the average level of EC during pre-monsoon was higher in 2013 (2.10s/cm^{-1}x 10^{-3}). *Nandesari* had the maximum level in 2011 and 2013 (5.53 s/cm^{-1}x 10^{-3} and 4.01s/cm^{-1}x 10^{-3} respectively). While in 2012, it was noted at *Sisva*

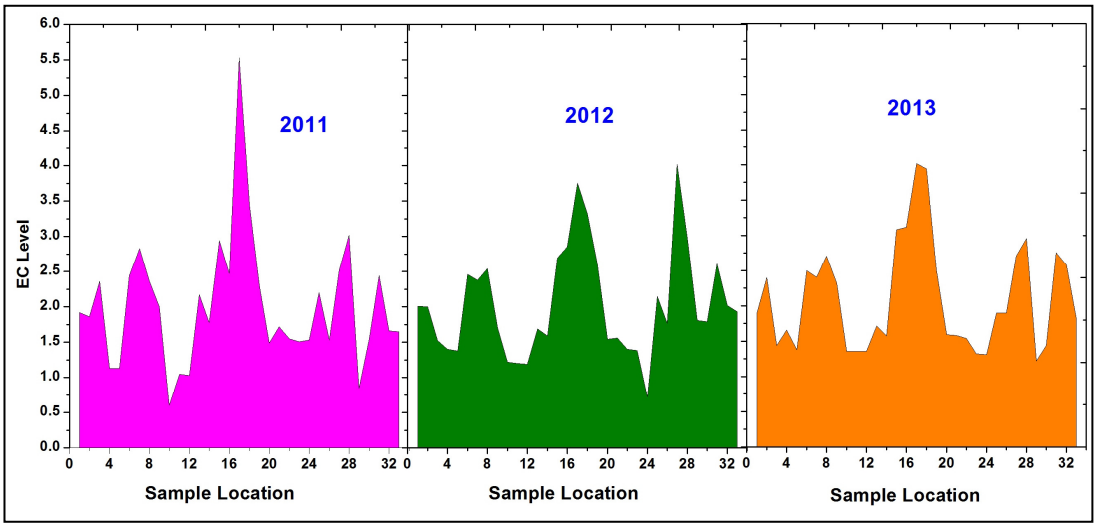

Fig.2.13: Concentration of *EC* in Sub-surface Water during Pre-monsoon

(4.02s/cm^{-1}x 10^{-3}). The lowest was at *Dodka* (0.60s/cm^{-1}x 10^{-3} in 2011), *Rayaka* (0.72s/cm^{-1}x 10^{-3} in 2012) and *Sokhda* (1.22s/cm^{-1}x 10^{-3} in 2013). The standard deviation decreased from 2.53 in 2011 to 1.43 in 2013.

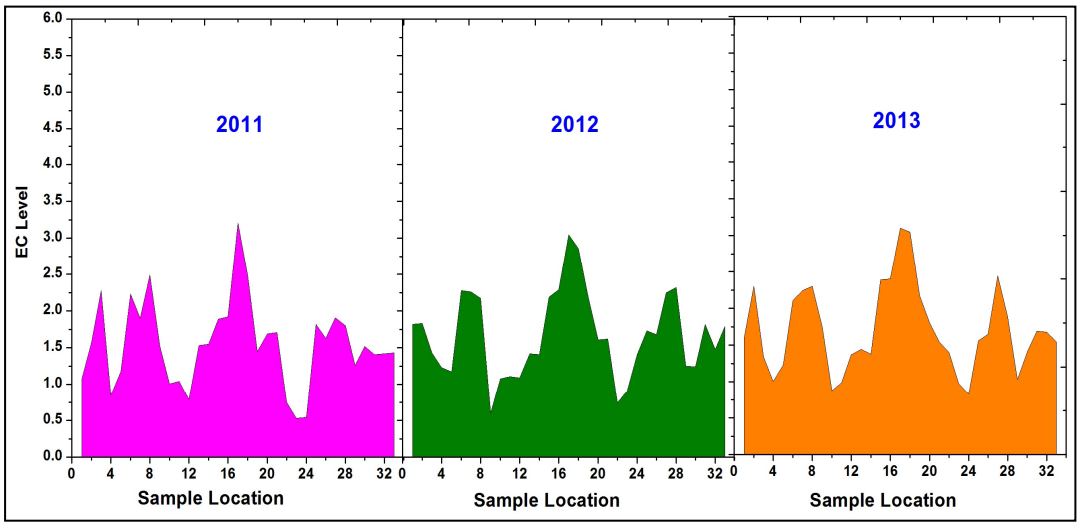

Fig.2.14: Concentration of *EC* in Sub-surface Water during Post-Monsoon

After the rainy season, the average *EC* level decreased but relatively higher level was noted in 2013 (Table 2.14). The maximum level was in *Nandesari* in all the

three years (Table 2.5). Lowest was noted in *Dhanora* (0.60 in 2012) and at *Rayaka* (0.53 in 2011 and 0.83 in 2013). The standard deviation value was lowered 1.14 in 2013 and 1.35 in 2011.

Table 2.6: *EC*: Sub-surface Water (2011-13)

Season	N	Average	Minimum	Maximum	Std. Deviation
Pre-Monsoon (2011)	33	2.02	0.6	5.53	2.54
Pre-Monsoon (2012)	33	2.04	0.72	4.02	1.66
Pre-Monsoon (2013)	33	2.1	1.22	4.02	1.43
Post-monsoon (2011)	33	1.56	0.53	3.21	1.35
Post-monsoon (2012)	33	1.68	0.6	3.05	1.23
Post-monsoon (2013)	33	1.71	0.83	3.1	1.14

The unit of the parameters is in s/cm-1x 10-3

Source: Computed

2.2.7 *Iron* Concentration in Surface Water

In the pre-monsoon, the maximum concentration of iron in surface water was noted at *Dhanora* (3.68 mg/l) in 2011 and minimum *Ankodiya* (1.01 mg/l) during 2011. In 2012, the maximum level was observed in *Karodiya* whereas the lowest was noted in *Ajod*. (Fig.2.15). The sample from *Bajwa* depicted the highest concentration (4.94 mg/l) while *Karachiya* had the minimum level in 2013. The average value presented the gradual increased of iron level from 1.01 mg/l in 2011 to 4.96 mg/l in 2013 (Table 2.7). The deviation from mean was relatively lower in 2011 (0.79).

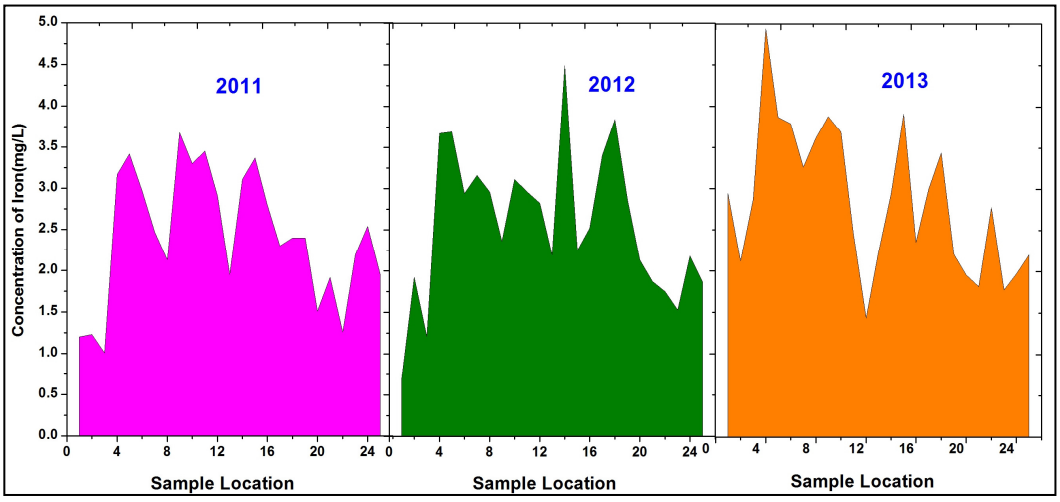

Fig.2.15: Concentration of *iron* in Surface Water during Pre-Monsoon

In post-monsoon, the iron concentration was maximum at *Nandesari* (3.36 mg/l in 2011) while in 2012 and 2013 the highest concentration was observed in *Bajwa* (3.74 mg/land 3.63 mg/l). *Gorva* had the lowest concentration in 2011 (0.86 mg/l) and 2013 (0.92 mg/l). Whereas in 2012, the minimum level observed in *Chhani*

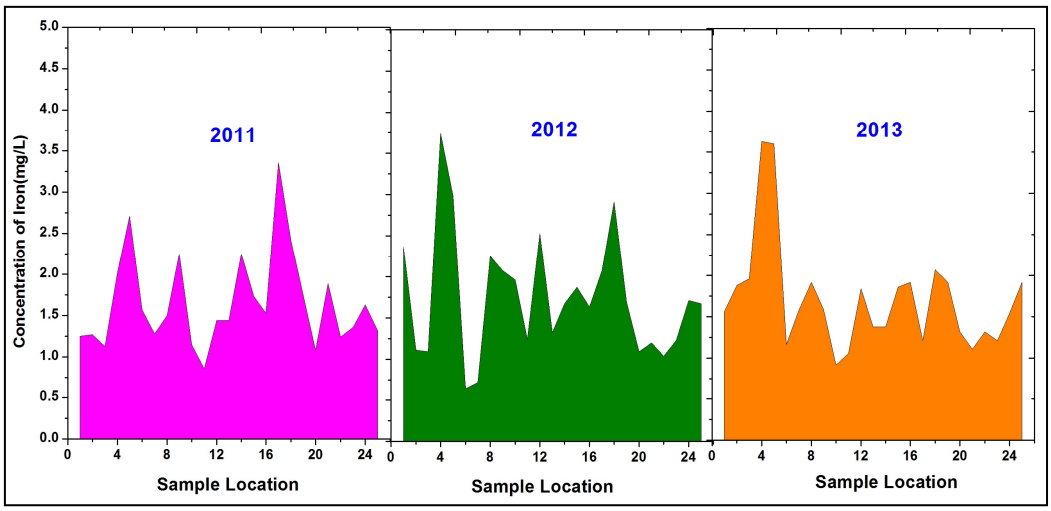

Fig.2.16: Concentration of *Iron* in Surface Water during Post-Monsoon

(0.63 mg/l) which is the least in surface water in the entire study area. The average value in 2012 was greater than the other two years (Table 2.7). 0.58, 0.75 and 0.66 was the standard deviation in the three years (2011 to 2013).

Table 2.7: *Iron* : Surface Water (2011-13)

Season	N	Average	Minimum	Maximum	Std. Deviation
Pre-Monsoon (2011)	25	2.43	1.01	3.68	0.79
Pre-Monsoon (2012)	25	2.57	0.69	4.49	0.89
Pre-Monsoon (2013)	25	2.85	1.44	4.94	0.87
Post-monsoon (2011)	25	1.67	0.86	3.36	0.58
Post-monsoon (2012)	25	1.75	0.63	3.74	0.75
Post-monsoon (2013)	25	1.71	0.92	3.63	0.66

The unit of the parameters is in mg/l

Source: Computed

2.2.8 *Iron* Concentration in Sub-Surface Water

During pre-monsoon, maximum concentration of iron in sub-surface water was found at *Nandesari* in year 2011 (3.45 mg/l) and 2013 (4.27 mg/l). While in 2012, it was noted at *Bajwa* (3.76 mg/l). In all the three years the lowest concentration was observed at *Sokhda* (Fig.2.7). The average value was 1.43 mg/l (2011), 1.39 mg/l (2012)

and 1.58 mg/l in 2013. The variation of iron level was less 2012 (0.84 mg/l) as compared to other years.

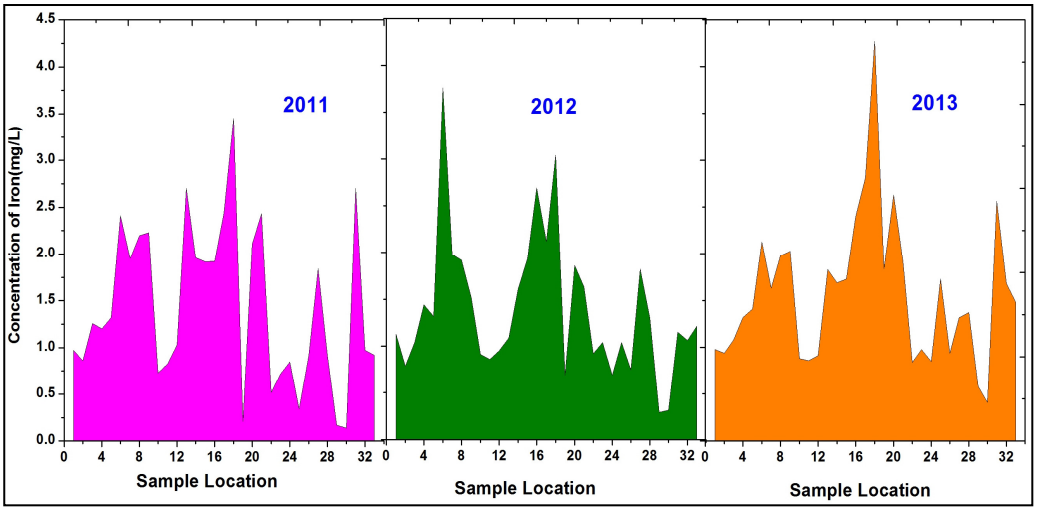

Fig.2.17: Concentration of *Iron* in Sub-Surface Water during Pre-Monsoon

After the rainfall, *Nandesari* had the maximum concentration throughout the time period. The maximum level in this site increased from 3.45 mg/l (pre-monsoon) to 4.15 mg/l in post-monsoon season. The lowest level again observed at *Sokhda* in

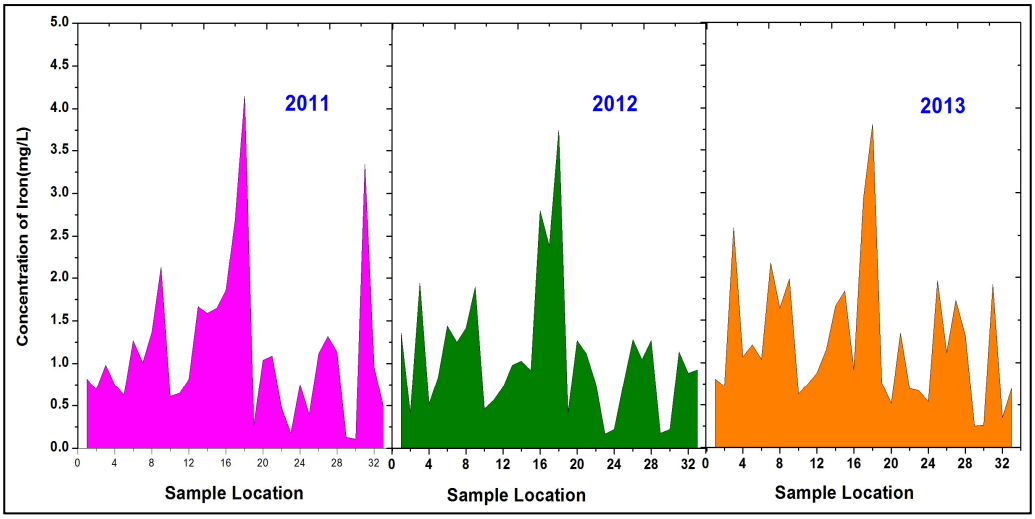

Fig.2.18: Concentration of *Iron* in Sub-surface Water during Post-monsoon

2011 and 2013 (Fig.2.18). In 2012, the minimum value was observed at *Rayaka* (0.17 mg/l). The mean was highest in 2013 (1.29 mg/l) and in 2011 and 2012 it was 1.18 mg/l and 1.11 mg/l respectively. The deviation from the mean was relatively higher in 2011 (Table 2.8).

Table 2.8: *Iron* : Sub-surface Water (2011-13)

Season	N	Average	Minimum	Maximum	Std. Deviation
Pre-Monsoon (2011)	33	1.43	0.14	3.45	0.91
Pre-Monsoon (2012)	33	1.39	0.29	3.76	0.84
Pre-Monsoon (2013)	33	1.58	0.41	4.27	0.89
Post-monsoon (2011)	33	1.18	0.11	4.15	1
Post-monsoon (2012)	33	1.11	0.17	3.75	0.88
Post-monsoon (2013)	33	1.29	0.25	3.81	0.9

The unit of the parameters is in mg/l

Source Computed

2.2.9 *Nitrite* Concentration in Surface Water

The maximum concentration of nitrite in surface water during pre-monsoon was noted at *Dhanora* in 2011, at *Gorva* in 2012 and *Vasna-Kotariya* in 2013.13.39

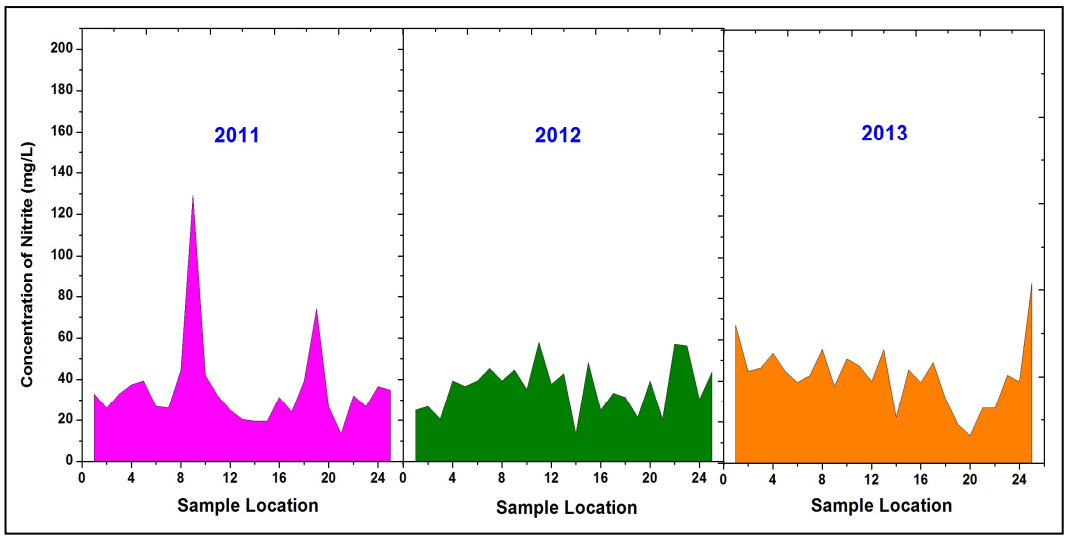

Fig.2.19: Concentration of *Nitrite* in Surface Water during Pre-Monsoon

mg/l was the minimum level in all the three years. There was no significant variation in the average concentration. However, it slightly increased from 35.74 mg/l in 2011 to 42.73 mg/l in 2013(Table: 2.9). Higher standard deviation was noted in 2011 (22.72 mg/l) while in it was 11.90 mg/l in 2012 and 15.46 mg/l in 2013.

In post-monsoon, the maximum concentration of *nitrite* in 2011 was observed at *Undera* (159.82 mg/l), while the lowest was noted in *Karodiya*. In 2012 and 2013 the highest value was observed at *Anagadh* (158.93 mg/l) and *Vasna-Kotariya* (117.84 mg/l) respectively whereas the lowest was observed at *Padmala* in both the years that

is in 2012 (33.04 mg/l) and 2013 (54.27 mg/l). The average value was highest in 2011(81.03 mg/l) and it decreased to 75.02 mg/l in 2013. The standard deviation was 30.35 mg/l and 32.82 mg/l 2011 and 2012 but it was significantly less in 2013 (15.38 mg/l).

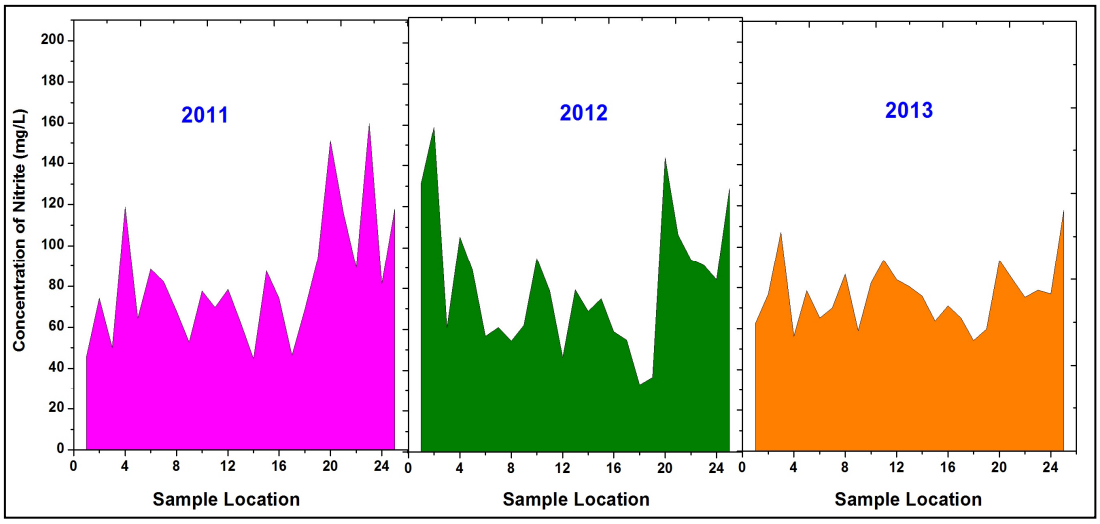

Fig.2.20: Concentration of *Nitrite* in Surface Water during Post-Monsoon

Table 2.9: *Nitrite* : Surface Water (2011-13)

Season	N	Average	Minimum	Maximum	Std. Dev.
Pre-Monsoon (2011)	25	35.74	13.39	129.4	22.72
Pre-Monsoon (2012)	25	36.44	13.39	58.04	11.9
Pre-Monsoon (2013)	25	42.73	13.39	87.43	15.46
Post-monsoon (2011)	25	81.03	44.64	159.82	30.35
Post-monsoon (2012)	25	80.23	33.04	158.93	32.82
Post-monsoon (2013)	25	75.02	54.27	117.84	15.38

The unit of the parameters is in mg/l

Source: Computed

2.2.10 *Nitrite* Concentration in Sub-Surface Water

During pre-monsoon 2011, the maximum concentration in sub-surface water was noted in *Sankarda* 113.3 mg/l. While in 2012 and 2013 the highest level was observed in *Vasna-Kotariya* (78.57 mg/land 189.29 mg/l respectively). The lowest concentration (16.07 mg/l) in the entire region was noted in 2012 at *Dasharath*. The mean concentration (48.18 mg/l) which was recorded in 2011 decreased to 41.56 mg/l in 2012 and once again increased to 51.19 mg/l in 2013. Low deviation (16.51)

from the mean was observed 2012 while 2013 data depicted significant increase of standard deviation.

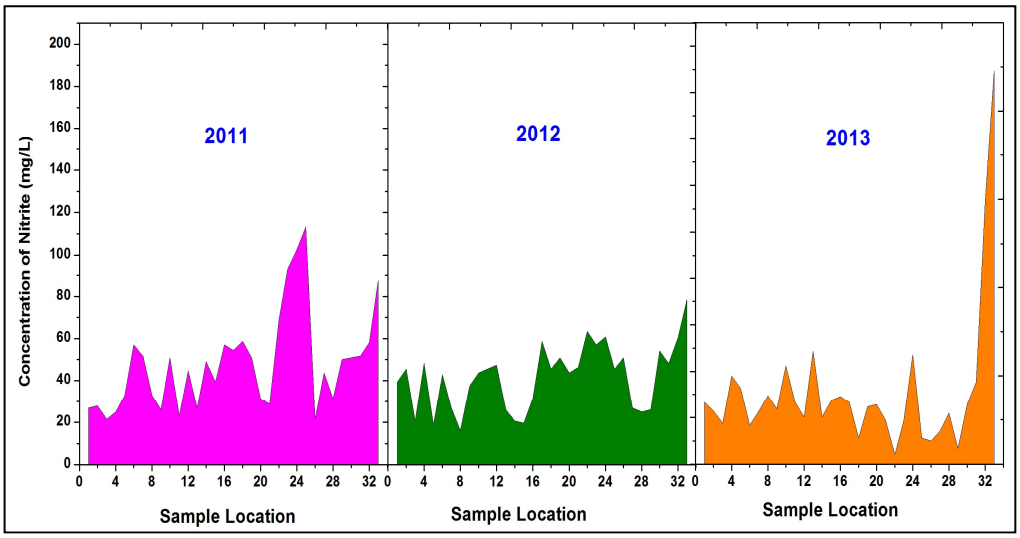

Fig.2.21: Concentration of *Nitrite* in Sub-Surface Water during Pre-Monsoon

After the monsoon season, the concentration of nitrite in sub-surface considerably increased. In all the years the highest concentration was noted in the far villages from the industrial estate. The highest concentration was observed at *Dodka* (118.75 mg/l), *Rayaka* (206.25 mg/l) and *Vasna-Kotariya* (151.36 mg/l) in 2011, 2012 and 2013 respectively. The lowest concentration was noted at *Karodiya* 43.75 mg/l in 2011. 34.82 mg/l in 2012 and 36.61 mg/l were in 2013. The average concentration (96.75 mg/l) was highest in 2012. (Table 2.10)

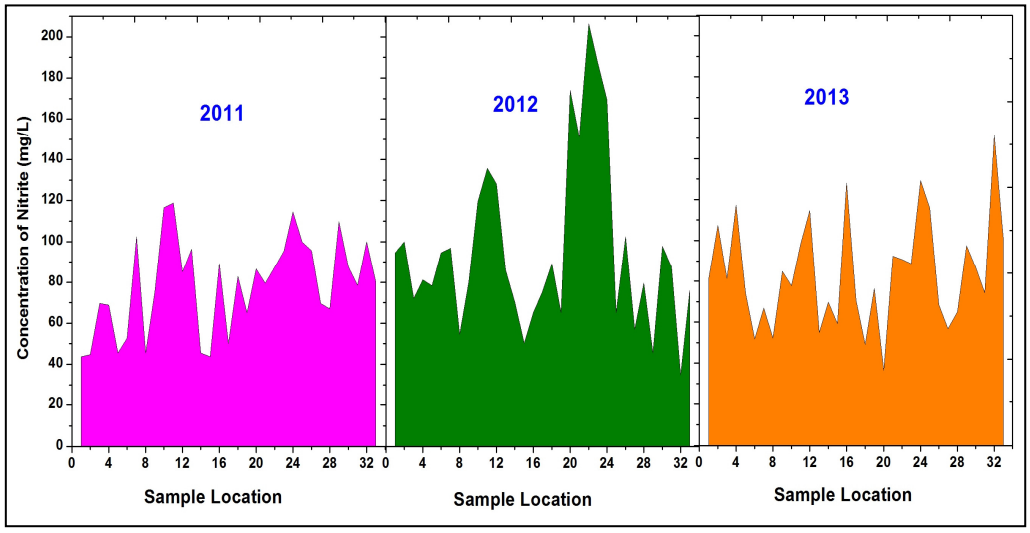

Fig.2.22: Concentration of *Nitrite* in Sub-Surface Water during Post-Monsoon

Table 2.10: *Nitrite* : Sub-surface Water (2011-13)					
Season	**N**	**Average**	**Minimum**	**Maximum**	**Std. Dev.**
Pre-Monsoon (2011)	33	48.18	21.42	113.3	25.4
Pre-Monsoon (2012)	33	41.56	16.07	78.57	16.51
Pre-Monsoon (2013)	33	51.19	24.11	189.29	37.9
Post-monsoon (2011)	33	78.53	43.75	118.75	23.81
Post-monsoon (2012)	33	96.75	34.82	206.25	45.31
Post-monsoon (2013)	33	83.41	36.61	151.36	28.8
The unit of the parameters is in mg/l					
Source: Computed					

2.3 SPATIAL AND SEASONAL PATTERN

2.3.1 *TDS* Concentration in Sub-Surface Water

In 2011, the maximum concentration (>2000 mg/l) of *TDS* in surface water during the pre-monsoon was noted in the small area lying on the eastern and southern part. The level between 1500 mg/l to 2000 mg/l was observed in the western and also in the region extending from east to south. The maximum area had the concentration of 1000 mg/l-1500 mg/l which was found in the northern, central,

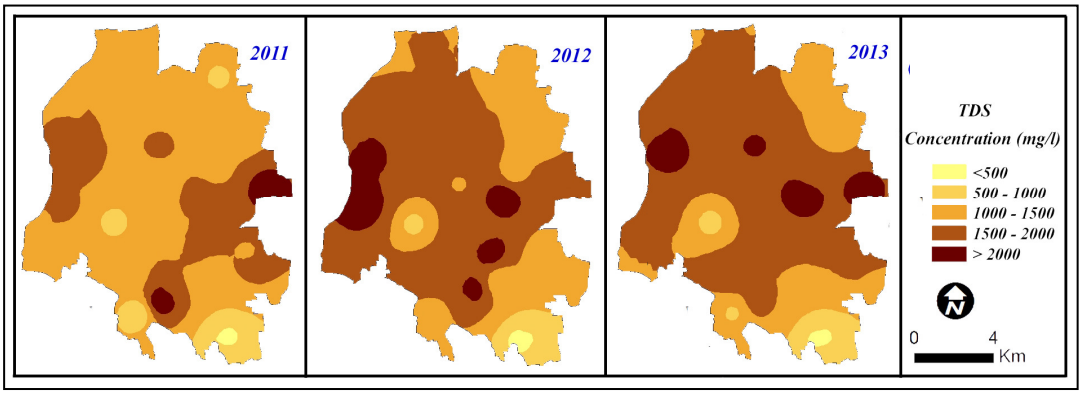

Fig.2.23: Spatial Distribution of *TDS* in Surface Water during Pre-Monsoon

southern and western portion (Fig.2.23). In 2012, the highest concentration of >2000 mg/l was observed in the western, southern and central part. In the northern, southern, western and eastern part the concentration was 1500 mg/l-2000 mg/l. While the concentration of 1000 mg/l-1500 mg/l was located in the north-eastern, southern and south-eastern portion. During 2013, the western, eastern and central part depicted the concentration of >2000 mg/l. Whereas the northern, western, central and

eastern parts of the study area had the concentration of 1500 mg/l-2000 mg/l. The level of 1000 mg/l-1500 mg/l was noted in the northern, eastern and central part. In all the three years the southern most part showed the lower concentration (<500 mg/l).

In post-monsoon, the concentration of *TDS* in surface water decreased considerably. During 2011, the maximum level was noted in a very small area of the central part. While in northern, western, eastern and central parts the concentration was between 1000 mg/l-1500 mg/l. An absorption of 500 mg/l-1000 mg/l was observed in the northern, eastern and southern part. In 2012, the concentration of

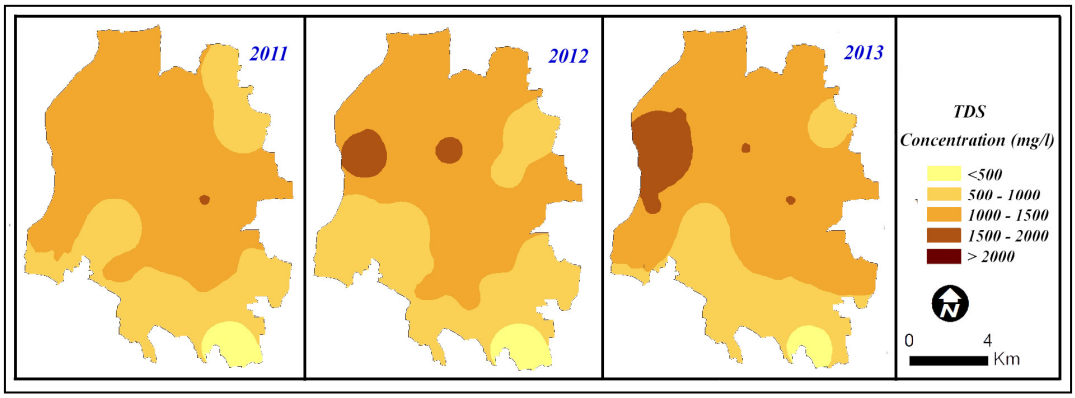

Fig.2.24: Spatial Distribution of *TDS* in Surface Water during Post-Monsoon

1500 mg/l-2000 mg/l was noted in the western part touching the western border and central part (Fig.2.24). Northern, eastern and central portion had the *TDS* level of 1000 mg/l-1500 mg/l. The northern, eastern and southern part denoted the concentration between 500-1000 mg/l. In 2013 the distribution pattern of *TDS* was more or less similar to the previous years. However, the area of concentration 1500 mg/l-2000 mg/l in the western part increased. On the other hand, the concentration (500 mg/l-1000 mg/l) in the north and south was shrinked.

2.3.2 *TDS* Concentration in Sub-Surface Water

In the sub-surface water, the western part had the highest concentration (>2000 mg/l) of *TDS* throughout the time period (Fig.2.25). In 2011 it covered the largest area. During 2011 and 2012 the concentration of 1500 mg/l-2000 mg/l was noted in western, eastern and some patch at southern part. In 2013, level of *TDS* in sub-surface water extended from east to west in the southern part excluding the

central portion. Eastern, central and southern part had level of 1000 mg/l-1500 mg/l *TDS*. In the northern and a small patch in the southern part had the concentration of 500 mg/l-1000 mg/l. This level was observed in north-eastern part during 2011 and 2013.

In post-monsoon, the higher level of *TDS* (1500 mg/l-2000 mg/l) in sub-surface water was observed in the western part (Fig.2.26). The level of 1000 mg/l to 1500 mg/l was spread in the largest area extending from east to west. Whereas in the northern and southern part the concentration was between 500 mg/l to 1000 mg/l. In 2011, more area was in the northern part. In the same year, the minimum level (<500 mg/l) was observed in the north-western part. While in 2012 it was noted at northern and southern portion covering a very small area.

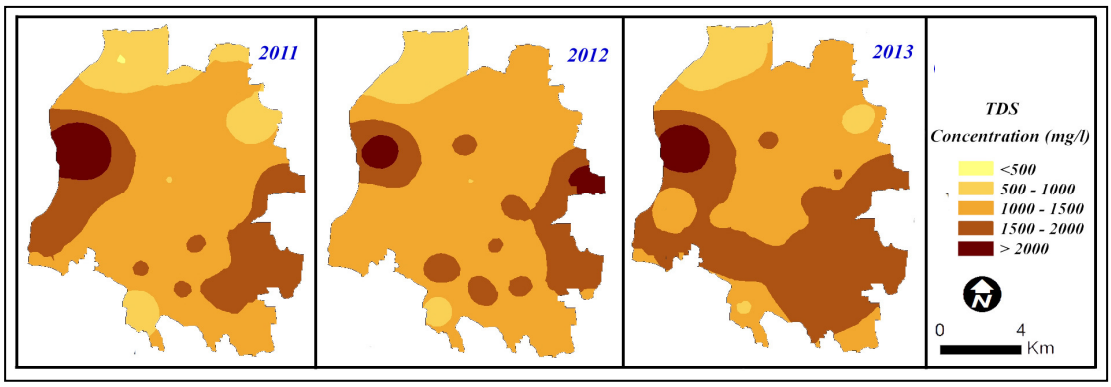

Fig.2.25: Spatial Distribution of *TDS* in Sub-Surface Water during Pre-Monsoon

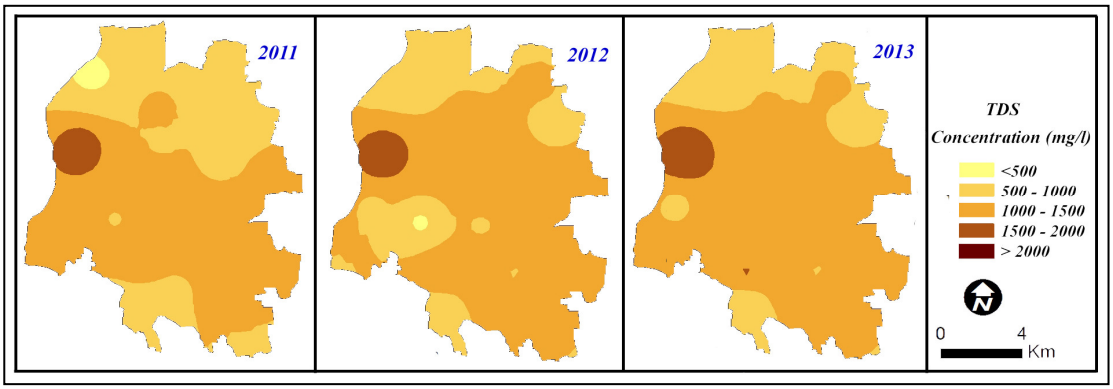

Fig.2.26: Spatial Distribution of *TDS* in Sub-Surface Water during Post-Monsoon

2.3.3 *pH* Level in Surface Water

In 2011 the *pH* level during pre-monsoon in surface water ranged from 7.5 to >8. The higher *pH* value (>8) was observed in the eastern part and the region extended from northern to the entire southern touching the central part of the study

region (Fig.2.27). The western and eastern part depicted the *pH* level of 7.5 to 8 excluding the patches of extreme east. In 2012, it varied between 7 to >8. The major portion of the study area showed the *pH* level of 7.5 - 8. 7-7.5 *pH* was observed in the north-western and central eastern part while >8 was noted in the south. In 2013, 7.5 to 8 was found in the northern, central, western and southern segment. While 7-7.5 *pH* value was noted in the eastern and north-western part.

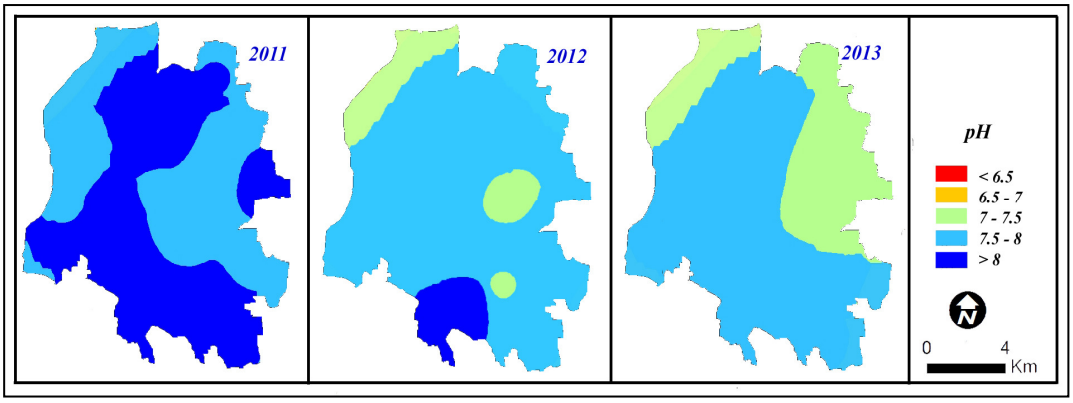

Fig.2.27: Spatial Distribution of *pH* in Surface Water during Pre-Monsoon

After the monsoon, the *pH* level in surface water reduced tremendously. In 2011, the *pH* value of 6.5-7 was found in the central and northern part while 7 to 7.5 was noticed in the eastern, western and southern part (Fig.2.28). During 2012, the level of *pH* in the study area was between 6.5-7 except in the extreme east and a part in south-west. In 2013, the area of 7-7.5 increased and noted in the belt extending from north-east to south-west. 6.5-7.0 was observed at the south-eastern, north-western and north-eastern part.

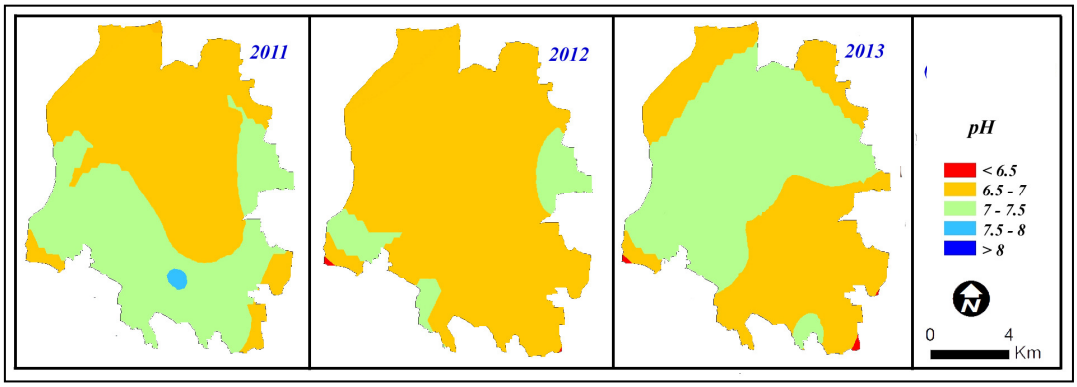

Fig.2.28: Spatial Distribution of *pH* in Surface Water during Post-Monsoon

2.3.4 *pH* Level in Sub-Surface Water

In the sub-surface water the level of *pH* of >8 during pre-monsoon (2011) was observed in the south-western section. Major parts were occupied by 7.5-8 *pH* value (Fig.2.29). 7-7.5 was noted in western, central and southern sides. In 2012, the entire region was divided into two parts i.e. area of *pH* value 7.5-8 in the east and *pH* level of 7-7.5 in the west. In 2013, the 7-7.5 *pH* covered the western and the entire northern sector. *pH* 7.5-8 was observed in the southern and south-eastern part.

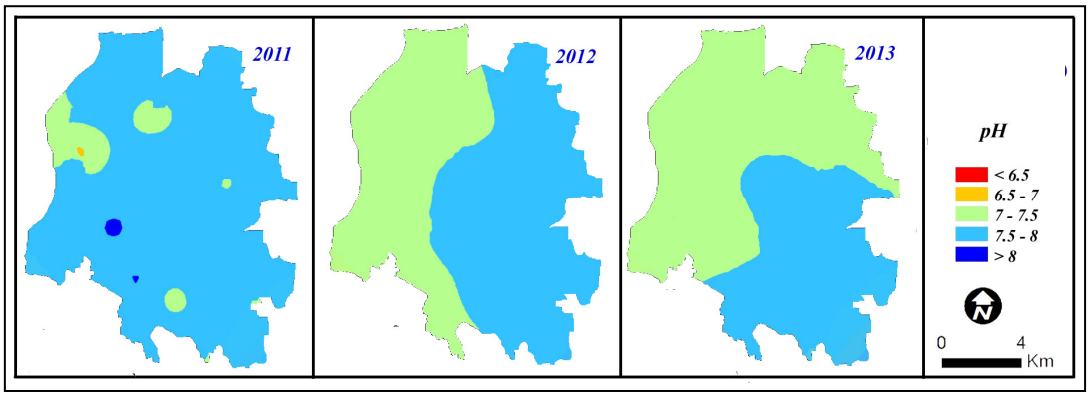

Fig.2.29: Spatial Distribution of *pH* in Sub-Surface Water during Pre-Monsoon

During the post-monsoon, the level of *pH* in sub-surface water ranged from 6.5 to 7.5. In 2011, the 7- 7.5 *pH* value was noted in the largest area (Fig.2.30). The *pH* of 6.5-7 was traced at the western and central-eastern part. In 2012, the western, north-eastern and central part had *pH* value of 6.5 to 7. North-eastern, eastern, and southern

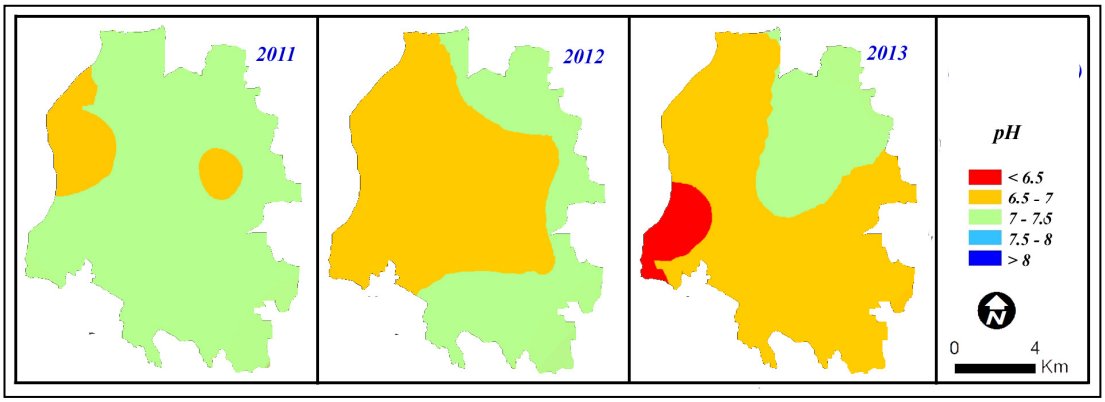

Fig.2.30: Spatial Distribution of *pH* in Sub-Surface Water during Post-Monsoon

part depicted the 7-7.5 *pH*. In 2013, the central to north-eastern part had 7-7.5 *pH*. The *pH* value 6.5-7 was observed in the largest area. It was confined in the north-

western, south and eastern part. While the lowest <6.5 were observed in the western part.

2.3.5 *EC* Concentration in Surface Water

In 2011, the higher level of *EC* in sub-surface water during pre-monsoon was observed in the eastern, western and southern part. In the north-eastern, northern and southern part the level of 1.5 -2s/cm^{-1}x 10^{-3} was noted in 2011. During 2012 and 2013, this level (1.5-2s/cm^{-1}x 10^{-3}) disappeared in the northern part and confined in north-eastern and southern parts. In south-eastern part the area of 1.5-2s/cm^{-1}x 10^{-3} was larger in 2012. In the later two years, the northern, western and eastern were occupied with the >2s/cm^{-1}x 10^{-3}. In all the years the south-eastern section had the lowest concentration.

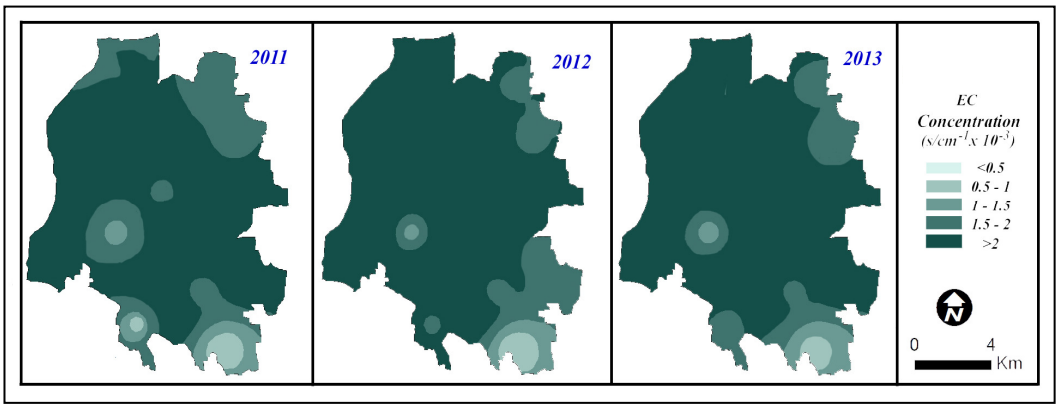

Fig.2.31: Spatial Distribution of *EC* in Surface Water during Pre-Monsoon

During the post-monsoon, western, central and eastern segments had the concentration of >2 s/cm^{-1}x 10^{-3}. The level of *EC* 1.5-2 s/cm^{-1}x 10^{-3} was observed in the northern and central part. In the north-eastern and southern parts 1-1.5 s/cm^{-1}x 10^{-3} *EC* was noted. The lowest concentration (0.5-1 s/cm^{-1}x 10^{-3}) was observed in south. In 2012, the concentration of >2 s/cm^{-1}x 10^{-3} was noted in the western, central and at some spots of eastern part. In the northern and eastern parts the concentration between 1.5-2 s/cm^{-1}x 10^{-3} was observed. The concentration of 1-1.5 s/cm^{-1}x 10^{-3} was found in north-eastern and southern segment. The southern tip had relatively lower concentration. In 2013, the maximum concentration >2 s/cm^{-1}x 10^{-3} was observed at the central, western and eastern part. North-eastern and central parts had

concentration of 1.5-2 s/cm^{-1}x 10^{-3}. The entire southern segment had lower level (0.5-1s/cm^{-1}x 10^{-3}).

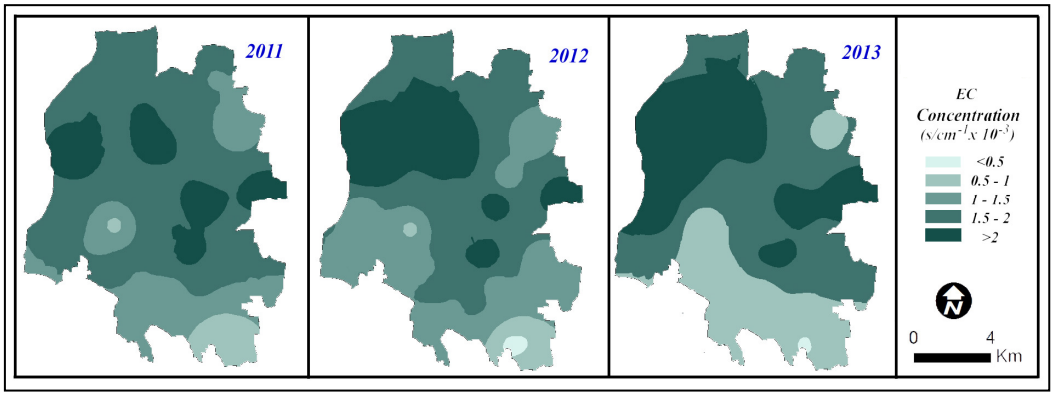

Fig.2.32: Spatial Distribution of *EC* in Surface Water during Post-Monsoon

2.3.6 *EC* Concentration in Sub-Surface Water

In sub-surface water, the concentration of >2 s/cm^{-1}x 10^{-3} *EC* during pre-monsoon was found in the western, eastern and southern part (Fig.2.33). The concentration between 1.5 to 2 s/cm^{-1}x 10^{-3} was observed in the central and northern part. During 2012 it was also noted in the western part. The lower concentration 1-1.5 s/cm^{-1}x 10^{-3} was observed in the northern most part. This level was also noted in north- east during 2011 and 2013.

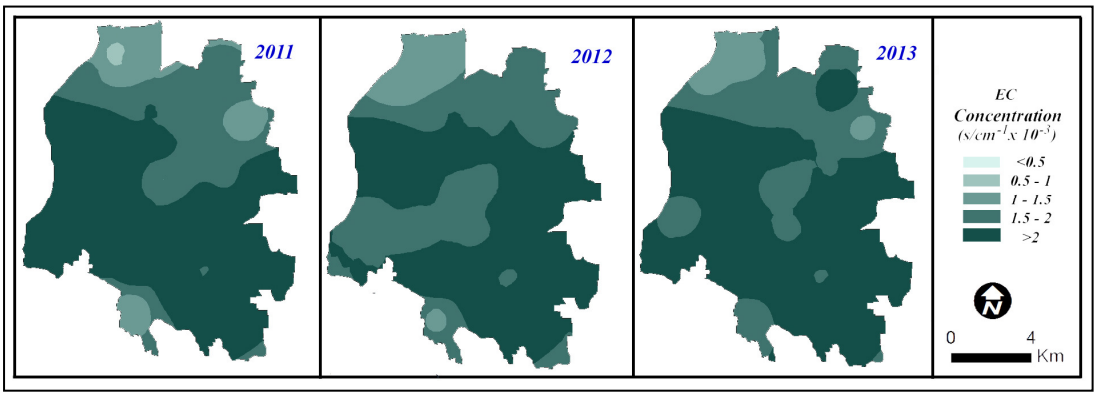

Fig.2.33: Spatial Distribution of EC in Sub-Surface Water during Pre-Monsoon

In post-monsoon (2011), *EC* of >2 s/cm^{-1}x 10^{-3} in sub-surface water was in the east and in pockets of the central part. During 2012 and 2013, it was observed in western, eastern and the small area in the central part. The concentration of 1.5-2 s/cm^{-1}x 10^{-3} covered the largest area of the study area located in the central, north-eastern and southern part. In 2011, the northern part had the concentration of 1-1.5 s/cm^{-1}x 10^{-3}and north-western part depicted the concentration of <0.51 s/cm^{-1}x 10^{-3}. In

2012 and 2013, the north-western and small area of southern part had 1-1.5 s/cm^{-1}x 10^{-3} concentration which was located in north-east in 2013.

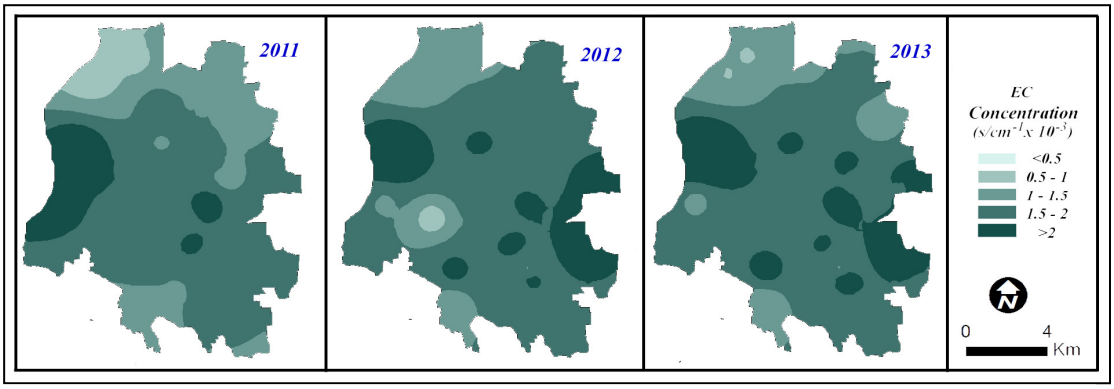

Fig.2.34: Spatial Distribution of *EC* in Sub-Surface Water during Post-Monsoon

2.3.7 *Iron* Concentration in Surface Water

During pre-monsoon season, the high level of *iron* in surface water was observed throughout the area. In 2011, the highest concentration of >2 mg/l was found in the region which extended from north-western to south-eastern part including the central and southern portions. The northern and north-eastern parts had concentration of 1.5 mg/l -2 mg/l. This concentration was also noted in the pockets of western and southern part of the study area. The concentration of 1 mg/l-1.5 mg/l was in small area lying in the western, southern and north-east. During pre-monsoon (2012), the study area had >2 mg/l of iron except in the north-east. A small area lying on the south had the concentration of 1-2 mg/l. In 2013 the entire region had >2 mg/l.

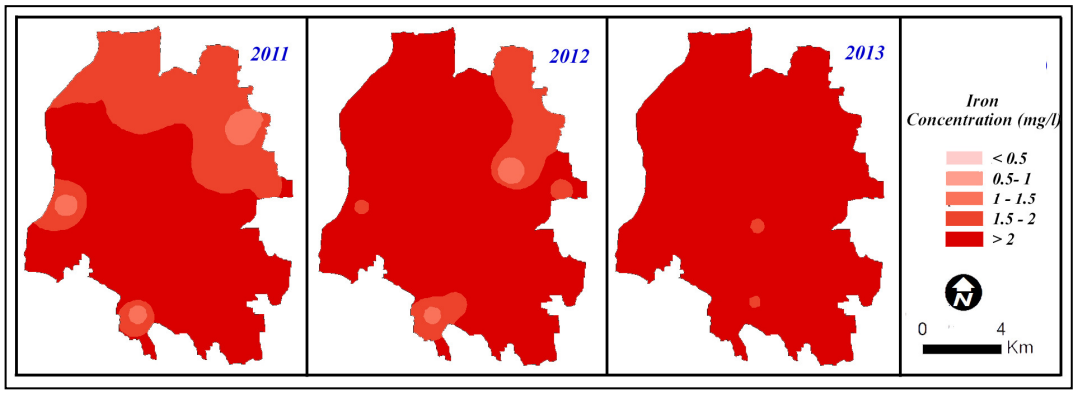

Fig.2.35: Spatial Distribution of *Iron* in Surface Water during Pre-Monsoon

After the rainy season, the level of *iron* reduced in surface water. In 2011, the maximum concentration was >2 mg/l and was seen in the western part and in patches

of the central portion. The concentration of 1.5-2 mg/l was spread in north-western, south-western, central and eastern segment. North-eastern and southern parts depicted iron level of 1-1.5 mg/l. In 2012, the maximum concentration (>2 mg/l) was observed in the centre. Northern, western and southern part had 1.5 to 2 mg/l while the eastern part denoted lower concentration (1-1.5 mg/l) and the least concentration (0.5-1 mg/l) was observed in south-eastern part. In 2013, the higher concentration (>2 mg/l) was noted in the southern part. 1.5-2 mg/l was found in the central part and relatively lower concentration (1-1.5 mg/l) was observed at north-west, east and south-west.

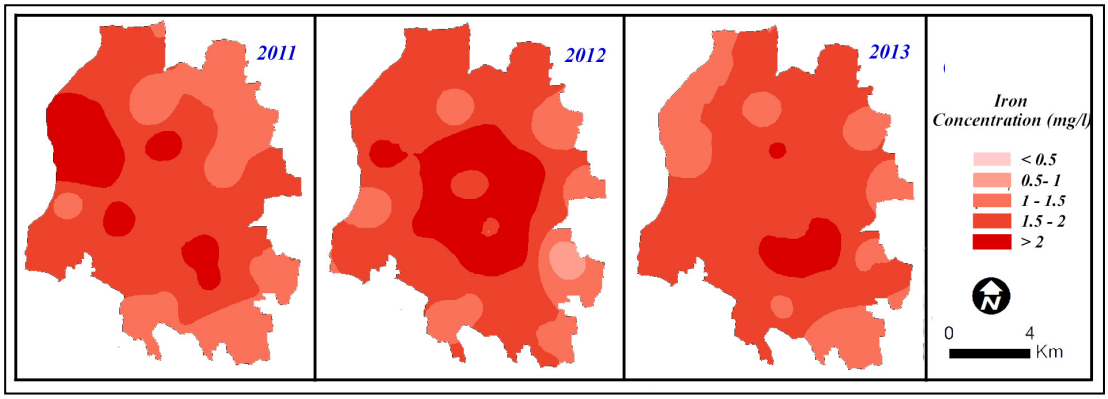

Fig.2.36: Spatial Distribution of *Iron* in Surface Water during Post-Monsoon

2.3.8 *Iron* Concentration in Sub-Surface Water

In the sub-surface water, the concentration of *iron* was higher in the south. In 2011 and 2013, the maximum concentration extended from western to southern portion. In 2012, it was observed in the western and central part. The concentration

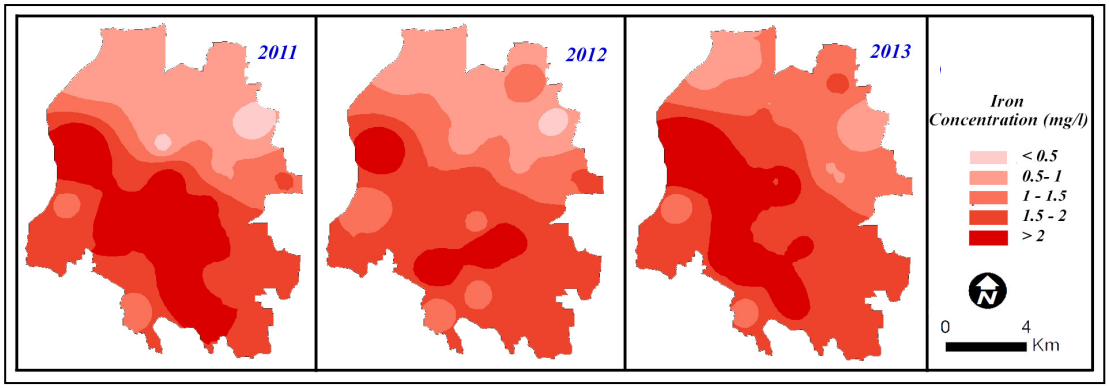

Fig.2.37: Spatial Distribution of *Iron* in Sub- Surface Water during Pre-Monsoon

of 1.5-2 mg/l in all the three years was observed in the north and south-west. During 2011 and 2012, 1-1.5 mg/l concentration was noted in central portion. In 2013, 1-1.5

mg/l was observed in north. In 2011 and 2012, the lower concentration of 0.5-1 mg/l covered the northern part whereas in 2013 it was observed at north-western and north-eastern segment.

In all the years, during post-monsoon, the western part showed the highest level of *iron* (>2 mg/l) (Fig.2.38). In 2012 and 2013, it was noted in a smaller area of the south. In 2011, the concentration of 1.5-2 mg/l was observed towards west and south. In 2012, it was confined at the western and south-western part while in 2013, it was noted in western and south-east part. 1-1.5 mg/l of iron was observed at eastern, central and southern section. The lower concentration (0.5-1 mg/l) was observed in the entire northern side. Throughout, the least concentration (<0.5 mg/l) was observed in north-eastern part.

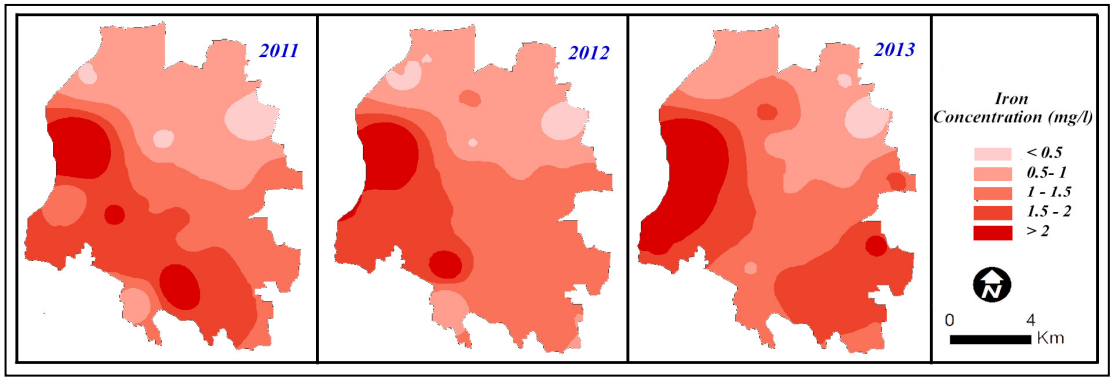

Fig.2.38: Spatial Distribution of *Iron* in Sub- Surface Water during Post-Monsoon

2.3.9 *Nitrite* Concentration in Surface Water

In all the years, the level of *nitrite* in surface water was comparatively low during the pre-monsoon. In 2011, the major portion of the study area showed the *nitrite* level of <45 mg/l (Fig.2.39). The higher concentration extended from the centre towards south-west. The south-western part showed the maximum concentration of nitrite. In 2012, the entire region had a concentration of <45 mg/l except the patches at north-eastern and south-east which had 45-65 mg/l of *nitrite*. In 2013, the maximum concentration (65-85 mg/l) was noted in the north-eastern part. Western, central eastern and southern segments denoted 45-65 mg/l of *nitrite*. The concentration <45 mg/l covered the largest area.

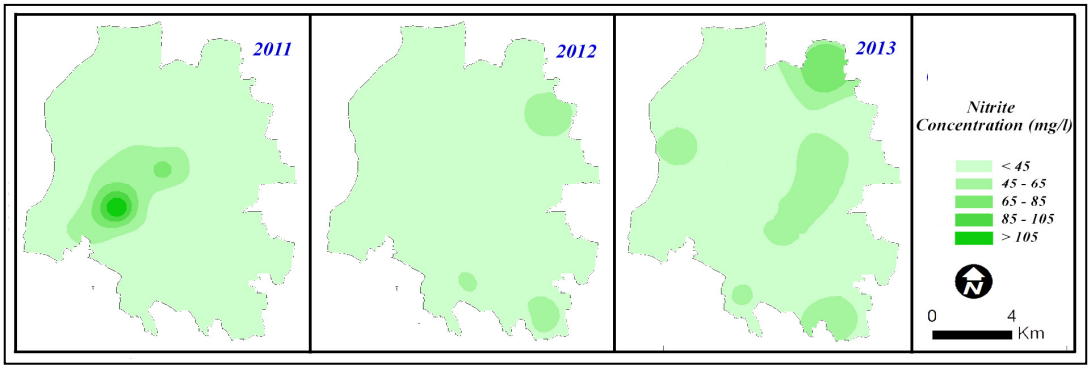

Fig.2.39: Spatial Distribution of *Nitrite* in Surface Water during Pre-Monsoon

In post-monsoon, the concentration of *nitrite* in surface water increased. In all the years, the highest concentration (<105 mg/l) was observed in north while the central portion had lower concentration (Fig.2.40). In 2011, the peak level (>105 mg/l) was noted in north-east and south. In 2012, it was found in northern, western and central eastern parts while in 2013, it was confined only in north-east. The concentration of 85-105 mg/l was observed at northern, eastern, and southern parts in 2011, north-eastern and eastern in 2012 and northern and southern part in 2013. The concentration of 65-85 mg/l extended from north-west to south-east throughout the time period. In 2013, it was observed in eastern portion. The lower concentration (45-65 mg/l) was observed in the central portion.

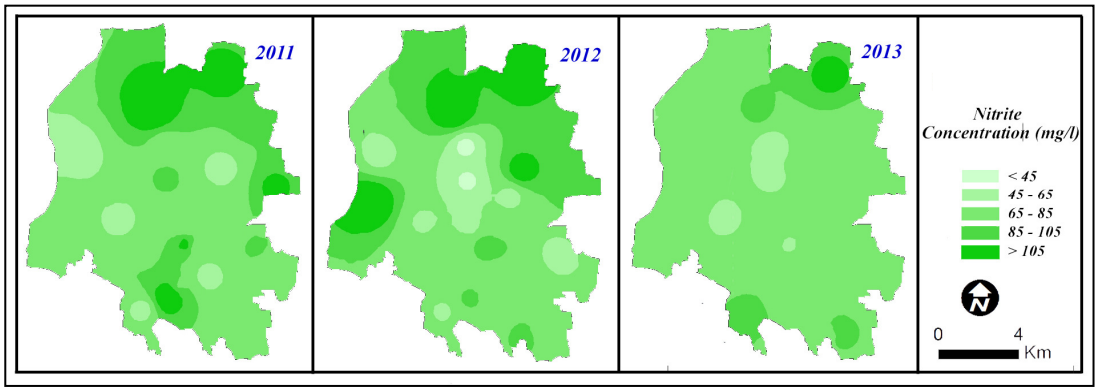

Fig.2.40: Spatial Distribution of *Nitrite* in Surface Water during Post-Monsoon

2.3.10 *Nitrite* Concentration in Sub-Surface Water

During the pre-monsoon of 2011, the higher concentration (85-105 mg/l) of *nitrite* in sub-surface water was observed in a small patch in the north-western part (Fig.2.41). The entire northern and small area in the south had an absorption of 45-65 mg/l while eastern, western, central and southern segments had <45 mg/l. In 2012, the

study area had well defined two parts viz the lower concentration (>45 mg/l) on the south and relatively higher concentration (45-65) in the north. In 2013, the topmost level (>105 mg/l) was observed in north-east. The concentration between 45-65 mg/l was observed in north, north-eastern and south while in the western, eastern, south-eastern had the least amount (<45 mg/l).

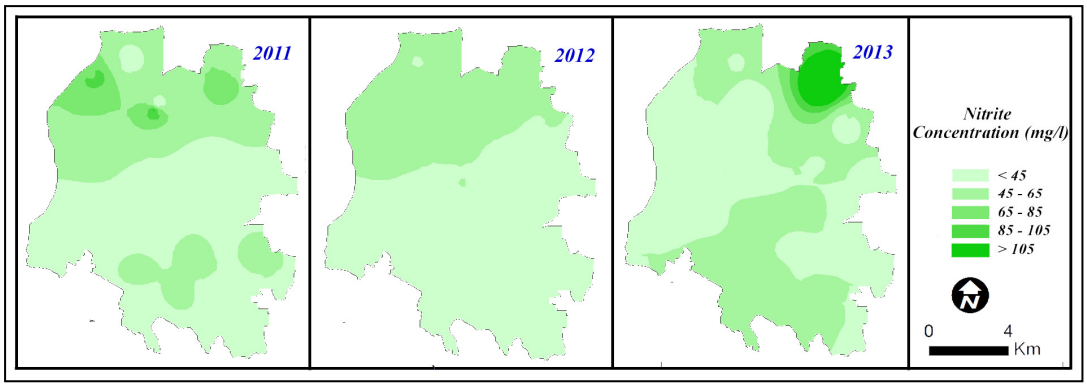

Fig.2.41: Spatial Distribution of *Nitrite* in Sub-Surface Water during Pre-Monsoon

After the rainfall, the concentration of *nitrite* in sub-surface water increased in all the years. In 2011, the entire north had the concentration of 85 to 105 mg/l and the highest level (>105 mg/l) was observed in the northern most area. Absorption between 65-85 mg/l was spread on the western, central and eastern side, while 45-65 mg/l extended from central to southern part. In 2012, the central and north-western depicted the higher concentration (>105 mg/l). In the western and central part concentration of 85-105 mg/l was observed while in the eastern, entire western and southern part it was of 65-85 mg/l. A small patch with 45-65 mg/l was noted in the

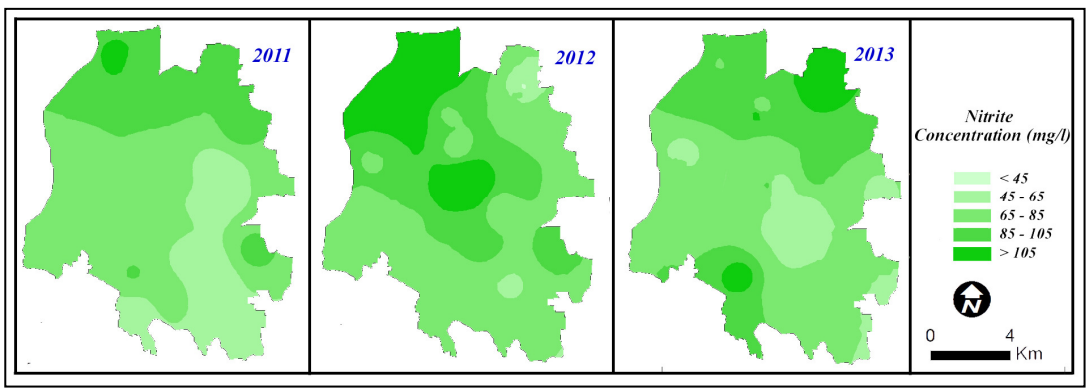

Fig.2.42: Spatial Distribution of *Nitrite* in Sub-Surface Water during Post-Monsoon

north-eastern and south-eastern sides. In 2013, dilution of 85-105 mg/l and >105 mg/l was observed in the entire northern and south-western parts. Western, eastern and south-western part had of 65-85 mg/l of nitrite while the central portion comprised of 45-65 mg/l.

2.4 SEASONAL VARIABILITY OF WATER PARAMETER:

Pair t-test was performed for *TDS, pH, EC, iron* and *nitrite* for pre and post-monsoon season of surface and sub-surface water sample of three years. Twenty-five (25) surface water and thirty-three (33) sub-surface water samples were analysed with 95% significance level. The result from the t-test analysis depicted the changing pattern in the concentration of the parameters in different seasons. For the analysis, three pairs for each of the parameters were formed for different years (Table 2.11).

2.4.1 Surface Water Parameters

The correlation value of pair a1, pair a2 and pair a3 for *TDS* was (+)0.536, (+)0.744 and (+)0.824 respectively (Table 2.11). The calculated value of 't' was greater than the tabulated value i.e. 2.064. Thus, the null hypothesis was rejected for all the three pairs and it can be concluded that the concentration of *TDS* in pre and post-monsoon season had significant variation during 2011, 2012 and 2013.

The correlation values of *pH* for the pairs a4, a5 and a6 was (+)0.615, (+)0.233 and (+)0.342. The 't' statistics for the three pairs (11.626, 10.119 and 8.570) was more than the table value. Hence, alternative hypothesis can be accepted indicating the significant change of *pH* level in different season.

Positive correlation was observed in all the pairs of *EC*. The calculated 't' value of the pairs a7, a8 and a9 was (+)3.547, (+)5.704 and (+)7.083 which was higher than the tabulated 't' value. It can be inferred that there was a significant change in the concentration of *EC* during pre and post-monsoon in the three years.

The correlation of pairs a10, pair a11 and pair a12 was (+)0.349, (+)0.409 and (+)0.467 respectively. The calculated 't' values for the three pairs (+4.819, +4.588 and +7.054) were greater than the table value. Thus, null hypothesis can be rejected. The

results depicted the variation of *iron* concentration in different season in the three years.

Negative correlation was observed in pair a13 of *nitrite* (-0.186). While the pairs a14 and a15 had the positive relationship (+0.053 and +0.316).The value of 't' statistics was (-5.680,-6.664 and -9.429). In all the cases (excluded minus sign), the calculated 't' value was greater than tabulated value. Hence, alternative hypothesis is accepted and concluded that there was seasonal variation in the concentration of *nitrite* in the time period.

Table 2.11: Correlation and Paired 't' Statistics of Pre and Post-Monsoon Season in Surface Water (2011-13)

Parameter	Pairs	Seasons Combination	Correlation	t	df	Sig.(2-tailed)
TDS	Pair a1	pre-post-monsoon(2011)	0.536	3.547	24	.002
TDS	Pair a2	pre - post-monsoon(2012)	0.744	5.704	24	.000
TDS	Pair a3	pre - post-monsoon(2013)	0.824	7.083	24	.000
pH	Pair a4	pre - post-monsoon(2011)	0.615	11.626	24	.000
pH	Pair a5	pre - post-monsoon(2012)	0.233	10.119	24	.000
pH	Pair a6	pre - post-monsoon(2013)	0.342	8.570	24	.000
EC	Pair a7	pre - post-monsoon(2011)	0.536	3.547	24	.002
EC	Pair a8	pre - post-monsoon(2012)	0.744	5.704	24	.000
EC	Pair a9	pre - post-monsoon(2013)	0.824	7.083	24	.000
Iron	Pair a10	pre - post-monsoon(2011)	0.349	4.819	24	.000
Iron	Pair a11	pre - post-monsoon(2012)	0.409	4.588	24	.000
Iron	Pair a12	pre - post-monsoon(2013)	0.467	7.054	24	.000
Nitrite	Pair a13	pre - post-monsoon(2011)	- 0.186	-5.680	24	.000
Nitrite	Pair a14	pre - post-monsoon(2012)	0.053	-6.664	24	.000
Nitrite	Pair a15	pre - post-monsoon(2013)	0.316	-9.429	24	.000

Source: Computed

2.4.2 Sub-Surface Water Parameter

Correlation value of pair b1, pair b2 and pair b3 for *TDS* was (+)0.805, (+)0.850 and (+)0.907 (Table 2.12). The 't' statistics was 4.676, 5.074 and 7.765 which was greater than the table value (2.036). It indicated a change in the level of *TDS* in sub-surface water in different seasons of the year 2011, 2012 and 2013.

For pair b4, pair b5, and pair b6 of *pH* the correlation value was (+)0.674, (+)0.424 and (+)0.558. The calculated 't' values for the three years was higher than the

table value. Hence, significant change was observed in the pair b4, pair b5, and pair b6. Consequently, alternative hypothesis was accepted.

Table 2.12: Correlation and Paired 't' Statistics of Pre and Post Monsoon Season in Sub-Surface Water (2011-13)

Parameter	Pairs	Seasons Combination	Correlation	t	df	Sig.(2-tailed)
TDS	Pair b1	pre-post-monsoon(2011)	0.805	4.676	32	.000
TDS	Pair b2	pre - post-monsoon(2012)	0.850	5.074	32	.000
TDS	Pair b3	pre - post-monsoon(2013)	0.907	7.765	32	.000
pH	Pair b4	pre - post-monsoon(2011)	0.674	14.596	32	.000
pH	Pair b5	pre - post-monsoon(2012)	0.424	10.109	32	.000
pH	Pair b6	pre - post-monsoon(2013)	0.558	12.279	32	.000
EC	Pair b7	pre - post-monsoon(2011)	0.805	4.676	32	.000
EC	Pair b8	pre - post-monsoon(2012)	0.850	5.074	32	.000
EC	Pair b9	pre - post-monsoon(2013)	0.918	7.005	32	.000
Iron	Pair b10	pre - post-monsoon(2011)	0.850	3.254	32	.003
Iron	Pair b11	pre - post-monsoon(2012)	0.710	2.853	32	.008
Iron	Pair b12	pre - post-monsoon(2013)	0.671	2.723	32	.010
Nitrite	Pair b13	pre - post-monsoon(2011)	0.348	-6.568	32	.000
Nitrite	Pair b14	pre - post-monsoon(2012)	0.438	-8.304	32	.000
Nitrite	Pair b15	pre - post-monsoon(2013)	0.349	-5.705	32	.000

Source: Computed

For *EC* the correlation value was (+)0.805, (+)0.850 and (+)0.918. The value of calculated 't' was greater than the tabulated 't' value. Therefore, alternative hypothesis was observed in all the pairs, depicting the variation in the concentration of *EC* among pre and post-monsoon season.

The correlation of pair b10, pair b11, and pair b12 for iron was (+)0.850, (+)0.710 and (+)0.671. The 't' statistic of the three pairs was higher than the table value. It signified a change in the level of *iron* in sub-surface water for different seasons of 2011, 2012 and 2013.

The correlation value of the pair b13, pair b14, and pair b15 was (+)0.348, (+)0.438 and (+)0.349. In all the pairs, the calculated 't' value was more than the tabulated value which denoted the variation of *nitrite* concentration among different seasons in all the three years. Thus, alternative hypothesis was accepted for all the pairs.

2.5 AVERAGE LEVEL OF WATER PARAMETER DURING 2011 TO 2013

2.5.1 Concentration of *TDS* in Surface Water

During pre-monsoon season, the level of *TDS* in surface water varied between 400.93 mg/l and 2476.00 mg/l. 1046.87 mg/l was the average concentration with the standard deviation of 558.63 indicating high variation in the level of *TDS* in the study area. The highest concentration (2476.00 mg/l) was observed in the *Dasharath* village which is adjacent to Gujarat State Fertilizer Corporation (GSFC). In the post-monsoon season, the *TDS* level ranged between 233.85 mg/l to 1767.36 mg/l. The mean level in surface water was 1046.87 mg/l and standard deviation was 384.33. *Nandesari* depicted the highest dilution (1794.86 mg/l) of *TDS* after rains. In both pre and post-monsoon season the average *TDS* level was considerably higher (Table 2.13) than the permissible limit (500 mg/l). The surface water at *Gorva* had the lowest concentration (Fig2.43) in both the season.

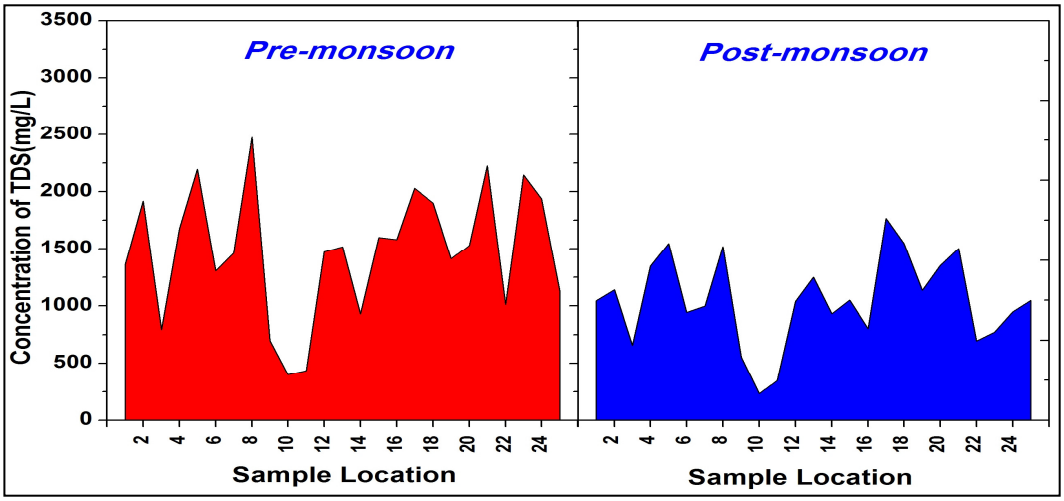

Fig.2.43: Concentration of *TDS* in Surface Water

2.5.2 Concentration of *TDS* in Sub-Surface Water

In sub-surface water, the minimum level of *TDS* before the rainy season was 384.00mg/l. While the maximum concentration (3540.00 mg/l) was at *Nandesari*. The average was 1290.33 mg/l with the standard deviation of 585.91. After the rains, the level of *TDS* ranged between 460.80 mg/l to 2572.80 mg/l. 1303.73 mg/l and 460.80 were the mean and standard deviation respectively. The least level of *TDS* in sub-

surface water was lower than the desirable limit (500 mg/l) which was noted at the village *Dodka* (during pre-monsoon) and *Rayaka* (post-monsoon). Both villages are on the upstream of *River Mahi* and all the industries are downstream of the river.

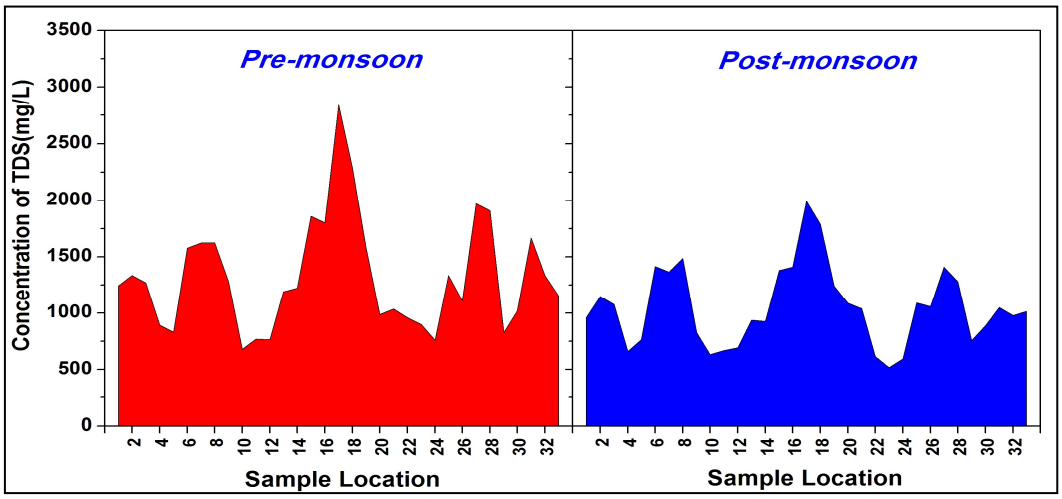

Fig.2.44: Concentration of *TDS* in Sub-surface Water

2.5.3 *pH* Level in Surface Water

During the pre-monsoon season, the *pH* in surface water ranged from 7.16 to 8.65. The average value was 7.86 indicating a normal condition and a low deviation of 0.31. The *pH* level was above the desirable limit (6.5-8.5) at *Undera* depicting a slightly alkaline condition (Table 2.13). In the post-monsoon season, it decreased and varied between 6.50 to 7.33. The mean was 7.00 while 0.21 was the deviation from the

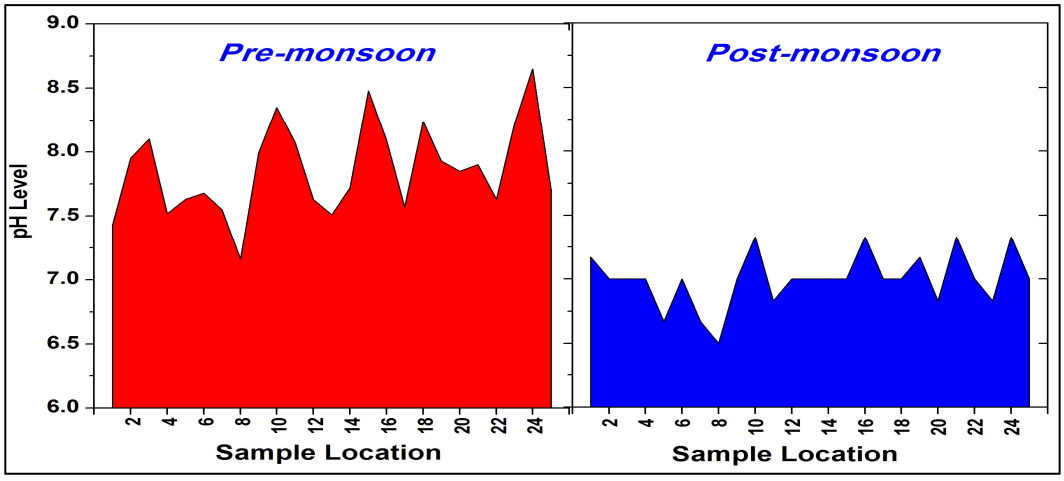

Fig.2.45: *pH* Level in Surface Water

mean. In surface water the lowest (6.50) *pH* level was observed at *Dasharath* during the entire year.

2.5.4 *pH* Level In Sub-Surface Water

The *pH* value was between 6.93 to 7.88 in sub-surface water during pre-monsoon season which reduced to 6.50-7.33 after the rains. In the post monsoon, water was slightly in alkaline condition (Fig.2.46). In both the seasons, the sub-surface water of *Nandesari* had the lowest *pH* value. The average value in pre and post-monsoon seasons was 7.53 and 6.98 respectively whereas 0.20 and 6.98 was deviation from the mean.

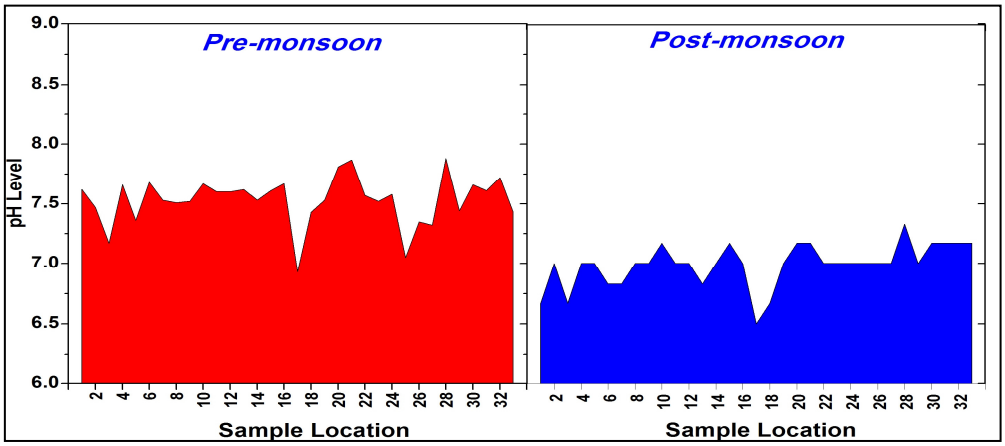

Fig.2.46: *pH* Level in Sub-Surface Water

2.5.5 Concentration *EC* in Surface Water

During the pre-monsoon season, the level of *EC* in surface water varied from 0.63 s/cm^{-1}x 10^{-3} to 2.87 s/cm^{-1}x 10^{-3} with mean of 2.32 s/cm^{-1}x 10^{-3} (Table 2.13). After the monsoon the amount of *EC* ranged from 0.37 s/cm^{-1}x 10^{-3} to 2.76 s/cm^{-1}x 10^{-3}. 1.64

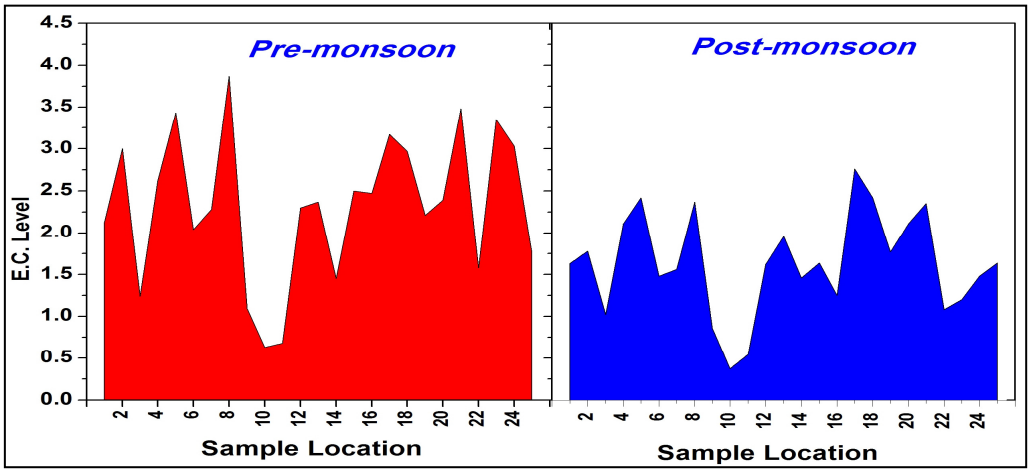

Fig.2.47: Concentration of *EC* in Surface Water

s/cm^{-1}x 10^{-3} was the average. In post-monsoon season the standard deviation indicated relatively lesser variability (Table 2.13).The maximum absorption was noted at *Dasharath* before monsoon and after rains it was observed in *Nandesari*. *Ajod* and *Gorva* had the minimum level in pre and post-monsoon season.

Table 2.13: Surface Water Parameters during Pre and Post-Monsoon Seasons (2011-13)

Parameter	Season	N	Average	Minimum	Maximum	Std. Dev.
TDS	Pre-monsoon	25	1485.61	400.93	2476.00	558.63
TDS	Post-monsoon	25	1046.87	233.85	1767.13	384.33
pH	Pre-monsoon	25	7.86	7.16	8.65	0.36
pH	Post-monsoon	25	7.00	6.50	7.33	0.21
EC	Pre-monsoon	25	2.32	0.63	3.87	0.87
EC	Post-monsoon	25	1.64	0.37	2.76	0.60
Iron	Pre-monsoon	25	2.62	1.61	3.93	0.70
Iron	Post-monsoon	25	1.71	1.05	3.13	0.55
Nitrite	Pre-monsoon	25	38.30	18.45	70.51	10.30
Nitrite	Post-monsoon	25	80.47	52.02	129.31	19.80

The unit of the parameters is in mg/l except EC (s/cm-1x 10-3) and pH, N=Total number of samples

Source: Computed

2.5.6 Concentration *EC* in Sub-Surface Water

In the sub-surface water, the level of *EC* varied between 1.06 s/cm^{-1}x 10^{-3} to 4.43 s/cm^{-1}x 10^{-3} during the pre-monsoon. 2.05 s/cm^{-1}x 10^{-3} was the mean and 0.77 standard deviation. During the post-monsoon, the level stretched between 0.81 s/cm^{-1}x 10^{-3} to 3.12 s/cm^{-1}x 10^{-3}. The mean (1.65 s/cm^{-1}x 10^{-3}) and deviation from the mean (0.55) was lower after the rainfall. In both the seasons, the highest level (>3 s/cm^{-1}x 10^{-}

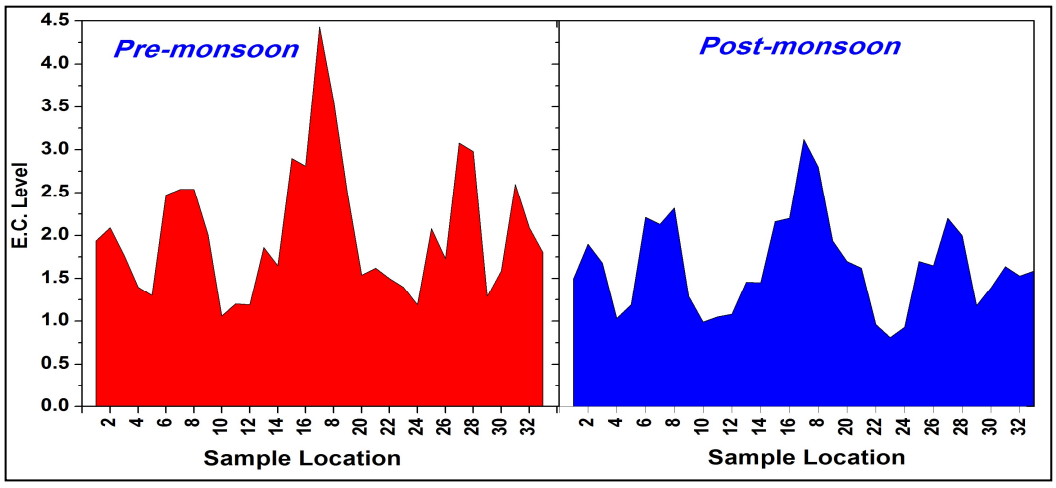

Fig.2.48: Concentration of *EC* in Sub-Surface Water

^{3}) of *EC* was observed at *Nandesari* and the lowest (≤1.6 s/cm^{-1}x 10^{3}) was noted at *Dodka* and *Rayaka* before and after the monsoon season.

Table 2.14: Sub-Surface Water Parameters during Pre and Post-Monsoon Season (2011-13)

Parameter	Season	N	Average	Minimum	Maximum	Std. Deviation
TDS	Pre-monsoon	33	1322.26	678.40	2838.13	489.68
TDS	Post-monsoon	33	1052.81	515.44	1994.89	349.32
pH	Pre-monsoon	33	7.53	6.93	7.88	0.20
pH	Post-monsoon	33	6.99	6.50	7.33	0.18
E.C.	Pre-monsoon	33	2.05	1.06	4.43	0.77
E.C.	Post-monsoon	33	1.65	0.81	3.12	0.55
Iron	Pre-monsoon	33	1.46	0.29	3.59	0.73
Iron	Post-monsoon	33	1.18	0.19	3.90	0.76
Nitrite	Pre-monsoon	33	46.97	26.52	118.45	17.94
Nitrite	Post-monsoon	33	86.21	50.79	137.69	21.39

The unit of the parameters is in mg/ll except EC (s/cm-1x 10-3) and pH, N=Total number of samples

Source: Computed

2.5.7 *Iron* Concentration in Surface Water

Before the rains, the level of *iron* was above the desirable limit (0.3 mg/l). The maximum concentration in surface water was 3.93 mg/l with an average of 2.62 mg/l and 0.70 standard deviation. The lower value of deviation indicated relatively lesser

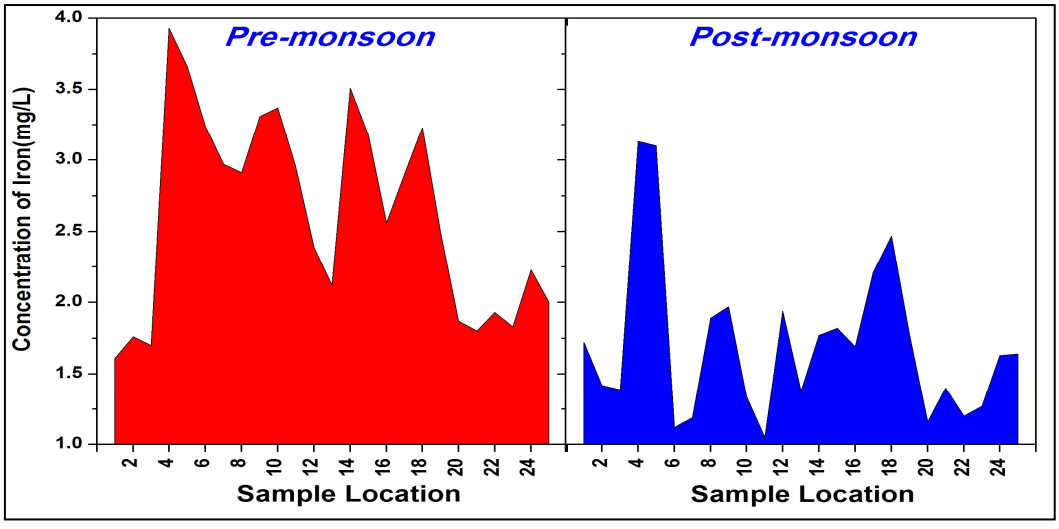

Fig. 2.49: Concentration of *Iron* in Surface Water

variation in the level of *iron* in the year. During the post-monsoon season, the level of *iron* varied between 1.05 mg/l to 3.12 mg/l. The mean was 1.71 and deviation from mean was 0.55.

2.5.8 *Iron* Concentration in Sub-Surface Water

The lowest concentration of *iron* in sub-surface water was 0.29 mg/l and the highest and 3.59 mg/l. In post-monsoon season, it ranged from 0.19 mg/l to 3.90 mg/l. The average level of *iron* was 1.46mg/l before the rains while it reduced to1.18 mg/l after rain. 0.70 and 0.55 were the values of standard deviation in the two seasons. The concentration of *iron* was below the desirable limit (0.19 mg/l) at *Sokhda* village which is far (eastern side) from the *Nandesari* industrial estate.

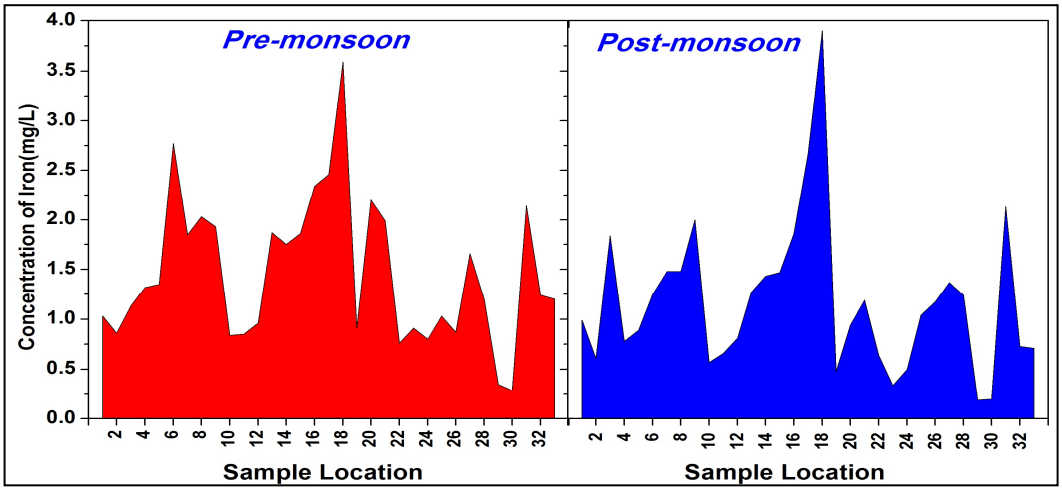

Fig.2.50: Concentration of *Iron* in Sub-Surface Water

2.5.9 *Nitrite* Concentration in Surface Water

During the pre-monsoon season, the concentration of *nitrite* in surface water ranged from 18.45 mg/l to 70.51 mg/l with the average value of 38.30 mg/l and 10.30

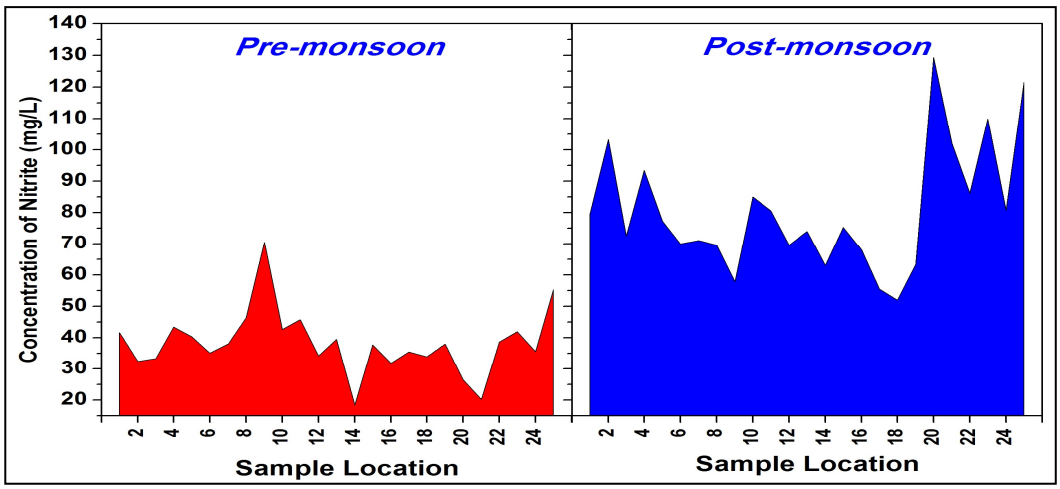

Fig.2.51: Concentration of *Nitrite* in Surface Water

mg/l as the standard deviation. The minimum and maximum level in post-monsoon period was 52.02 mg/l and 129.31 mg/l respectively which was observed at *Sankarda* village. 80.47 mg/l was the mean value and 19.80 was the standard deviation (Table 2.14).

2.5.10 *Nitrite* Concentration in Sub-Surface Water

In sub-surface water, the level of *nitrite* varied between 26.52 mg/l and 118.45 mg/l in pre-monsoon season, whereas in the post-monsoon season, it ranged from 86.21 mg/l to 137.69 mg/l. The maximum concentration during pre-monsoon was found at *Vasna-Kotariya* village while it was noted at *Sankarda* after the rains. The average *nitrite* level in pre and post-monsoon was 46.97 mg/l and 86.21 mg/l respectively. The level of *nitrite* in sub-surface water increased in the post-monsoon period. 17.94 and 21.39 was the standard deviation in the two seasons.

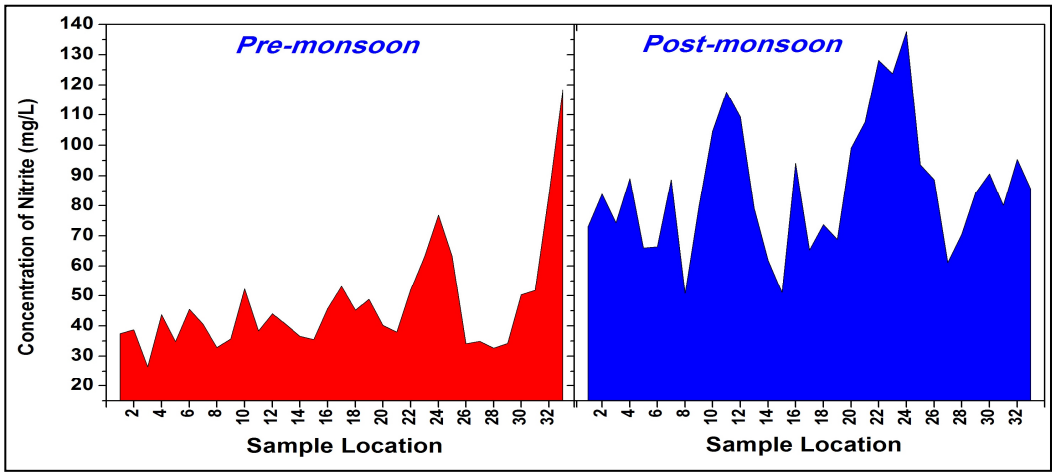

Fig.2.52: Concentration of *Nitrite* in Sub-Surface Water

2.6 SPATIAL AND SEASONAL PATTERN OF AVERAGE LEVEL OF PARAMETERS

2.6.1 *TDS* Concentration in Surface Water

The concentration of *TDS* in both the surface and sub-surface water declined after the rains. In the pre-monsoon season, the higher level (>1000 mg/l) was noted in the surface water in the entire region except for some isolated patches located in the southern and south-central part. The level of *TDS* decreased after the rains. An area of 100.41 sq.km. confined in the northern part had *TDS* >1000 mg/l and the maximum level (>2000 mg/l) was observed in the western side.

During the pre-monsoon season, 94.43% of the total area had *TDS* >1000 mg/l. The area with >1000 mg/l shrinked to 67.16% during post-monsoon. The patches of high concentration in surface water (>2000 mg/l) was observed in the eastern and western sector during pre-monsoon. Lowest was noted in the southern part. During post-monsoon period, the level of *TDS* gradually decreased from north-western side to the southern part. In this season, the area of lower concentration of *TDS* (<500 mg/l) increased from 0.85 sq.km. (0.57% of the total area) to 4.68 sq.km. (3.13% of the total area).

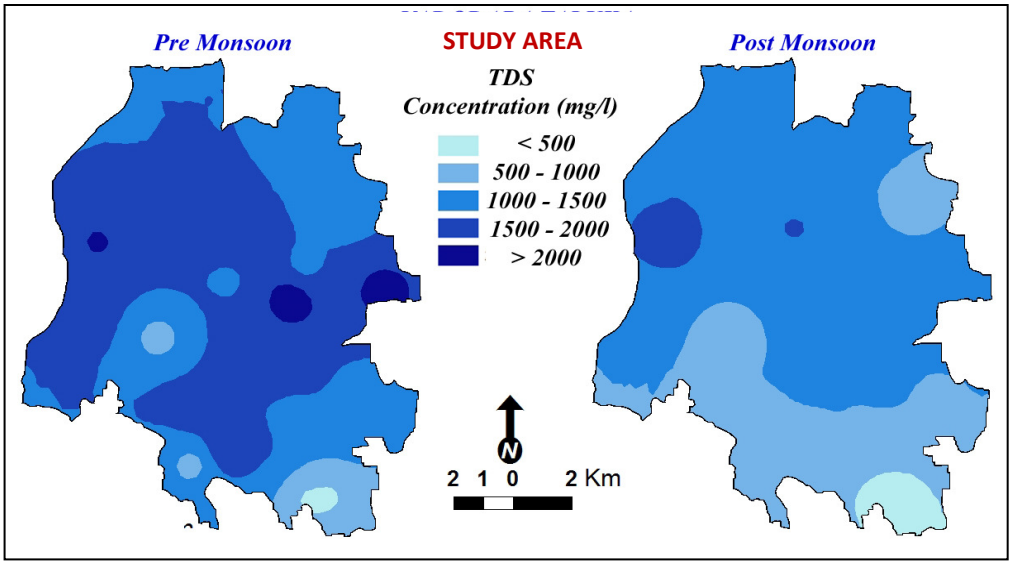

Fig.2.53: Concentration of *TDS* in Surface Water

Table 2.15: Area of *TDS* Concentration in Surface Water (2011-13)

Concentration (mg/l)	Pre-monsoon		Post-monsoon		Change of Area (%)
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	
<500	0.85	0.57	4.68	3.13	2.56
500-1000	7.96	5.32	44.42	29.71	24.39
1000-1500	55.54	37.15	95.44	63.84	26.69
1500-2000	81.67	54.63	4.97	3.32	-51.30
>2000	3.49	2.33	0	0.00	-2.33
Total	149.51	100.00	149.51	100.00	0.00

Source: Computed

2.6.2 *TDS* Concentration in Sub-Surface Water

In pre-monsoon season, the sub-surface water, 135.35 sq.km. of area had >1000 mg/l of *TDS* whereas in this period <1000 mg/l of *TDS* was spread over 14.15 sq.km. of

area. Before the rains, the western and south-eastern sites had the highest concentration while the lower level was confined to the north-western side and in isolated pockets lying on the south and north-east. During post-monsoon the area with >1000 mg/l reduced from 135.35 sq.km. to 72.78 sq.km. In the post-monsoon, the area with concentration <1000 mg/l increased from 14.15 sq.km. to 40.70 sq.km. The lower concentration at this time was observed in the north and south.

Table 2.16: Area of *TDS* Concentration in Sub-Surface Water (2011-13)

Concentration (mg/l)	Pre-monsoon		Post-monsoon		Change of area (%)
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	
<500	0	0	0	0	0
500-1000	14.15	9.46	40.7	27.22	17.76
1000-1500	93.66	62.65	103.87	69.48	6.83
1500-2000	36.9	24.68	4.94	3.3	-21.38
>2000	4.8	3.21	0	0	-3.21
Total	149.51	100	149.51	100	0

Source: Computed

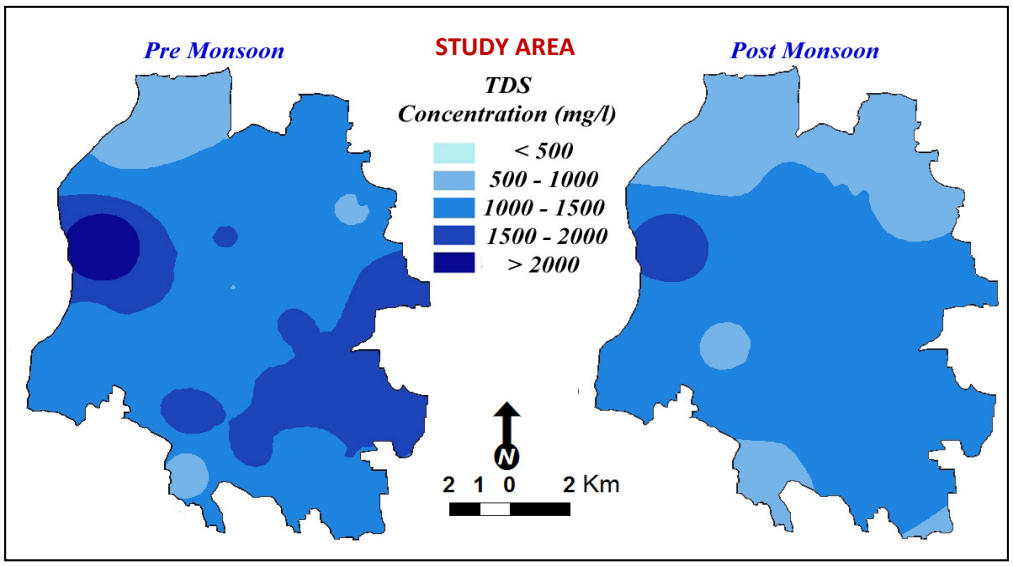

Fig.2.54: Concentration of *TDS* in Sub-surface Water

2.6.3 *pH* Level in Surface Water

In the pre-monsoon season, *pH* value of surface water depicted slightly alkaline condition. Only a very small pocket of higher alkalinity (>8.5 *pH* level) was observed in the southern part (Fig.2.55). In this season, 70.62% of the area of surface water (105.23 sq.km.) had the *pH* level between 7.5 to 8. The 8-8.5 *pH* value was

noted in the southern and central parts spreading over 27.02 sq.km. In the eastern part the *pH* value was 7 to 7.5 and it covered an area of 16.97 sq.km.

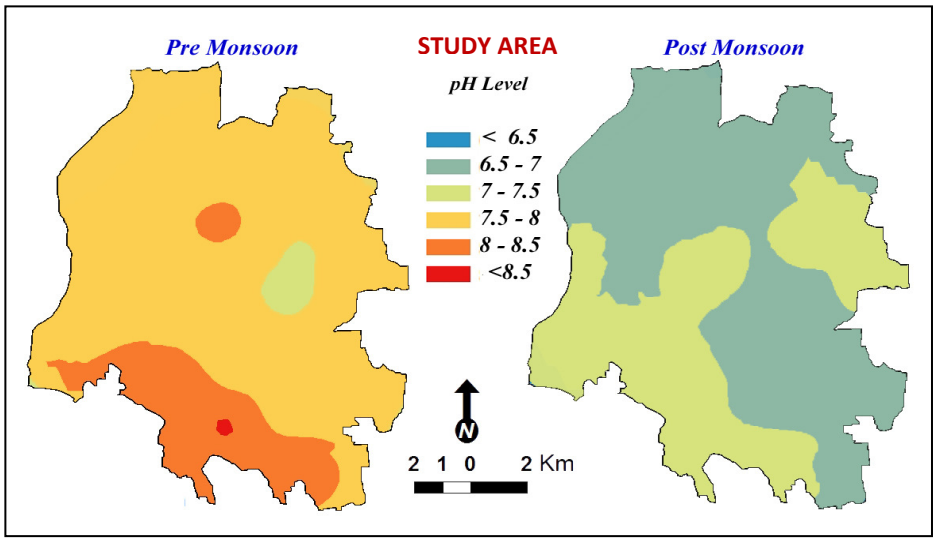

Fig.2.55: *pH* Level in Surface Water

Table 2.17: Area of *pH* Level Surface Water (2011-13)

pH Level	Pre-monsoon		Post-monsoon		Change of area (%)
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	
< 6.5	0	0	0	0	0
6.5 - 7	0	0	89.82	60.07	60.07
7 - 7.5	16.97	11.35	59.69	39.93	28.58
7.5 - 8	105.24	70.39	0	0	-70.39
8 - 8.5	27.02	18.07	0	0	-18.07
>8.5	0.28	0.19	0	0	-0.19
Total	149.51	100.00	149.51	100	0.00

Source: Computed

After the rainfall, *pH* in surface water reduced in the entire region (Table 2.17). In an area of 89.82 sq.km. the *pH* value was 6.5 to 7 and in 59.69 sq. km it was between 7 to 7.5. The *pH* value (6.5 to 7) of surface water indicated an increase of 60.08% of the area from pre to post-monsoon. This segment extended from north and north-western to the south and south-east. In the western, southern and eastern parts the *pH* value was 7 to 7.5 covering an area of 59.69 sq.km.

2.6.4 *pH* Level in Sub-Surface Water

In sub-surface water, the level between 7.5 to 8 was observed in 95.57 sq.km. During pre-monsoon, alkalinity was higher in the eastern side rather than the west. In

post-monsoon, northern, eastern, central and southern parts had higher *pH* value (7 to 7.5) covering >64.98 sq.km. of area (Fig.2.56). During pre-monsoon, the *pH* level of 6.5 to 7 was noted in 1.14 sq.km. area (0.76% of the total area). It increased to 84.57 sq.km. (56.57%) after the rains.

Table 2.18: Area of *pH* Level Sub-Surface Water (2011-13)

pH Level	Pre-monsoon		Post-monsoon		Change of of area (%)
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	
< 6.5	0	0		0	0
6.5 - 7	1.14	0.76	84.57	56.56	55.80
7 - 7.5	51.64	34.54	64.94	43.44	8.90
7.5 - 8	96.73	64.70	0	0	-64.70
8 - 8.5	0	0.00	0	0	0.00
>8.5	0	0.00	0	0	0.00
Total	149.51	100.00	149.51	100	0.00

Source: Computed

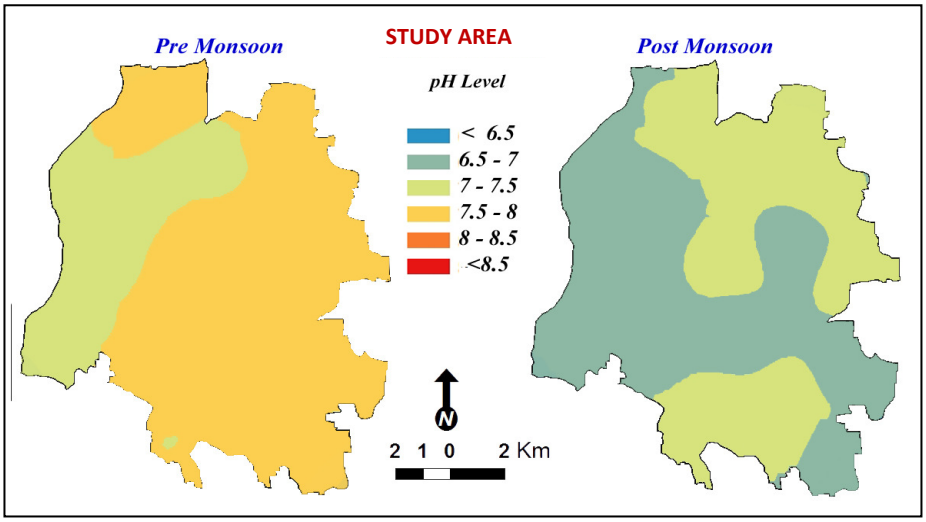

Fig.2.56: *pH* Level in Sub-Surface Water

2.6.5 *EC* Level In Surface Water

During pre-monsoon, the level of *EC* >2s/cm^{-1}x 10^{-3} in surface water covered the maximum parts (120.80 sq. km) comprising 81.07% of the area. It was noted at western, north western and eastern segment. In the north-eastern and southern most part the concentration of *EC* between 1.5 to 2 s/cm^{-1}x 10^{-3} was noted in the area of 20.63 sq. km (13.85%). The lowest concentration (0.5-1 s/cm^{-1}x 10^{-3}) was observed in the southern most part covering 2.72 sq. km (1.83%). In post-monsoon, the area of concentration >2 s/cm^{-1}x 10^{-3} decreased and was confined to the western and eastern

segments which stretched over an area of 36.48 sq. km (24.40%). The maximum area (74.40 sq. km) was occupied with the concentration of 1.5-2 s/cm^{-1}x 10^{-3} *EC* which was located at the northern and central parts. The level of *EC* in surface water decreased towards south. The lowest level (0.5 -1 s/cm^{-1}x 10^{-3}) of *EC* was noted in the south comprising of 4.86% (7.26 sq. km) of the area (Fig.2.57).

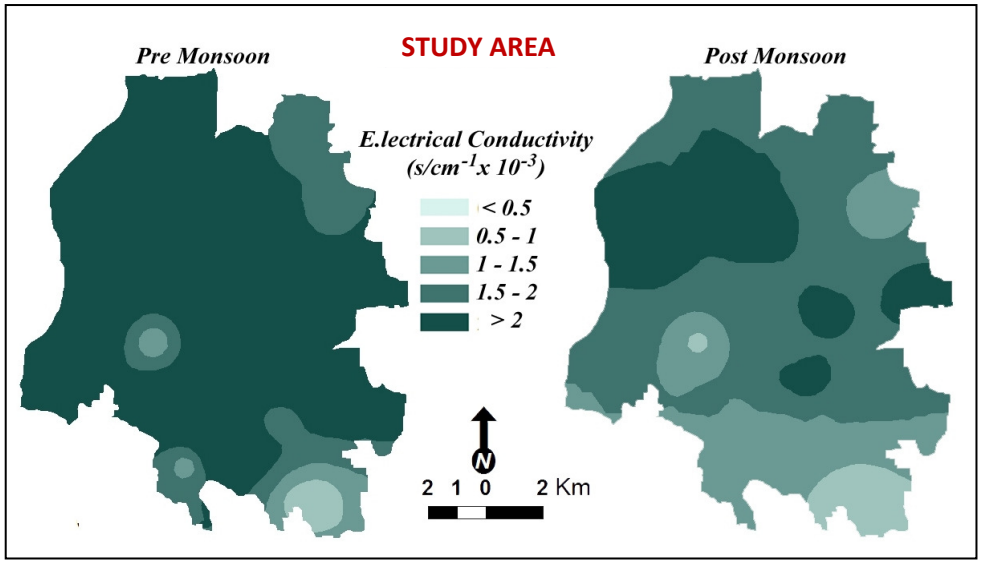

Fig.2.57: Concentration of *EC* in Surface Water

Table 2.19: Area of *EC* Level In Surface Water (2011-13)

EC level	Pre-monsoon		Post-monsoon		Change of of area (%)
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	
<0.5	0	0	0	0	0
0.5 - 1	2.72	1.82	7.26	4.86	3.04
1 - 1.5	5.33	3.56	31.37	20.98	17.42
1.5 - 2	20.63	13.80	74.4	49.76	35.96
>2	120.83	80.82	36.48	24.40	-56.42
Total	149.51	100.00	149.51	100.00	0.00

Source: Computed

2.6.6 *EC* Level in Sub-Surface Water

In the pre-monsoon season, the entire study area had an EC >1 s/cm^{-1}x 10^{-3}. The western, southern and eastern sectors >2 comprised of 94.30 sq. km area (63.08% of the area) had >2 s/cm^{-1}x 10^{-3}. 29.13% of the area (43.55 sq. km) had 1.5 to 2 s/cm^{-1}x 10^{-3} *EC* which was spread over north, north eastern and central parts. 1 to 1.5 s/cm^{-1}x

10^{-3} *EC* covered an area of 11.66 sq. km (7.80% of the area) in the northern part (Fig.2.58). During the post-monsoon season, the area of *EC* >2 s/cm^{-1}x 10^{-3} shrinked and was confined in the western and eastern parts covering an area of 17.17 sq. km

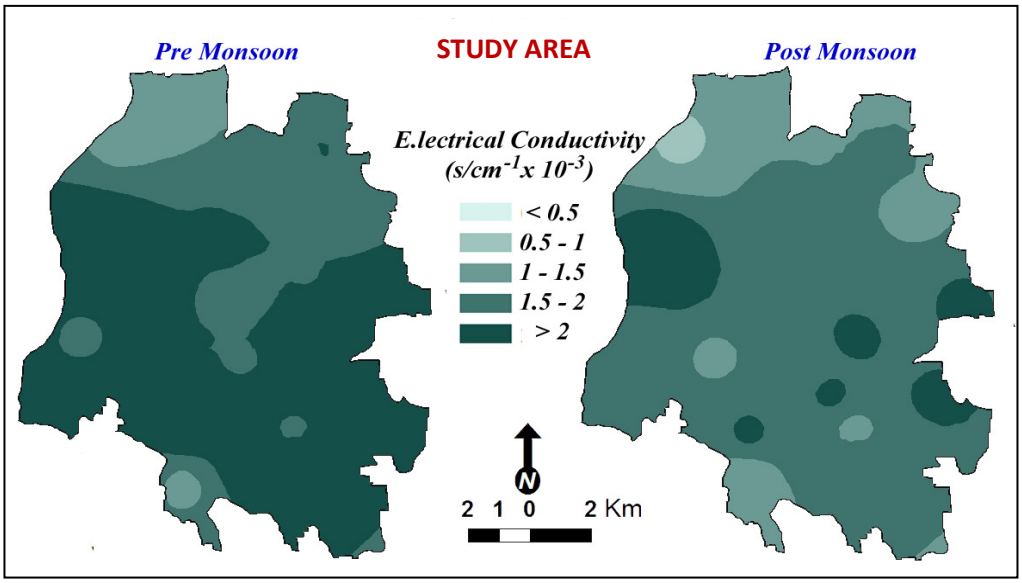

Fig.2.58: Concentration of *EC* in Sub-Surface Water

(11.55%). The area of concentration 1-1.5 s/cm^{-1}x 10^{-3} and 1.5 -2 s/cm^{-1}x 10^{-3} was larger in this season than the pre-monsoon. The north, north-eastern and small pocket of south had the 1-1.5 s/cm^{-1}x 10^{-3} of *EC* encompassing an area of 29.69 sq. km (19.86%). The level of *EC* between 1.5 s/cm^{-1}x 10^{-3} and 2s/cm^{-1}x 10^{-3} was noticed in the entire study region except in extreme north and small patches in south. It constituted 67.38% of the area (100.74 sq. km). A small area (1.81 sq. km) in the northern part depicted 0.5 – 1 s/cm^{-1}x 10^{-3} of *EC*.

Table 2.20: Area of *EC* Level In Sub-Surface Water (2011-13)

EC level	Pre-monsoon		Post-monsoon		Change of of area (%)
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	
<0.5	0	0	0	0	0
0.5 - 1	0	0	1.81	1.21	1.21
1 - 1.5	11.66	7.80	29.69	19.86	12.06
1.5 - 2	43.55	29.13	100.74	67.38	38.25
>2	94.3	63.07	17.27	11.55	-51.52
Total	149.51	100.00	149.51	100.00	0.00

Source: Computed

2.6.7 *Iron* Concentration in Surface Water

High concentration of *iron* (>1.5 mg/l) in surface water was noted in the region. During pre-monsoon, the section which extended from west to south east- showed the highest concentration (>2.5 mg/l) of *iron* and covered an area of 79.16 sq.km. (52.95%). In the northern and eastern parts, the major area with concentration of 2-2.5 mg/l was noted. Relatively lower level (1.5-2mg/l) was observed in north-eastern side and as isolated pockets in western and southern parts.

After the monsoon, the intensity of *iron* trimmed down (Fig.2.59). The concentration of >2.5 mg/l was restrained only in a small area of southern part covering 1.65 sq. km (1.10% of the area). 107.91 sq. km (72.18%) of area had 1.5-2 mg/l of *iron* (Table 2.21). While, >1.5 mg/l of *iron* in surface water stretched over 28.22 sq.km. of area. Major portion of this level of concentration was noticed in the eastern and south-eastern sector (Fig.2.59).

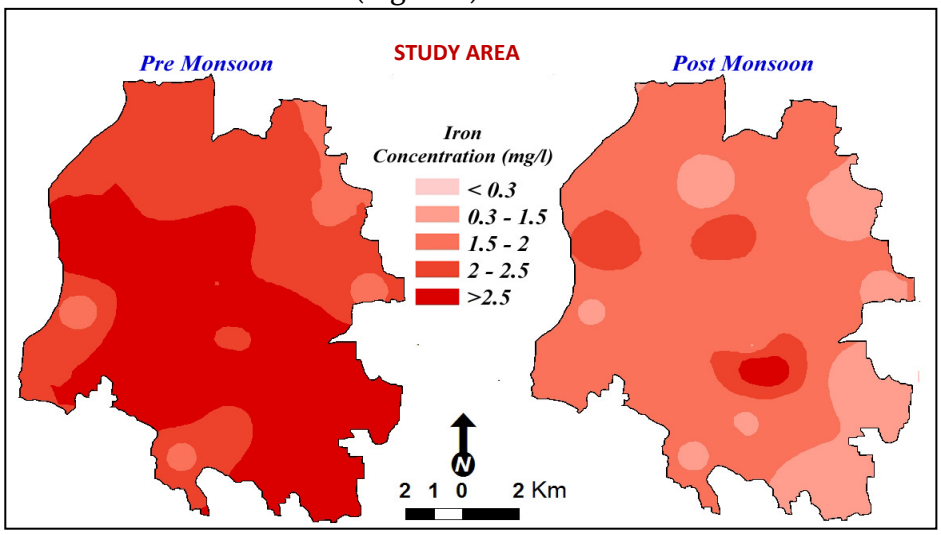

Fig.2.59: Concentration of *Iron* in Surface Water

Table 2.21: Area of *Iron* Concentration in Surface Water (2011-13)

Concentration (mg/l)	Pre-monsoon		Post-monsoon		Change of of area (%)
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	
>0.03	0	0	0	0	0
0.03-1.5	0	0	28.23	18.88	18.88
1.5 - 2	8.28	5.54	107.91	72.18	66.64
2 - 2.5	62.07	41.52	11.72	7.84	-33.68
>2.5	79.16	52.95	1.65	1.10	-51.84
Total	149.51	100.00	149.51	100.00	0.00

Source: Computed

2.6.8 *Iron* Concentration in Sub-Surface Water

In sub-surface water, the level of *iron* progressively increased from north and north-east to west and south. The highest level of *iron* (>1.5 mg/l) before the monsoon

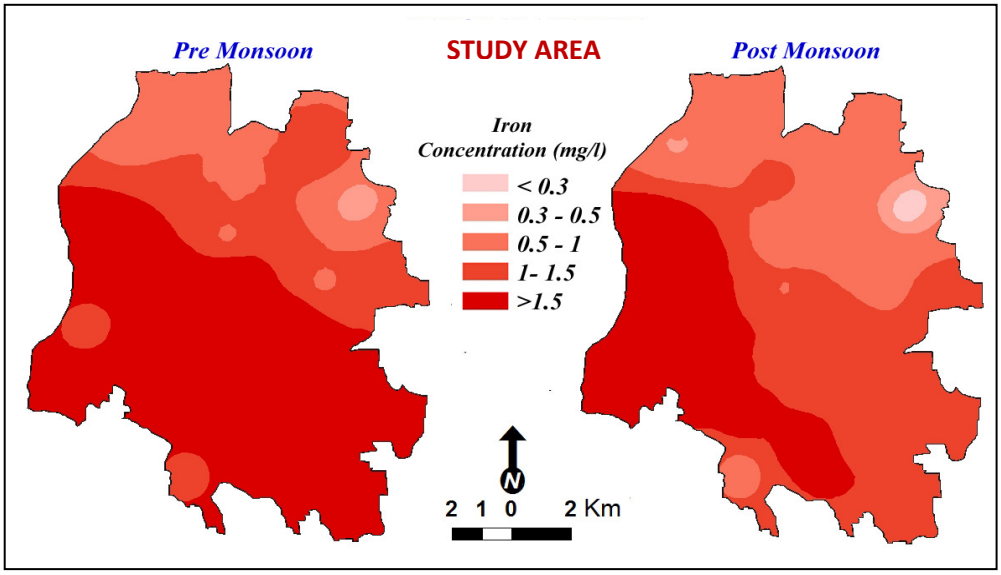

Fig.2.60: Concentration of *Iron* in Sub-surface Water

covered an area of 87.97 sq.km. (58.84% of the total area). In this season, the area of *iron* in sub-surface water increased with an enhancement of its concentration. In the post-monsoon season, the level >1.5 mg/l extended over 42.37 sq.km. (28.34% of the total area). 58.56 sq.km. had the concentration between 1 to 1.5 mg/l. A small area of lower concentration >0.3 mg/l was noted in the north eastern part during this season (Fig.2.60).

Table 2.22: Area of *Iron* Concentration in Sub-Surface Water (2011-13)

Concentration (mg/l)	Pre-monsoon		Post-monsoon		Change of of area (%)
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	
>0.03		0	0.95	0.64	0.64
0.03-0.5	1.33	0.89	2.99	2.00	1.11
0.5 - 1	24.03	16.07	44.64	29.86	13.79
1 - 1.5	36.18	24.2	58.56	39.17	14.97
>1.5	87.97	58.84	42.37	28.34	-30.50
Total	149.51	100.00	149.51	100.00	0.00

Source: Computed

2.6.9 *Nitrite* Concentration in Surface Water

In the pre-monsoon season, high *nitrite* concentration in surface water was observed in the northern and south-western segment (Fig.2.61). In surface water, prior to rains 136.99 sq.km. (91.94% of the total area) had *nitrite* concentration of <45 mg/l. Whereas 12.52 sq.km. (8.40%) had >45 mg/l of *nitrite*. The concentration <45 mg/l of *nitrite* increased in the post-monsoon season. After the rains the level of *nitrite* in surface inflated tremendously. 96.6 sq.km. (65.95% of the total area) had *nitrite* concentration between 65 to 85 mg/l while >85 mg/l of concentration was found in 44.14 sq.km. (29.53% of the total area) (Table 2.23). Thus, 95.48% of the study area had remarkably high level of *nitrite* (>65 mg/l) in surface water.

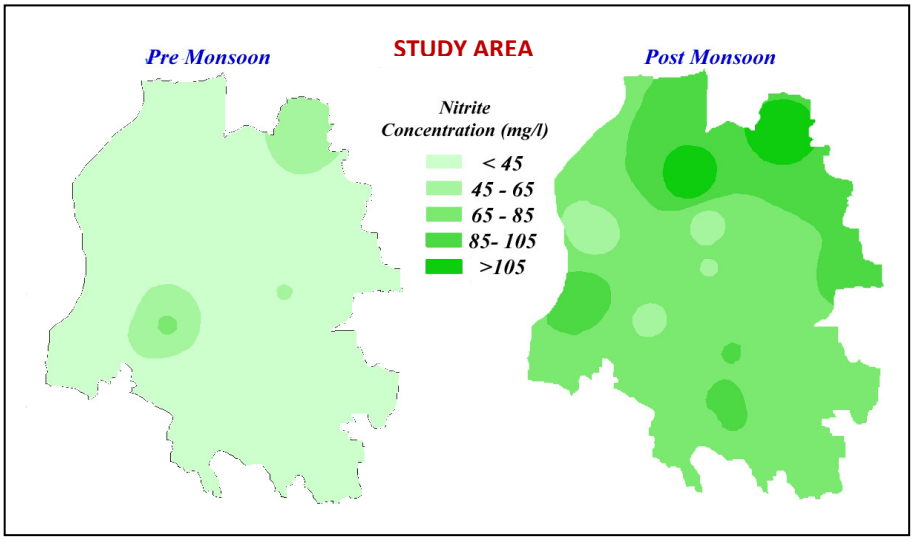

Fig.2.61: Concentration of *Nitrite* in Surface Water

Table 2.23: Area of *Nitrite* Concentration in Surface Water (2011-13)

Concentration (mg/l)	Pre-monsoon		Post-monsoon		Change of of area (%)
	Area (sq. km)	Area (%)	Area (. km)	Area (%)	
0-45	136.99	91.63	0	0	-91.63
45-65	12.1	8.09	6.69	4.47	-3.62
65-85	0.42	0.28	98.68	66.00	65.72
85 - 105	0	0.00	35.64	23.84	23.84
>105	0	0.00	8.5	5.69	5.69
Total	149.51	100.00	149.51	100.00	0.00

Source: Computed

2.6.10 *Nitrite* Concentration in Sub-Surface Water

The concentration of *nitrite* in the sub-surface water in the pre-monsoon season was low (Table 2.24). 86.04 sq.km. area, largely confined to the south of the

study area had <45 mg/l of *nitrite*. In terms of sub-surface water, the study region can be grouped into two halves viz northern with >45 mg/l of *nitrite* and southern with <45 mg/l (Fig2.62). The concentration between 45mg/l to 65 mg/l was noticed in 54.91 sq.km. In the pre-monsoon, the area of 6.11 sq.km. and 2.44 sq.km. had concentration between 65 to 85 mg/l and >85 mg/l respectively. During post-monsoon, this concentration (65 to 85 mg/l and >85 mg/l) increased from 6.11 sq.km. to 92.57 sq.km. and 2.44 sq.km. to 37.40 sq.km. respectively. The former was located at southern, eastern and western parts covering 66.12% of the study area (Fig.2.62). While the later, was confined to northern part comprising of 26.71% of area. An area with 85 to 105 mg/l of *nitrite* increased from 2.44 sq.km. to 37.40 sq.km. (26.71%) from pre to post-monsoon season (Table 2.24).

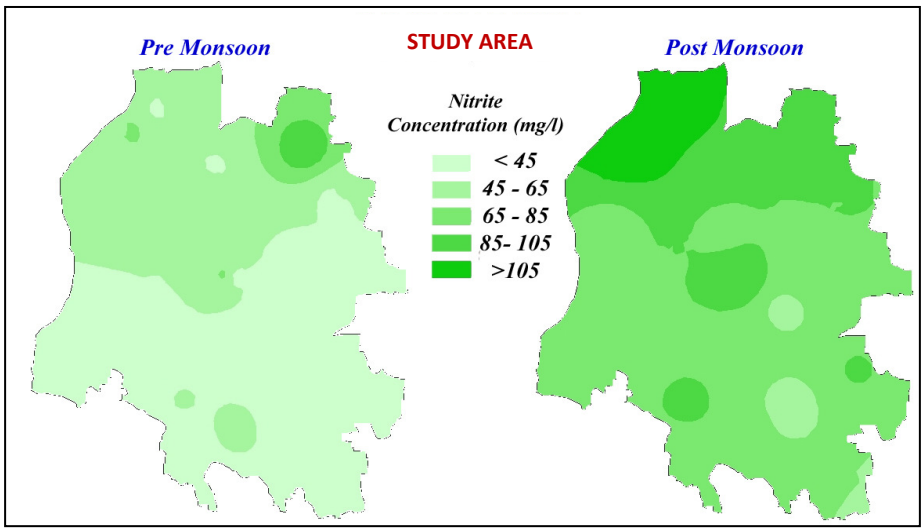

Fig.2.62: Concentration of *Nitrite* in Sub-surface Water

Table 2.24: Area of *Nitrite* Concentration in Sub-Surface Water (2011-13)

Concentration (mg/l)	Pre-monsoon		Post-monsoon		Change of of area (%)
	Area (sq.km.)	Area (%)	Area (sq.km.)	Area (%)	
0-45	86.04	57.55	0	0	-57.55
45-65	54.91	36.73	6.05	4.05	-32.68
65-85	6.12	4.09	92.57	61.92	57.82
85 - 105	2.44	1.63	37.4	25.02	23.38
>105	0	0.00	13.49	9.02	9.02
Total	149.51	100.00	149.51	100.00	0.00

Source: Computed

2.7 RELATIONSHIP AND SEASONAL VARIABILITY OF WATER PARAMETER

Pair t-test is a statistical technique for hypothesis testing used to determined compared the mean of the same sample in different time periods (Shier,2004). Initially

two hypothesis were proposed for the test if the test result is less than the tabulated 't' value null hypothesis is accepted i.e. there is no significant change between before and after. If the test value is more than the tabulated 't' value then the alternative hypothesis is accepted i.e there is a significant variation in the mean of the sample.

2.7.1 Surface Water Parameters

Pair 't' test was performed on the both the data set of pre and post-monsoon season. All the parameters of the surface and sub-surface water viz. *TDS*, *pH*, *EC*, *iron* and *nitrite* were incorporated in the test. These pair for surface water were designated as pair 2T, pair 2P, pair 2E, pair 2I and pair 2N respectively for pre-monsoon. All the pairs depicted positive correlation except for the pairs of *nitrite*. Strong positive relation existed in the pair of *TDS* and *EC* (Table 2.25). While the pairs of *nitrite* had negative correlation (-0.06).The tabulated value of pair 't' test with 24 degree of freedom at 95% significance level for surface water is 2.064. The result obtained from the pair 't' test showed the value of 6.50, 13.94, 6.50, 7.62 and 9.21 for *TDS*, *pH*, *EC*, *iron* and *nitrite* respectively. Thus, it is concluded that the calculated value of 't' is higher than tabulated value which leads to the rejection of null hypothesis and acceptance of the alternative hypothesis. All the parameters showed significant variation in mean concentration during pre-monsoon and post-monsoon season in surface water.

Table 2.25: Pair of Pre and Post-Monsoon Season of Surface Water for Seasonal Variability (2011-13)

Parameter	Pair Name	N	Correlation	t	df	Sig.(2-tailed)
TDS	Pair 2T	25	0.806	6.509	24	0
pH	Pair 2P	25	0.503	13.942	24	0
EC	Pair 2E	25	0.806	6.509	24	0
Iron	Pair 2I	25	0.569	7.627	24	0
Nitrite	Pair 2N	25	-0.061	-9.218	24	0

df= degree of freedom,the analysis was done at 95%significance level.

Source: Computed

2.7.2 Sub-surface Water Parameter

For the sub-surface water, the pairs of *TDS*, *pH, EC*, *iron and nitrite* were coded as pair 1T, pair 1P, pair 1E, pair 1I and pair IN respectively for both the season.

All the pairs indicated the positive correlation. The pairs of *TDS, iron and EC* showed high positive relationship with the value of (+)0.93, (+)0.83 and (+)0.92 respectively. The table value of 't' with 32 degree of freedom at 95% significance level was 2.0369. The calculated pair 't' test value for *TDS*, *pH, EC, Iron and nitrite* were 7.42, 17.97, 7.42, 3.89 and -10.11. It revealed that there was variation in the mean level of parameter in sub-surface water before and after the monsoon.

Table 2.26: Pair of Pre and Post-Monsoon Season of Sub-Surface Water for Seasonal Variability (2011-13)

Parameter	Pair Name	N	Correlation	t	df	Sig.(2-tailed)
TDS	Pair1T	33	0.93	7.42	32	0
pH	Pair1P	33	0.596	17.976	32	0
EC	Pair1E	33	0.926	7.42	32	0
Iron	Pair1I	33	0.836	3.894	32	0
Nitrite	Pair1N	33	0.368	-10.111	32	0

df= degree of freedom,the analysis was done at 95%significance level.

Source: Computed

2.8 DISCUSSION

The level of *TDS* in surface and sub-surface water was higher than the desirable limit (500 mg/L) in both the pre and post-monsoon seasons except for a small patch in the southern part. While the far village *Gorva* and *Ankodiya* had the lowest concentration during pre and post-monsoon in all the years. The higher concentration during different seasons was noted near the industrial estate i.e *Nandesari* GIDC, IPCL and GSFC. In the region, the industrial waste was deposited in the open space and the liquid waste was released in the effluent channel. According to WHO, 2003, the industrial waste is one of the reason of higher level of *TDS* in water. The industrial effluent from the petrochemical industry is also the major source of *TDS* (Verma, 2011).

During the pre-monsoon season, both the surface and sub-surface water showed higher level *TDS*. In the post-monsoon, the concentration of *TDS* in surface and sub-surface water decreased but the level was still above the desirable limit. One of the governing factors behind higher level of *TDS* during pre monsoon might be due to lowering down of surface water level due to evaporation during summer season.

The *pH* level of surface and sub-surface water was under the desirable limit, but during the pre-monsoon season the *pH* level in surface water showed slightly alkaline condition. In surface water, throughout the time period, the southern part had higher *pH* level which was near the *Nandasari* GIDC and IPCL. In sub-surface water the western part had lower concentration of *pH*. During post-monsoon season, the relatively lower level of *pH* was observed near the industrial estates. The surface water had more alkaline condition than the sub-surface water during pre-monsoon

Fig.2.63: Industrial Waste at *Nandesari* GIDC
Source: Photograph during Field Visit

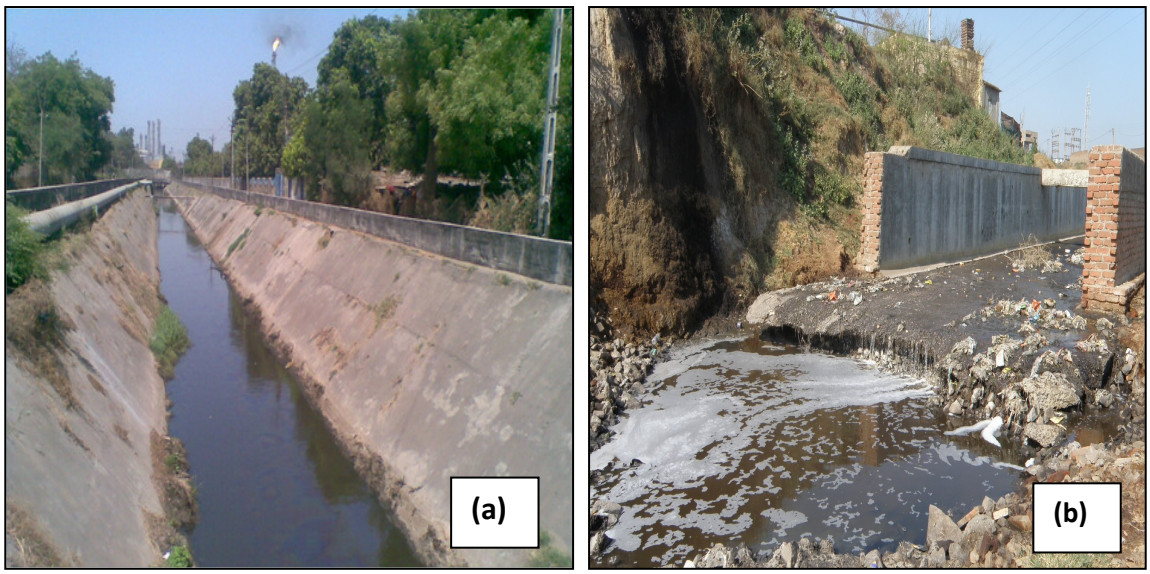

Fig.2.64: Effluent Channels (a) From IPCL at *Koyli* and (b) at *Nandesari* GIDC
Source: Photograph during Field Visit

season. During the post-monsoon season there was a considerably lower level of *pH* which might be due to the influence of rain water (Vaishali and Punita, 2013).

The level of *iron* in surface water was much higher than the desirable limit in the entire region. The higher concentration throughout the time period indicated the presence of iron in the area. Comparatively lower concentration of *iron* was depicted in the northern part during pre and post-monsoon seasons. Higher concentration was noted near the industrial estate. It might be due to the influence of industrial units such as discharging iron containing waste products and other industrial effluents (Thomas, et al. 2011). The concentration of *iron* in surface and sub-surface water was more during pre-monsoon season than in the post-monsoon season. Dilution of surface water with the rain water might be one of the reasons. The concentration of *iron* in surface water was high in both the seasons. During pre-monsoon season, high level of *iron* in water was noticed near *Nandesari* GIDC, IPCL and GSFC while after the rains the entire region had the high concentration of *iron* except the sub-surface water in the north-east.

Nitrite concentration in surface water was comparatively lower during pre-monsoon season. The high concentration during post-monsoon might be due to the discharge of sewage effluent and dilution of domestic waste (Thomas et al., 2011). Another reason for the higher concentration of *nitrite* after the rains was due to the application of nitrogenous fertilizers to agricultural land which drains during the rainy season and mixes with the surface water (Thomas, et al. 2011). During the field visit, it was observed that in most of the villages there was lack of proper sanitary system and animal rearing was practiced in open space. The contamination of water with human or animal wastes through runoff is also one of the factors for high *nitrite* level in post-monsoon season (WHO, 2011.). The concentration of *nitrite* water increased during post-monsoon season. Higher *nitrite* concentration in the season was also observed near the agricultural field and in a small area near *Nandesari* (in surface water) and adjoining the GSFC (in sub-surface water) which is a major industry in the study area producing fertilizers, chemicals, and petrochemicals and agricultural

products. The increasing use of chemical fertilizers and the disposal of generated wastes in the vicinity are the main factors responsible for the progressive increase of *nitrite* level in groundwater (WHO, 2011). When the *nitrites* containing industrial waste are dumped into the barren land, it can easily percolate down and pollute the sub-surface water.

Seasonal variability in the concentration of water parameters was observed. During the post-monsoon, the level of all parameters decreased except *nitrite*. It may be due to the dilution with rain water.

Resume

In this chapter, the characteristics of surface and sub-surface water were analysed with TDS, pH, EC, iron and nitrite for pre and post-monsoon season. High concentration of TDS and iron were observed particularly near the industrial areas. Statistical analysis (t-test) showed the significant variation in the level of parameters during different season. The following chapter analyses the more parameters (magnesium, sodium, potassium, calcium, TDS, pH, EC, iron and nitrite) in surface water for three (03) seasons.