Chapter– 4

Spatial and Seasonal Pattern of Geochemical Properties of Soil

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Spatial and Seasonal Pattern of Geochemical Properties of Soil

4.1 INTRODUCTION

Contemporarily, many studies focus on soil contamination and report an increasing trend of pollution. Thus, soil pollution has become a point of concern for further research. The emissions from industries which are released to atmosphere and subsequently get settled on the surface of the earth and the disposal of solid wastes are the major cause of soil pollution. Many studies have stated that properties of soil have been changing due to discharge of effluents from the industries (Swaminatha and Ravi 1987, Sivakumar and John de Brito 1995, Nagaraju et al. 2007). These contaminated soils may mix with surface and sub-surface water and ultimately affect the water quality. Al-Khashman (2004) and Isaac et al. (2004)und that the presence of heavy metals even at trace levels in soils and sediments play a vital role in human life because plants absorb the pollutants from the soil and in the process of food chain they are consumed by human. Krishna and Govil, 2007 stated that heavy metals such as *iron, copper, lead* and *zinc* are naturally available on the earth crust. However, industrial activities increase their level in the water and soil (Nilgun et al., 2004; Facchinelli et al., 2001 and Jonathan et al., 2004). A few studies are also related to grain size and concentration of heavy metals in soil. The study by Parizanganeh

(2008) shows that the concentration of different parameters in the sediment and concluded that the level of contamination in the soil not only depended on the depositional environment, anthropogenic and lithologic sources and mineralogical composition of the sediment but also on the grain size. It was noted that the absorption of substances increased with the decrease of grain size (Zhu et at., 2006). A study at north-western Spain stated that the particle size as well as industrial, urban and rural waste dumping sites play an important role in the level of metal concentration in the sediment (Rubio, et al., 2000). In the present chapter, concentration of heavy metals such as *iron* and *nitrite* in top-soil as well as sub-soil were analysed from the samples collected from 22 sample sites during pre and post-monsoon season from 2011 to 2013 (Fig.4.1). The results are presented in this chapter.

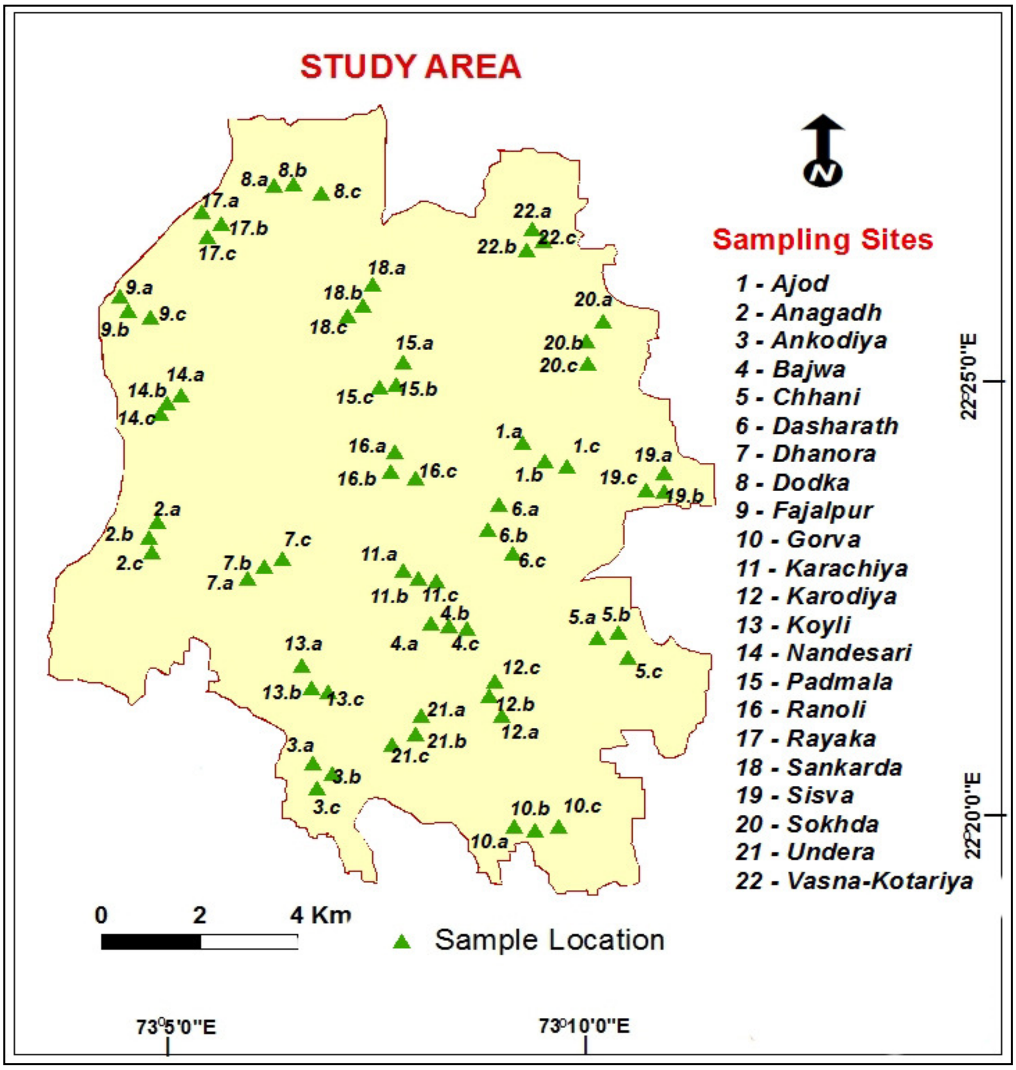

Fig.4.1: Top Soil Sampling Location

Another segment of the chapter is analysing the relationship between grain size distribution and concentration of *iron* and *nitrite* in soil. Sub-soil samples along the Mini river were also taken for analysis.

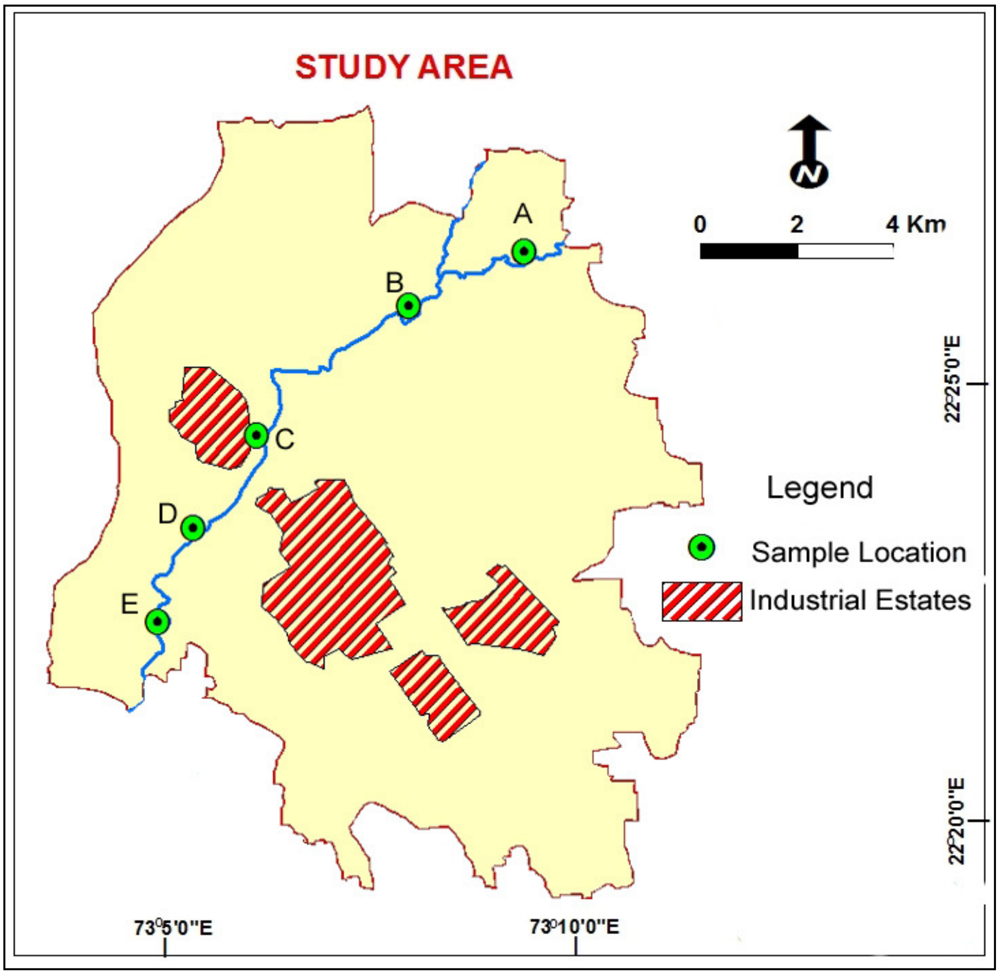

Fig.4.2: Sub-soil Sampling Location

4.2 CHARACTERISTICS OF SOIL

4.2.1 Concentration of *Iron*

During the pre-monsoon, the concentration of *iron* in soil gradually increased from 2011 to 2013 (Table 4.1). In the three years, the highest average level was noted in 2013 (8.57 mg/kg). In 2011, the maximum concentration was at *Ranoli* (14.50 mg/kg) while the minimum was noted at *Padmala*. In 2012 and 2013, *Bajwa* showed the highest level (Fig.4.2) and *Vasna-Kotariya* depicted the lowest. 2.23 was the value

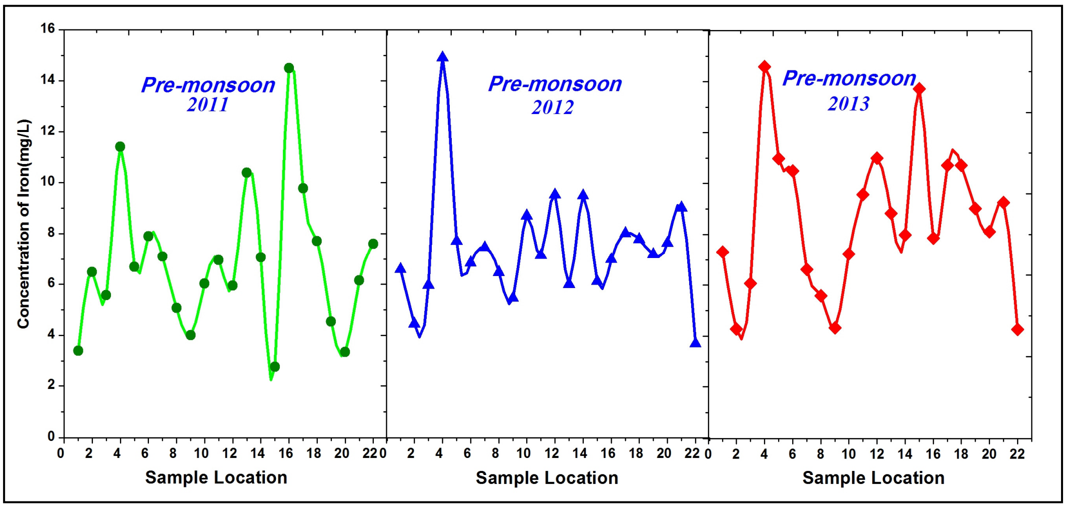

Fig.4.3: Concentration of *Iron* in Soil during Pre-Monsoon

of standard deviation during 2012. In 2013 the deviation from the mean was relatively higher (3.07).

In the post-monsoon season, the highest average *iron* concentration was at in 2012 (6.04 mg/kg). The average value during 2011 and 2013 were 5.16 mg/kg and 5.82 mg/kg respectively. The maximum value in 2011 and 2013 was noted near the

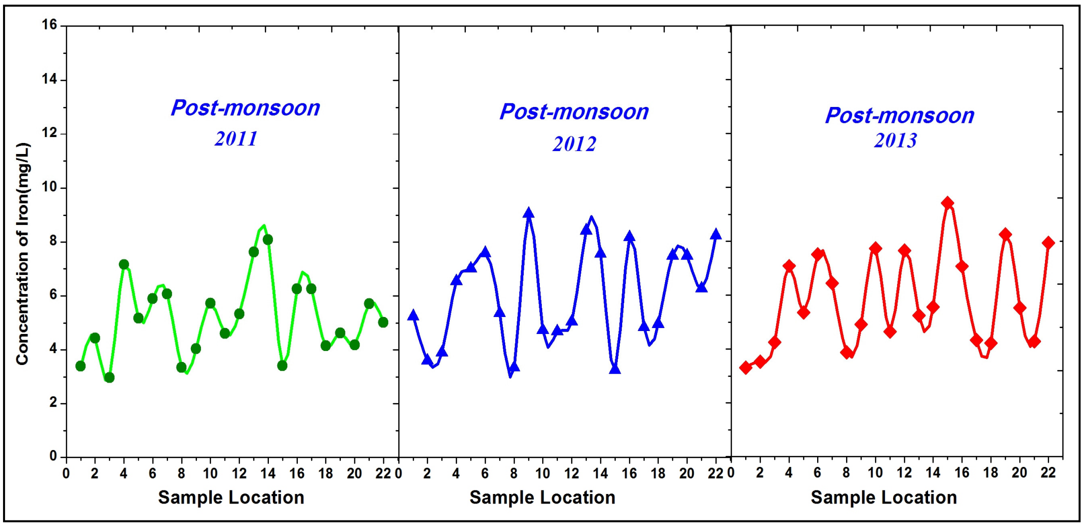

Fig.4.4: Concentration of *Iron* in Soil during Post-Monsoon Season

industrial estate at *Nandesari* (8.09 mg/kg) and *Padmala* (9.41 mg/kg) respectively. In 2012, *Fajalpur* had the maximum *iron* level whereas *Ankodiya* showed the minimum concentration (2.99 mg/kg) during 2011. In 2012 and 2013, the least concentration value was noted at *Padmala* (3.26 mg/kg) and *Ajod* (3.32 mg/kg) respectively. The deviation from the mean was highest in 2012 (1.80) and lowest in 2011 (1.41).

Table 4.1: Statistics of *Iron* Concentration

Season	N	Average	Min.	Max.	St. Dev.
Pre-monsoon (2011)	22	6.84	2.77	14.5	2.8
Pre-monsoon(2012)	22	7.41	3.67	14.9	2.23
Pre-monsoon (2013)	22	8.57	4.27	14.58	2.83
Post-monsoon (2011)	22	5.16	2.97	8.09	1.41
Post-monsoon (2012)	22	6.04	3.26	9.04	1.8
Post-monsoon (2013)	22	5.82	3.32	9.41	1.75

The unit of the parameters is in mg/kg

Source: Computed

4.2.2 Concentration of *Nitrite*

During pre-monsoon, the average concentration of nitrite in soil was highest in 2013 (88.61 mg/kg) followed by in 2011 (86.93 mg/kg). The maximum and minimum level in 2011 was observed at *Nandesari* (134.83 mg/kg) and *Karodiya* (43.45 mg/kg) respectively. *Bajwa* showed the highest level 178.89 mg/kg in 2012 and

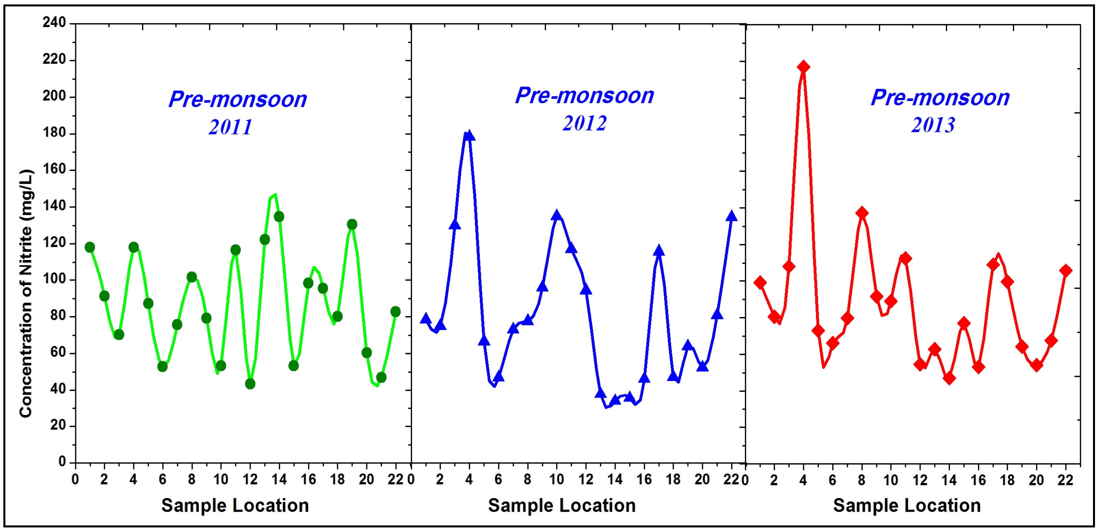

Fig.4.5: Concentration of *Nitrite* in Soil during Pre-Monsoon

217.00 mg/kg in 2013 while the lowest was observed at *Nandesari* in these years (Fig.4.4). The standard deviation during 2011 was 28.34 whereas in 2012 and 2013 it was almost same (Table 4.2).

After the rainfall, the concentration of *nitrite* in soil decreased in the time period. Relatively higher average concentration was observed in 2012 (74.130 mg/kg) followed by 61.08 mg/kg in 2013. Among the three years, 2011 showed the least absorption of nitrite (Table 4.2). In 2012 and 2013, 136.75 mg/kg and 191.471 mg/kg were the maximum concentrations which were noted at *Chhani* and *Bajwa* respectively while in 2012 the highest concentration was only 71.40 mg/kg. The lowest value of *nitrite* concentration in 2011 and 2013 was almost same (Table 4.2) but it was observed at different sampling location. In 2011, it was noted at *Koyli* while in 2013 it was observed at *Fajalpur*. The deviation from the mean was lowest in 2011

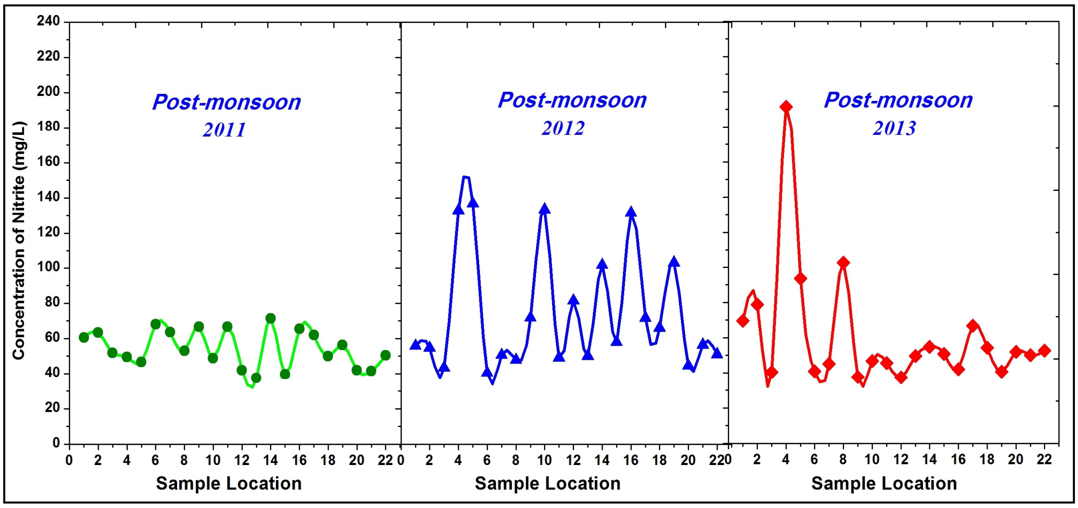

Fig.4.6: Concentration of *Nitrite* in Soil during Post-Monsoon

(10.47) whereas in the later two years standard deviation increased indicating more variation in the concentration of nitrite.

Table 4.2: Statistics of *Nitrite* Concentration

Season	N	Average	Min.	Max.	St. Dev.
Pre-monsoon (2011)	22	86.93	43.45	134.83	28.34
Pre-monsoon(2012)	22	82.56	33.97	178.39	38.79
Pre-monsoon (2013)	22	88.61	47.08	217	37.03
Post-monsoon (2011)	22	54.38	37.42	71.4	10.47
Post-monsoon (2012)	22	74.13	40.47	136.75	33.19
Post-monsoon (2013)	22	61.08	37.4	191.47	33.95

The unit of the parameters is in mg/kg

Source: Computed

4.3 SPATIAL AND SEASONAL PATTERN

4.3.1 *Iron* Concentration

During pre-monsoon 2011, the highest concentration of *iron* in soil (>8 mg/kg) was noted in the central and south-western part. The absorption of 6-8 mg/kg was spread in the entire study area except for the east. The eastern and small area at the northern and western parts had the concentration of 4-6 mg/kg. <4 mg/kg of *iron* in soil was observed at the small portion of central and eastern part. In 2012, >8 mg/kg concentration before the rains was noted in the south-eastern and western parts. Northern, eastern, south-western and central part had the level between 6 to 8 mg/kg. North-eastern and western portions had even lower concentration. During 2013, the area with maximum amount (>8 mg/kg) increased and occupied the entire eastern, central and southern parts. Northern, western and southern most part had of 6-8 mg/kg of *iron* in the soil. The lower concentration in this year (<6 mg/kg) was noted at the border of the north-eastern and western portion.

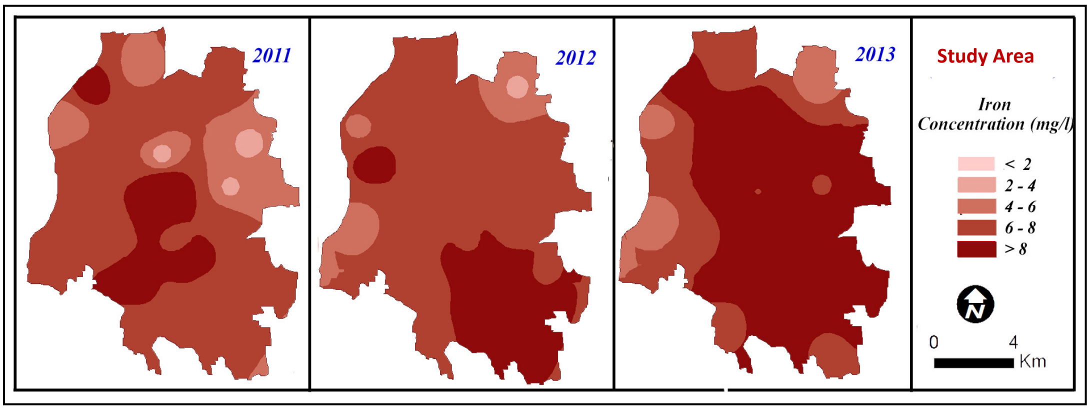

Fig.4.7: Spatial Distribution of *Iron* in Soil during Pre-Monsoon

After the rains, the concentration of *iron* in soil drastically reduced in the entire time period. In 2011, the concentration of >8 mg/kg was spotted only in the western part at *Nandesari*. Concentration between 6-8 mg/kg was observed in patches in west and south. 4-6 mg/kg of *iron* in the soil was found over the maximum area which was spread in all the directions. While small areas of the northern, central and southern parts had the lowest concentration (2-4 mg/kg). During 2012, the area of maximum concentration (>8 mg/kg) increased and was confined in the western, central and north-eastern segments. The eastern, central and western sectors had the concentration of 6-8 mg/kg. Whereas, the northern, southern and south-western parts had 4-6 mg/kg. The lower level of 2-4 mg/kg was found in small segment of northern, central and western parts. In 2013, >8 mg/kg absorption was observed only in the central part. The nortn-eastern, eastern and south-eastern parts portrayed 6-8 mg/kg of concentration. The entire western portion of the study area had 4-6 mg/kg.

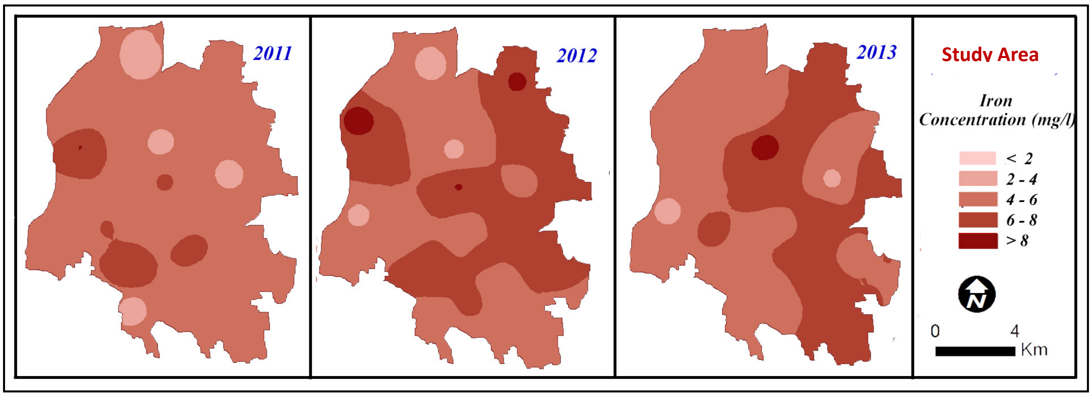

Fig.4.8: Spatial Distribution of Iron in Soil during Post-Monsoon

4.3.2 *Nitrite* Concentration

In the pre-monsoon season, the concentration of *nitrite* during 2011 was highest (>105 mg/kg) in the western, eastern south-central sectors. The level of 85-105 mg/kg was spread in the north, south-west and in the centre. The north-east and south-east had 65-85 mg/kg of *iron* while the lowest concentration was observed in the south-eastern most side. During 2012, the concentration >105 mg/kg was spread in

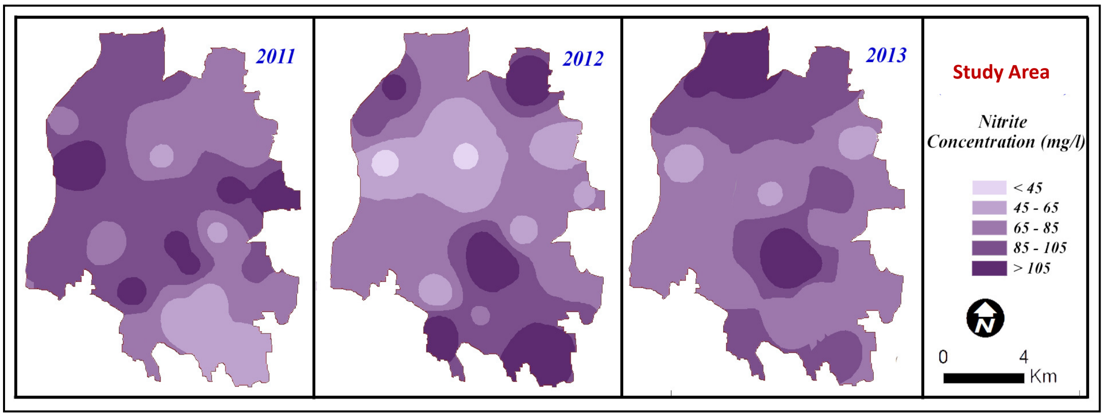

Fig.4.9: Spatial Distribution of *Nitrite* in Soil during Pre-Monsoon

the north-western, north-eastern and south-eastern parts (Fig.4.8). The north, east and south-west portions had a concentration of 65-85 mg/kg while <65 mg/kg absorption extended from the central to the western part and the same level was also noted in the north-east. In 2013, the northern and south-central parts had a concentration of >105 mg/kg whereas in the western and eastern segments the level ranged between 65 to 85 mg/kg. The lower concentration (<65 mg/kg) was noted in patches in central, north-eastern and western parts.

After the rainy season, the concentration of *nitrite* in soil reduced. In 2011, the major portion of the study area had 45-65 mg/kg (Fig.4.10). The higher concentration (65-85 mg/kg) was noted in the western and central eastern parts and lower level (<45 mg/kg) was observed in south and in a small area of central and north-eastern part. During 2012, the higher amount (>105 mg/kg) was observed in the central and south-eastern sectors. The level between 65-85 mg/kg extended from the west to east and south-east including the central portion. In both sides (northern, north-eastern and

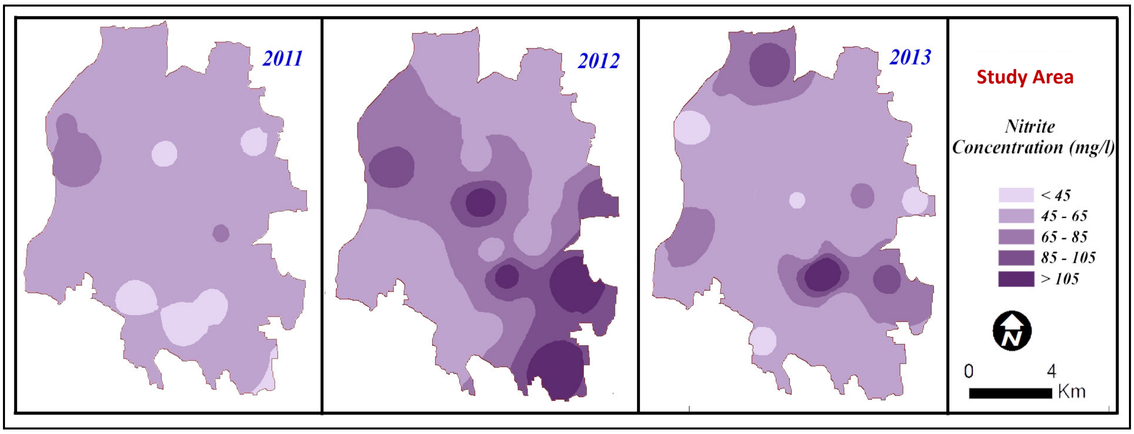

Fig.4.10: Spatial Distribution of *Nitrite* in Soil during Post-Monsoon

south-western) of this segment the concentration was between 45-85 mg/kg. In 2013, concentration of >85 mg/kg was observed in the northern and south-central part, while 65-85 mg/kg was found in the western, northern and south-eastern parts. The larger portion of the study area had the nitrite concentration of 45-65 mg/kg. <45 mg/kg of nitrite was observed in small scattered patches located at eastern, central, western and southern parts (Fig.4.9).

4.4 CHARACTERISTICS OF SOIL (AVERAGE OF 2011-2013)

4.4.1 Concentration of *Iron*

The level of *iron* during pre-monsoon season varied from 4.59 mg/kg to 13.63 mg/kg. The average concentration was 7.63 mg/kg and the deviation from the mean was 2.00. The highest level was noticed at *Bajwa* which is located near GSFC, while the lowest was recorded from *Fajalpur* village. This village is located at the upstream of the Mahi river. After the rainfall, the amount of *iron* concentration in soil decreased considerably. The maximum concentration (7.17 mg/kg) in this season reduced drastically from 13.63 mg/kg after the rains. The minimum concentration (3.52 mg/kg) of *iron* was once again noted in the northern part (*Dodka*) of the study area. 5.67 mg/kg was the average concentration and the standard deviation was significantly low in the year (Table 4.3).

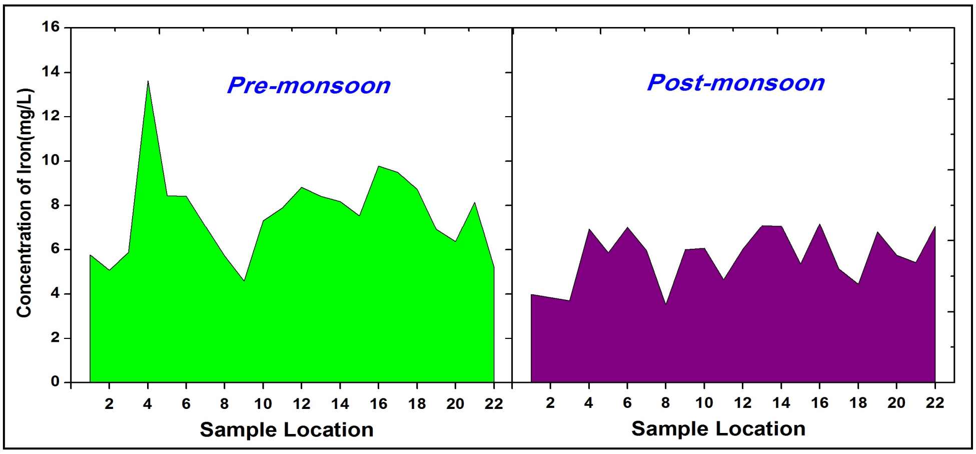

Fig.4.11: Concentration of *Iron* in Soil during Pre and Post-Monsoon Season

4.4.2 Concentration of *Nitrite*

The level of *nitrite* indicated a wide variation in the study area. During pre-monsoon the level ranged from 47.62 mg/kg to 214.58 mg/kg with mean value of 89.37 mg/kg. In both the seasons, the highest concentration was found in *Bajwa* (near GSFC). Before the onset of monsoon, the lowest concentration was observed at *Dasharath*, whereas after it the minimum concentration (38.78 mg/kg) was noted at the south-western part of the study area (*Ankodiya* village). 72.29 mg/kg was the average concentration in this season. In both the seasons the highest concentration was found at *Bajwa* (Fig.4.11) and the value of standard deviation was almost same in before (36.65) and after (35.93) the monsoon season.

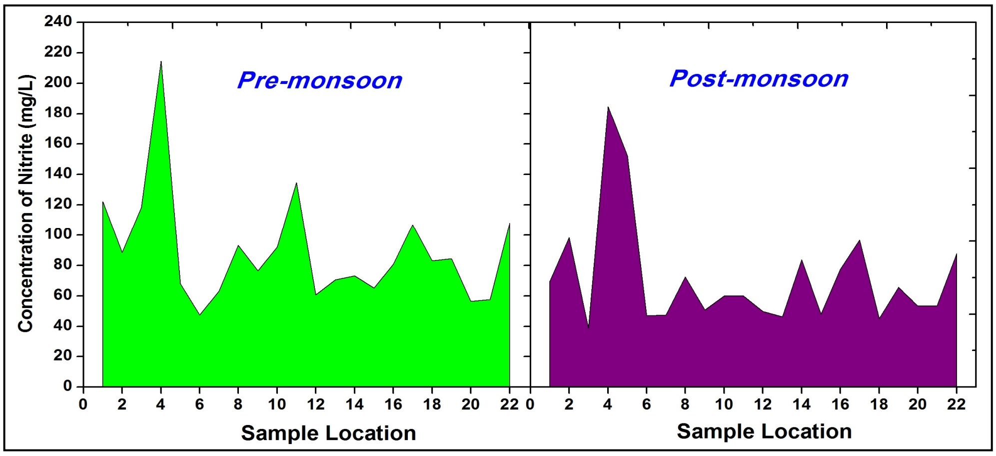

Fig.4.12: Concentration of *Nitrite* in Soil during Pre and Post-Monsoon Season

Table 4.3: Statistics of Soil Parameters (average of 2011- 2013)

Parameter	Season	N	Average	Min.	Max.	St. Dev.
Iron	Pre-monsoon	22	7.6	4.59	13.63	2
Iron	Post-monsoon	22	5.67	3.52	7.17	1.21
Nitrite	Pre-monsoon	22	89.37	47.62	214.58	36.26
Nitrite	Post-monsoon	22	72.29	38.78	184.73	35.93

The unit of the parameters is in mg/Kg

Source: Computed

4.5 SPATIAL AND SEASONAL PATTERN (AVERAGE OF 2011-2013)

4.5.1 Spatial Distribution of *Iron*

During pre-monsoon, the concentration of *iron* level of >8 mg/kg in soil covered an area of 49.44 sq.km. largely occupying central, eastern and a small area of north and north-eastern part. The concentration between 6-8 mg/kg was distributed in an area of 88.13 sq.km. (58.90% of the total area). 11.94 sq.km. had 4-6 mg/kg of *iron* observed in a small area at northern and western part. After the rainfall, the area with concentration of 4-6 mg/kg increased to 108.82 sq.km. (73.03% of the total area). Whereas the area with 6 to 8 mg/kg declined from 58.90 sq.km. (before rainfall) to 38.84 sq.km. (after rainfall). This area stretched from central to south-eastern part and was also found in the northern, western and southern segments. A small portion with concentration between 2 to 4 mg/kg was observed in the north and south.

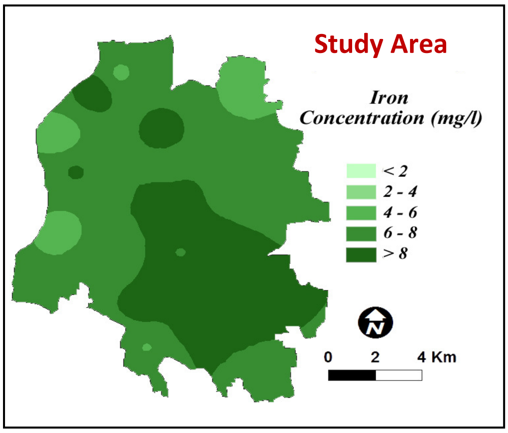

Fig.4.13: Spatial Distribution of *Iron* in Soil during Pre-Monsoon

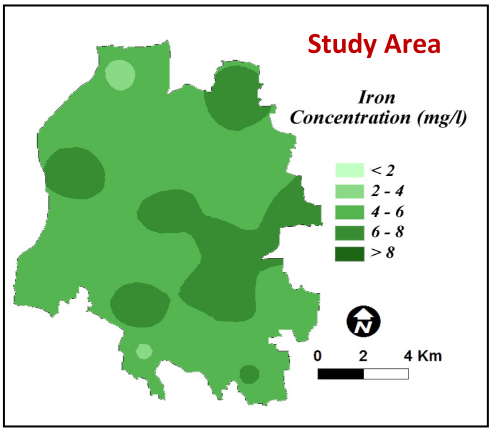

Fig.4.14: Spatial Distribution of *Iron* in Soil during Post-Monsoon

Table 4.4: Area of *Iron* Concentration in Soil (average of 2011-2013)

Concentration (mg/kg)	Pre-monsoon Area (sq. km)	Pre-monsoon Area (%)	Post-monsoon Area (sq. km)	Post-monsoon Area (%)	Change of area (%)
>0.03		0	0.95	0.64	0.64
0.03-0.5	1.33	0.89	2.99	2	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	-30.5

Source: Computed

4.5.2 Spatial Distribution of *Nitrite*

In pre-monsoon, 90.72% of the area had *nitrite* concentration between 65 to 105 mg/kg which was spread over the northern, north-eastern and southern parts. The western part has lower concentration (45 to 65 mg/kg) of *nitrite*. The highest concentration (>105 mg/kg) was observed in the southern, central eastern and in a small patch in the north-eastern part. During the post-monsoon season, the lowest concentration (<45 mg/kg) was noted in the southern most part at *Ankodiya* while the maximum concentration (>105 mg/kg) was found in the south-eastern side. The level between 65 to 85 mg/kg was observed in the northern, western and eastern segments. The area with >85 mg/kg of concentration decreased from 79.70 sq.km. (53.49% of the area) to 20.53 sq.km. (13.78% of the area). On the other hand, the level of nitrite (<65 mg/kg) increased from 46.85% to 86.55% of the area.

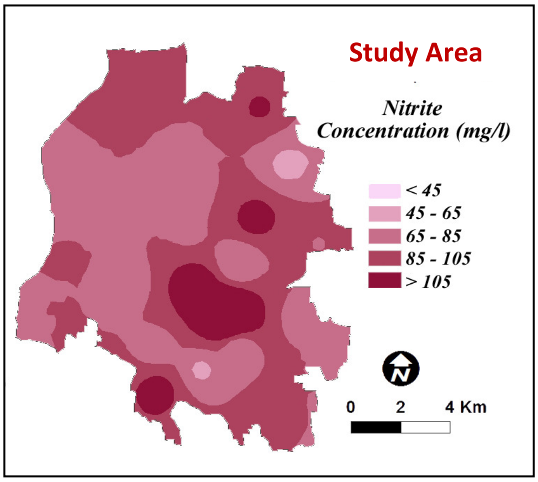

Fig.4.15: Spatial Distribution of *Nitrite* in Soil during Pre-Monsoon

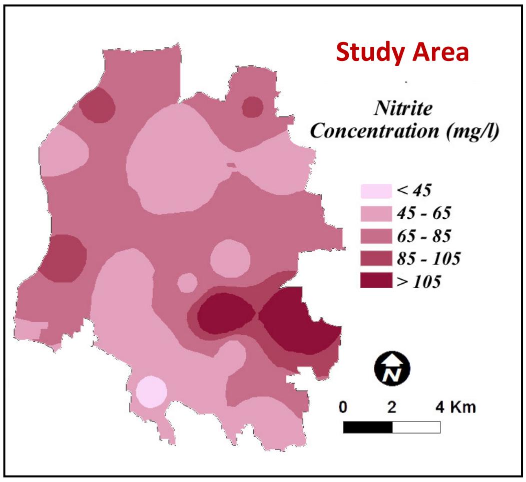

Fig.4.16: Spatial Distribution of *Nitrite* in Soil during Post-Monsoon

Table 4.5: Area of *Nitrite* Concentration in Soil (2011-2013)

Concentration (mg/L)	Pre-monsoon		Post-monsoon		Change of area (%)
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	
0-45	0	0	1.32	0.89	0.89
45-65	1.78	1.19	54.21	36.38	35.19
65-85	68.03	45.66	73.43	49.28	3.62
85 - 105	67.15	45.07	12	8.05	-37.01
>105	12.55	8.42	8.53	5.72	-2.7

Source: Computed

4.6 SEASONAL VARIABILITY OF SOIL PARAMETERS (AVERAGE OF 2011-2013)

Correlation and pair 't' test were generated on the data of pre and post-monsoon season for *iron* and *nitrite* concentration in soil. To perform the 't' test the pair for *iron* and *nitrite* in soil were formed and designated as pair sI and pair sN respectively. Positive correlation was observed in both the pairs (+0.417 and +0.596). The tabulated value of pair t test with 21 degree of freedom at 95% significance level was 2.080. The results obtained from the pair 't' test showed the value of 4.884 and 2.468 for *iron* and *nitrite* respectively. The calculated value of 't' was higher than tabulated value which leads to the rejection of the null hypothesis and acceptance of the alternative hypothesis. Thus, it can be inferred that the concentration of *iron* and *nitrite* in soil showed significant variation between pre and post-monsoon season.

Table 4.6: Pair 't' test Result of Pre And Post-Monsoon Season of Soil for Seasonal Variability (2011-2013)						
Parameter	**Pair**	**N**	**Correlation**	**t**	**df**	**Sig.(2-tailed)**
Iron	Pair sI	22	0.417	4.884	21	0
Nitrite	Pair sN	22	0.596	2.468	21	0.022
df= degree of freedom,the analysis was done at 95%significance level.						
Source: Computed						

4.7 DISTRIBUTION OF GRAIN SIZE

Clay comprised of 59.17% in the upper most layer of the study area. In the intermediate layer (4 - 5 inch of depth) it was 44.90% and in the deepest layer (8-9 inch of depth) clay constitute about 56.28% (Table 4.7). Thus, clay was dominantly found in the study area with 53.45% of the total quantity of the sediment. One-third of the soil samples composed of silt (36.53%). However, in the intermediate zone the percentage of silt was highest (41.26%) and in this part the proportion of clay was lower. In totality, clay and silt contributed to 90% of the total soil sample, whereas, the proportion of the sand was least (nearly 10%).

Table 4.7: Distribution of Grain Size in Immediate Layer (0-1 inch)			
Sample Site	**Sand (%)**	**Silt (%)**	**Clay (%)**
A	8.1	31.87	60.03
B	7.1	65.55	27.35
C	6.22	29.35	64.43
D	5.16	26.81	68.03
E	10.11	13.85	76.04
Average	7.34	33.49	59.18
Source: Computed			

Spatial variation was observed in grain size distribution of the sediment. The clay percentage in 0-1 inch of depth (immediate layer) increased from 60% upstream to 76% downstream (Table 4.7). A reverse pattern was noted in case of silt, which reduced from 31.87% to 13.85% downstream. Sampling site B was the only exception to this trend where the percentage of clay (27.35%) was lesser than the silt percentage (65.55%) (Table: 4.7). In the intermediate layer dominance of clay was noted. The average percentage of clay was lower (44.90%) and it ranged from 65.37% in the upstream to 56.43% downstream (at 4-5 inch depth) (Table 4.8). The amount of silt in the intermediate layer was 41.26% which was more than the immediate layer.

Table 4.8: Distribution of Grain Size in Intermediate Layer (4-5 inch)

Sample Site	Sand (%)	Silt (%)	Clay (%)
A	7.22	27.41	65.37
B	6.08	80.58	13.34
C	34.80	11.84	53.36
D	8.07	55.91	36.02
E	13.03	30.54	56.43
Average	13.84	41.26	44.90

Source : Computed

The highest amount of clay was observed at the sample site B (80.58%) (Table 4.8). Whereas, the lowest (11.58%) was at the adjoining point (Sampling Site C). Later, it again enhanced to 55.91% at site D. The bottom layer (8-9 inch of depth) was characterised with maximum percentage of clay (56.28%) and proportion of silt and sand was lower (34.86% and 8.86% respectively) (Table 4.9).

In the bottom layer, the highest percentage (85.18%) of clay was noted downstream. Silt percentage was least in this layer (56.69%) was observed at Sampling Site C. The proportion of silt reduced from this point both upstream and downstream. The percentage of sand was lowest (10% approximately) in all the layers, only with Sampling Site C of the intermediate layer being the only exception.

Table 4.9: Distribution of Grain Size in Bottom (8-9 inch)

Sample Site	Sand (%)	Silt (%)	Clay (%)
A	10.29	29.01	60.70
B	6.23	48.41	45.36
C	11.29	56.69	32.02
D	2.83	39.01	58.16
E	13.67	1.15	85.18
Average	8.86	34.86	56.28

Source : Computed

4.8 CONCENTRATION OF *IRON* AND *NITRITE* IN SUB-SOIL

4.8.1 Concentration of *Iron* in Sub-Soil

The concentration of *iron* in sub-soil along the Mini River was greater downstream. In the immediate layer (0-1 inch of depth), the concentration of *iron* progressively increased from 2.13 mg/kg at upstream to 55.64 mg/kg downstream with the mean value of 43.39 mg/kg. The concentration of *iron* ranged from 5.87 mg/kg to 43.14 mg/kg in the middle layer (4-5 inch of depth). The average level of *iron* concentration was 24.75 mg/kg in this layer which was lesser than in the immediate layer (0-1 inch depth) and also in the deepest layer (8-9 inch depth). In the bottom layer of sub-soil, the concentration of *iron* ranged from 3.16 mg/kg to 101.15 mg/kg with the average of 29.18 mg/kg.

Table 4.10: Concentration of *Iron* (mg/kg) in Sediment

Sample Site	Immediate Layer	Intermediate Layer	Bottom Layer of Top Soil	Average
A	2.13	5.87	3.16	3.72
B	21.83	7.71	4.43	11.32
C	84.44	50.51	101.15	78.70
D	52.93	16.53	15.58	28.35
E	55.64	43.14	21.6	40.13
Average	43.39	24.75	29.18	32.44

Source : Computed

In the sampling site B, D and E, the highest concentration of *iron* was noted in the immediate layer (0-1 inch of depth). The level of *iron* at sites B, D and E was 21.83 mg/kg, 52.93 mg/kg and 55.64 mg/kg respectively. In all the sampling sites, the lowest level of *iron* was observed at the deepest layer except for sampling site C, where the concentration increased upto 101.15 mg/kg at the bottom layer of the sub-soil (8-9 inch depth). The average concentration of *iron* at sampling site A depicted the lowest level (3.72 mg/kg) but relatively more intensity was noted at the middle layer (4-5 inch of depth). The sampling site C showed the maximum concentration as well as the fluctuating pattern of *iron* 84.44 mg/kg was observed in the upper most layer which decreased in the intermediate layer (4-5 inch depth), and again increased upto 101.15 mg/kg at the deepest layer indicating the highest concentration in the entire region.

4.8.2 Concentration of *Nitrite* in Sub-Soil

A decrease of *nitrite* with the increase of depth was evident. The highest concentration (67.67 mg/kg) was observed at the upper most layer. While the least (27.67 mg/kg) was noted at the deepest layer. In the immediate layer, the minimum concentration was noted at Site C (51.78 mg/kg) whereas, it was maximum (77.67 mg/kg) at the adjacent sampling location (Site D). On an average, the level of *nitrite* in the immediate and deepest layer of sub-soil along the river was greater downstream. The highest amount of *nitrite* at 4-5 inch of depth (intermediate) and 8-9 inch of depth (deepest layer of sub-soil) were found in the sampling Site D (50.89 mg/kg) and Site C (39.28 mg/kg) respectively.

Sampling location wise the level of *nitrite* illustrated that Site D had the maximum average concentration (53.86 mg/kg) (Table 4.11). In all the sampling Sites the upper most layer depicted the highest level of nitrite. Whereas, the bottom layer of the Site A, B and D had the lowest absorption. For the Site C and E the lower level was noted in the middle layer (4-5 inch depth).

4.9 CORRELATION BETWEEN GRAIN SIZE DISTRIBUTION AND THE PARAMETERS

The relationship for the concentration of *iron* and *nitrite* and grain size distribution were analysed by using Karl Pearson correlation. The positive correlation existed between the level of *iron* and *nitrite* in the sub-soil along the Mini River. The sampling sites B and D showed the strong positive correlation (+0.99 and +0.93). Whereas the sampling site A, C and E depicted relatively lesser correlation values of (+)0.12, (+)0.35 and (+)0.42 respectively.

Table 4.12: Correlation between *Iron* and *Nitrite* in Sediment

	Iron				
	Location				
	A	***B***	***C***	***D***	***E***
Nitrite	0.12	0.99	0.35	0.93	0.42

Source: Computed

Table 4.11: Concentration of *Nitrite* (mg/kg) in Sediment

Sample Site	Immediate Layer	Intermediate Layer	Bottom Layer of Top Soil	Average
A	56.25	50	12.5	39.58
B	63.39	31.25	16.07	36.90
C	51.78	36.6	39.28	42.55
D	77.67	50.89	33.03	53.86
E	64.28	16.07	37.5	39.28
Average	62.67	36.96	27.67	42.44

Source : Computed

4.9.1 Correlation between *Iron* Concentration and Grain Size Distribution

In all the sampling sites, negative correlation existed between *iron* concentration and sand. Sampling site B was the only exception to this rule. Negative relationship existed between sand percentage and concentration of *nitrite*. Sampling sites A, C and E had correlation values of -0.92, -0.76 and -0.81 respectively. Positive correlation was observed at sampling sites B and D. The relationship between percentage of silt and concentration of *iron* showed strong positive correction at sampling site C which is nearer to *Nandesari* industrial estate. At Sampling Site A and D, negative relationship existed between *iron* concentration and percentage of silt (-0.91 and -0.81). A volte-face pattern was noted between the clay percentage concentration of *iron*.

Table 4.13: Correlation of Grain Size and Level of *Iron* in Sediments

	Location				
	A	B	C	D	E
	sand	*sand*	*sand*	*sand*	*sand*
Iron level	-0.51	0.95	-0.88	-0.04	-0.87
	silt	*silt*	*silt*	*silt*	*silt*
Iron level	-0.91	0.21	0.95	-0.8	0.56
	clay	*clay*	*clay*	*clay*	*clay*
Iron level	0.99	-0.25	-0.49	0.72	-0.45

Source: Computed

4.9.2 Correlation between *Nitrite* Concentration and Grain Size Distribution

Nitrite concentration and percentage of silt at the soil sampling site D and E had negative relationship viz (-)0.51 and (-)0.52 respectively. On the other hand, the sampling site A, B and C depicted positive correlation i.e. (+)0.28, (+)0.34 and (+)0.04

Table 4.14: Correlation of Grain Size and Level of *Nitrite* in Sediments

	Location				
	A	B	C	D	E
Nitrite level	*sand*	*sand*	*sand*	*sand*	*sand*
	-0.92	0.9	-0.76	0.34	-0.81
Nitrite level	*silt*	*silt*	*silt*	*silt*	*silt*
	0.29	0.35	0.04	-0.52	-0.51
Nitrite level	*clay*	*clay*	*clay*	*clay*	*clay*
	0.27	-0.38	0.64	0.41	0.62

Source: Computed

respectively. Positive correlation was observed between *nitrite* concentration and clay percentage excluding the sampling site B.

4.10 CORRELATION BETWEEN GRAIN SIZE (WITH DEPTH) AND THE PARAMETERS

Depth wise correlation between grain size and level of parameters in the sediments depicted a few important facts. In the upper most layer, the relationship between percentage of sand with *iron* and *nitrite* was weak and negative i.e. (-)0.24 and (-)0.28. In the depth between 4-5 inch, the relation of *iron* concentration with sand particles depicted positive correlation (+0.83), whereas in the same layer, with *nitrite* it was negative (-0.16). In the deepest layer, the correlation value of *iron* and *nitrite* with sand particles was positive viz +0.35 and +0.24 respectively (Table 4.5). The relation between *iron* and silt was negative in the upper (-0.45) and middle layers (-0.66). However, 8-9 inch depth the correlation value was (+)0.45. Negative relationship was noted between silt particles and nitrite concentration. It was very low positive correlation (+0.02) at the depth of 4-5 inch. In all the layers, positive correlation existed between the percentage of clay and *iron* and *nitrite*.

Table 4.15: Depth Wise (in inch) Correlation Between Grain Size and Parameters

	0-1 depth		4-5 depth		8-9 depth	
	Iron	*Nitrite*	*Iron*	*Nitrite*	*Iron*	*Nitrite*
sand	-0.24	-0.28	0.83	-0.16	0.35	0.24
silt	-0.45	-0.07	-0.66	0.02	0.45	-0.12
clay	0.48	0.1	0.38	0.07	0.38	0.07

Source: Computed

4.11 DISCUSSION

In the study area, the concentration of *iron* and *nitrite* in soil are higher near the industrial estate of *Nandesari*, GSFC and IPCL. The industrial activities such as dumping of industrial waste and release of effluents in the nearby areas are one of the reasons for high concentration of *iron* and *nitrite* (Kanchan and Chandabadani, 2014). After the rainfall, the concentration of these parameters decreased. Hence, it can be inferred that rainfall played an important role in determining the soil quality. This decrease in the level of *iron* and *nitrite* are perhaps due to the dilution with rainwater.

Fig.4.17: Change of Soil Colour Due To Industrial Waste and Effluent in *Nandesari* GIDC
Source: Photograph during Field Visit

Clay was abundantly found in the upper-most layer (Fig.3.16) which was followed by silt and sand. Therefore, it can be concluded, that the soil is clayey along the river Mini which is considered to one of the alluvial types of soil. The occurrence of such type of soil in the north-western part of the study area is largely due to the fluvial processes (Gupte, 2010). The level of *nitrite* was high in the upper-most layer which reduces with the increase of depth (Fig.3.18). In the upper-most layer significant concentration of *iron* was also observed where the percentage of clay was highest (Fig.4.16). When the grain size gets finer the rate of infiltration reduces significantly, therefore, infiltration rate from the upper most layer to the subsurface layer reduced and mainly gets concentrated in the immediate layers (Schwimmer, 2007). The sampling site C depicted the highest level of *iron* in all the layers (Table 4.10). It is situated near *Nandesari* GIDC and many chemicals related to *iron* and nitrites are used in the industries. Sampling site A which is at a distance from the industries had minimum concentration of *iron* (Fig.3.17) clearly depicting the influence of industrial activities like dumping of industrial waste and release of effluents in the nearby areas. However, at sampling site E (downstream) which is also outlying from the industrial estate depicted higher concentration of *iron* and *nitrite*. The site was situated at the downstream of the river Mini. The effluent channels from the *Nandesari* GIDC and IPCL were released into the Mini river and as it passes through the industrial areas and carries the waste of the industries. The concentration of *iron* and *nitrite* in the sediment increases as it flows down. During the monsoon season, the wastes get mix up with rainwater and flow southwards resulting into high concentration of *nitrite* and *iron* in the sediment mainly in the downstream. Thus, the downstream Site indicate higher concentration than the upstream sites.

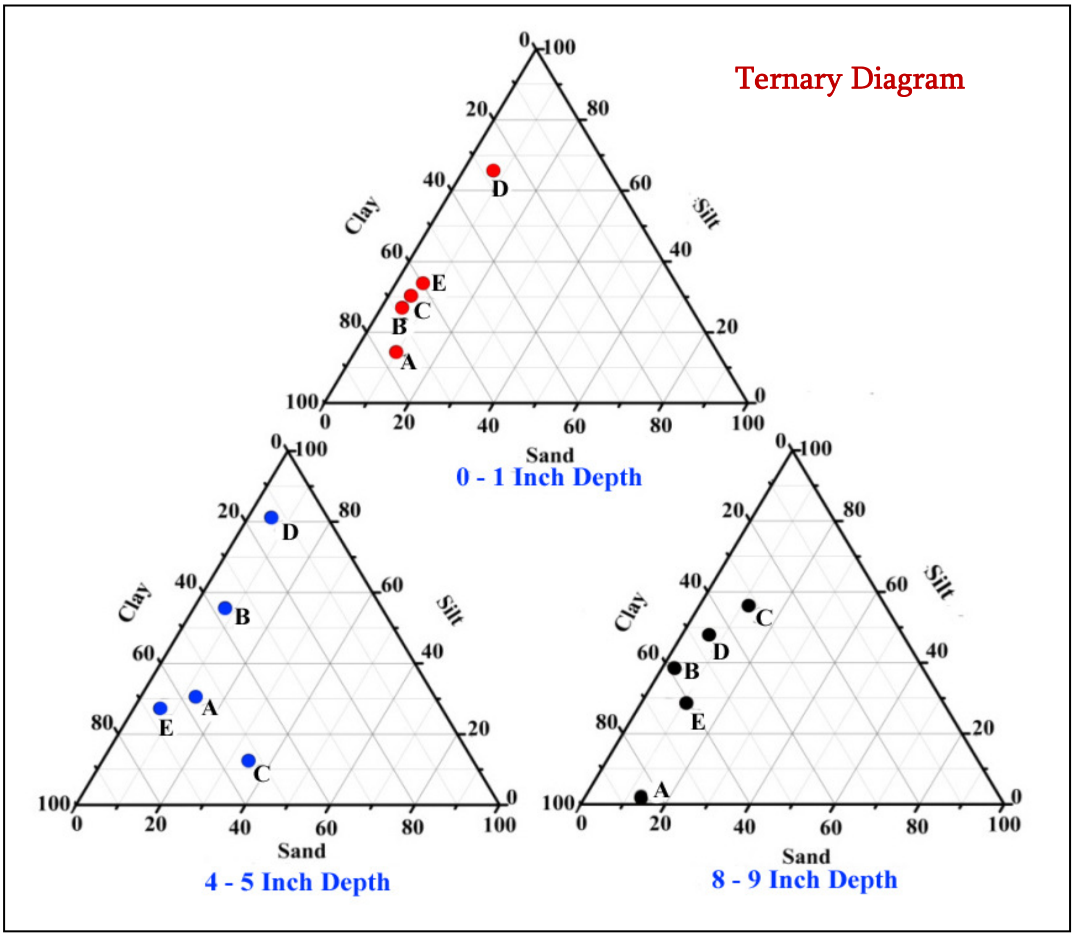

Fig.4.18: Distribution of Grain Size in Different Depth

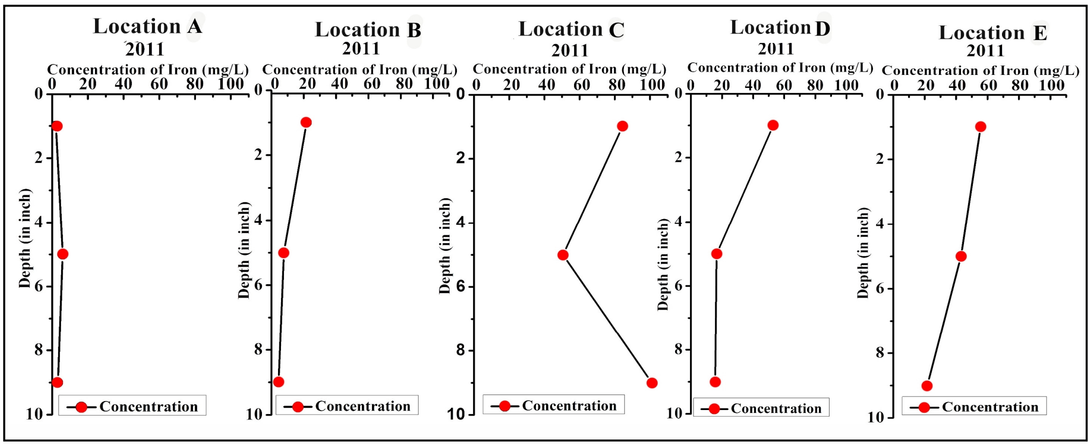

Fig.4.19: Depth-Wise Concentration of *Iron* in Sediment

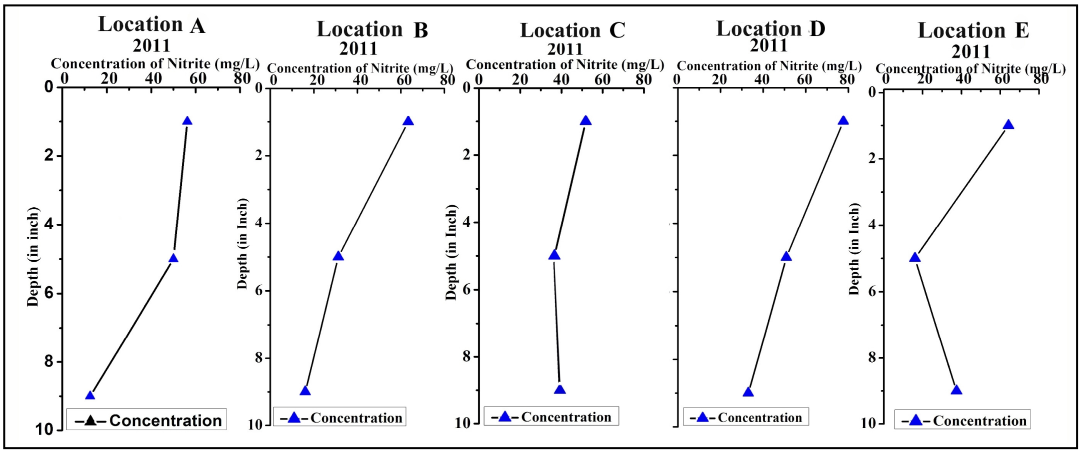

Fig.4.20: Depth-Wise Concentration of *Nitrite* in Sediment

Resume

In this chapter, iron and nitrite level in soil were examined during pre and post-monsoon period. The concentration of these parameters were more near the GSFC in both the seasons. Grain size analysis depicted that the study area is dominated by clayey soil. Negative correlation existed between grain size and concentration of parameters. High level of parameters in upper most layer near Nandesari GIDC and downstream of Mini river indicated the influence of industries and river. The following chapter focuses upon the identification of industrial waste disposal sites (IWDS), its impact on subsurface water and selection of most suitable IWDS.