Chapter– 5

Assessment and Suitability of Industrial Waste Disposal Sites Using GIS

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5.1 INTRODUCTION

Industrial waste could be defined as the products of industrial activities which are regarded as being useless. In chemical industry, the waste may include semi-finished products, impurity in raw materials, discharged from chemical reaction during production, process and decomposition. In case of petroleum or oil chemical industry waste such as oil mud, waste catalyst, tar, shale, slag and waste organic are generated. With the increase of industrialization the generation of such industrial waste materials had also increased (Ewa et al., 2011). It is necessary to manage such industrial waste as improper management have adverse impact on environment quality, human health and water quality (Ogedangbe and Akinbile, 2004). In addition to this, improper management of solid waste creates problems like odor nuisance, fire hazards, diseases transmission, atmospheric pollution, aesthetic nuisance (Jilani et al. 2002). Thus, proper solid waste disposal site should be considered as one of the important factors while selecting the location of industry as it causes risk to the environment and human health. In the present study, industrial waste disposal sites were identified through field observation and satellite image (Google earth- Image Landsat / Copernicus. Image© 2013 Digital Globe, Imagery Date: 2/21/2007, Google earth- Image© 2015 Digital Globe, Imagery Date: 2/27/2011, Google earth- Image© 2015 Digital Globe, Imagery Date: 2/20/2015 and IRS-P6, satellite image, sensor-L4 MN, Date of pass 31 Jan. 2011) in 2007, 2011 and 2015. The study region is divided into two parts viz (a) southern site (in and around industrial area) (b) northern site (far from industrial areas). Samples of sub-surface water quality during pre and post-monsoon season from the industrial waste disposal sites were also collected and the results are presented in this chapter. An attempt has been made to find out the suitability of the waste disposal sites by using Arc GIS 10.1.

5.2 IDENTIFICATION OF WASTE DISPOSAL SITES

The waste disposal sites around industrial area were in southern segment whereas far from industrial area were in the northern part of the study area. The coverage area of the waste disposal sites in the study area are identified and analysed. The assessment shows that there was tremendous increased of waste disposal sites from 2007 to 2011 but it slightly decreased in 2015. New waste disposal sites came up in the southern as well as and northern parts.

5.2.1 Assessment of Waste Disposal Sites in 2007

During 2007, 42 (forty-two) waste disposal sites were identified in and around the industries and also along the NH-08 covering an area of 0.17 sq km. (0.11% of the study area). This waste disposal sites were noted in *Nandesari, Anagadh, Ranoli, Dhanora, Karachiya, Koyli, Dasharath, Chhani, Sankarda* and *Padmala*. The maximum numbers of waste disposal sites were observed in the southern part. *Nandesari* industrial area had the highest number of waste disposal sites (Fig.5.1) followed by Indian Petro Chemical Limited industrial area. Least number of waste disposal sites was observed at Gujarat State Fertilizer Cooperation Limited. In the northern parts only 08 (eight) waste disposal sites were noted at *Sankarda* and *Padmala* along the NH-08 and River Mini.

5.2.2 Assessment of Waste Disposal Sites in 2011

After four years i.e. in 2011, waste disposal sites were assessed in the southern part. They were noted in *Nandesari, Anagadh, Ranoli, Dhanora, Karachiya, Koyli,*

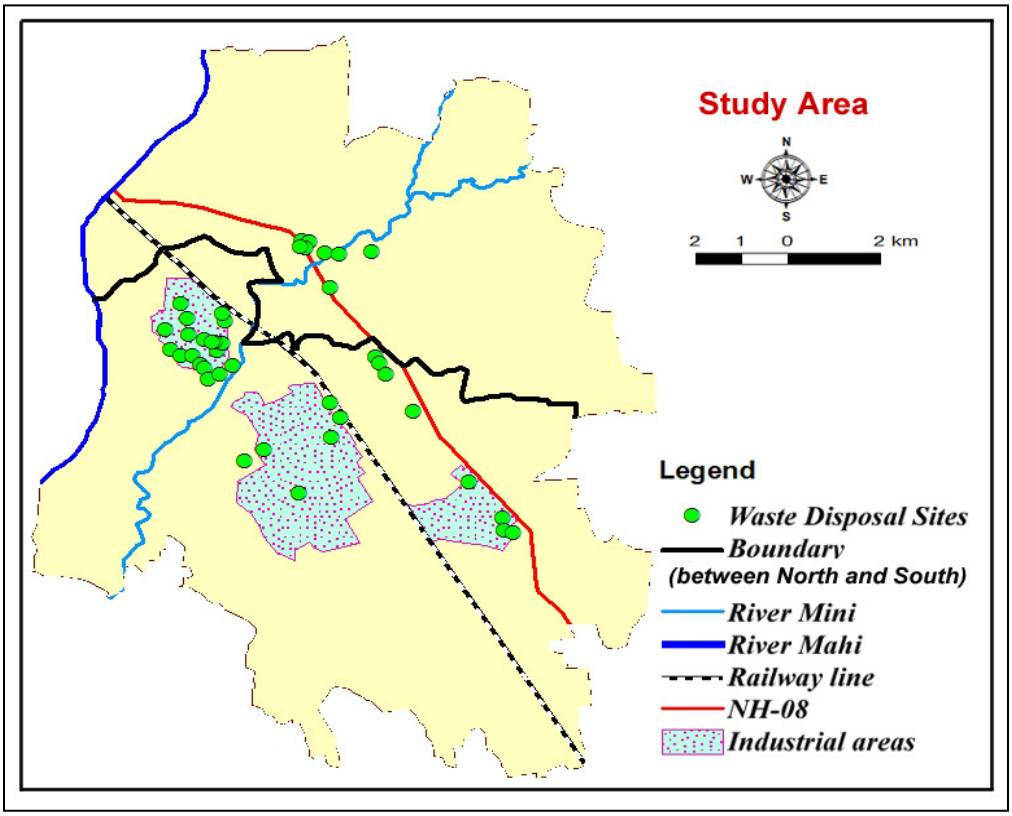

Fig.5.1: Waste Disposal Sites in 2007

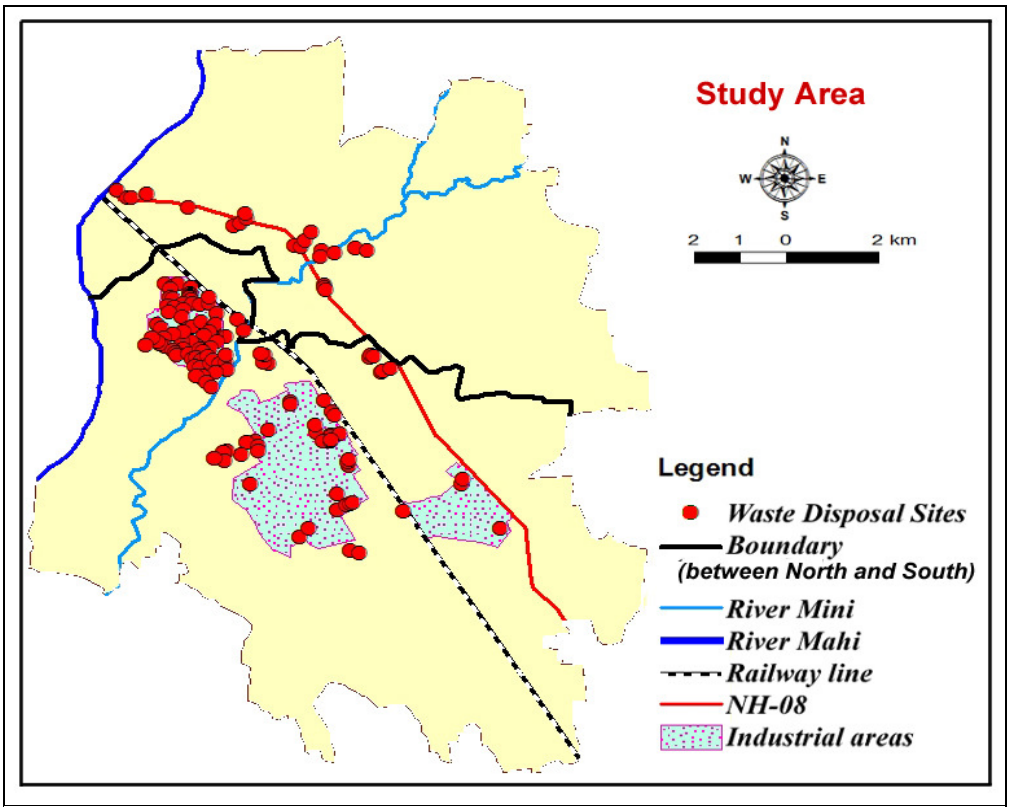

Fig.5.2: Waste Disposal Sites in 2011

Dasharath, Chhani and *Bajwa*. The number of sites increased from 42 in 2007 to 159 (one hundred fifty-nine) in 2011. They were spread over 0.49 sq. km. (0.33% sq.km. of the study area). In the *Nandesari* GIDC and Indian Petro Chemical Limited. The number of waste disposal sites increased remarkably. However, no significant increase was observed in the Gujarat State fertilizer Cooperation Limited. Most of the industrial wastes in *Nandesari* were dumped within the industrial notified areas. In the northern part, industrial waste disposal sites were observed at *Fajalpur*, *Sankarda* and *Padmala*. The number of sites increased in this part. New waste disposal sites came up at *Fajalpur*. All the industrial waste sites in northern part were located along the NH-08 and were extended up to the Mahi river.

5.2.3 Assessment of Waste Disposal Sites In 2015

During 2015, 151 (one hundred and fifty-one) waste disposal sites were observed in the study area. It was observed that though the number of sites decreased in 2015, but the overall area increased from 0.49 sq.km. in 2011 to 0.58 sq.km. in 2015. Some locations shrank and vanished while a few new sites emerged. In the southern part, the waste was dumped at *Nandesari, Anagadh, Ranoli, Dhanora,*

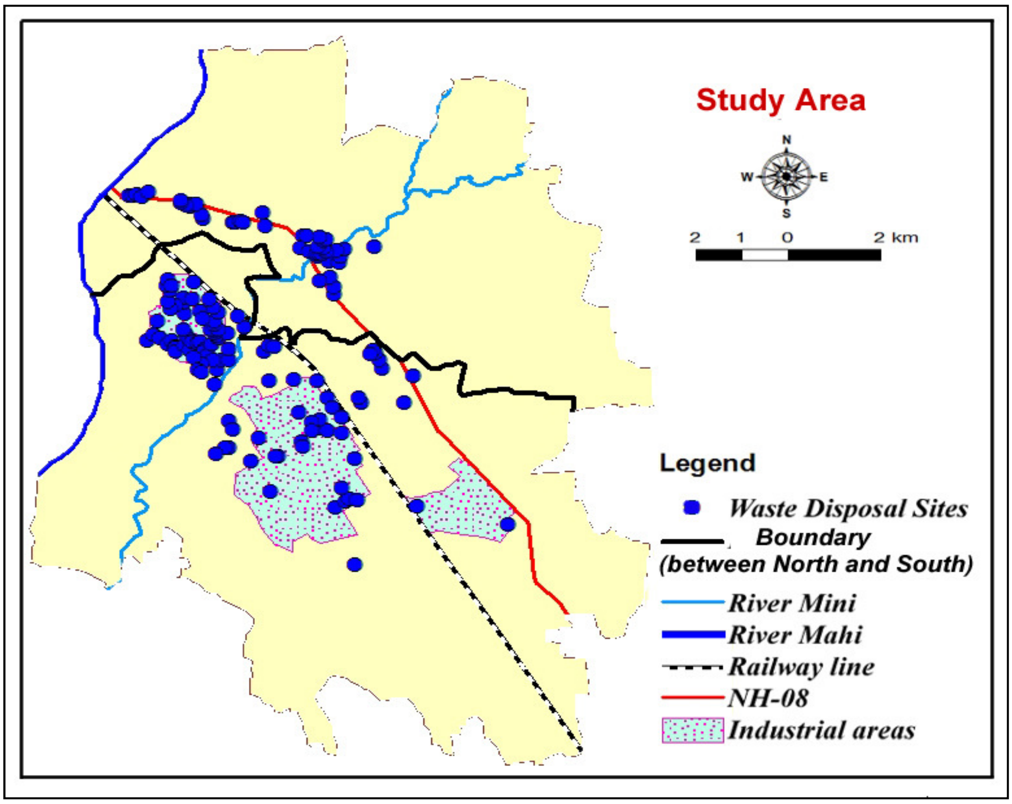

Fig.5.3: Waste Disposal Sites in 2015

Karachiya, Koyli, Dashrath, Chhani and *Bajwa.* In this year too, most of the sites were confined in the notified industrial area of *Nandesari* GIDC and Indian Petro Chemical Limited. Change in location of sites was observed in the western part of the Indian Petro Chemical Limited. Few scattered new sites appeared in the eastern part of this industrial area.

In the northern part, significant increased of solid waste disposal sites were observed they were noted in *Fajalpur, Rayaka, Sankarda* and *Padmala* villages. The maximum number of them were observed where NH-08 traversed through the river Mini.

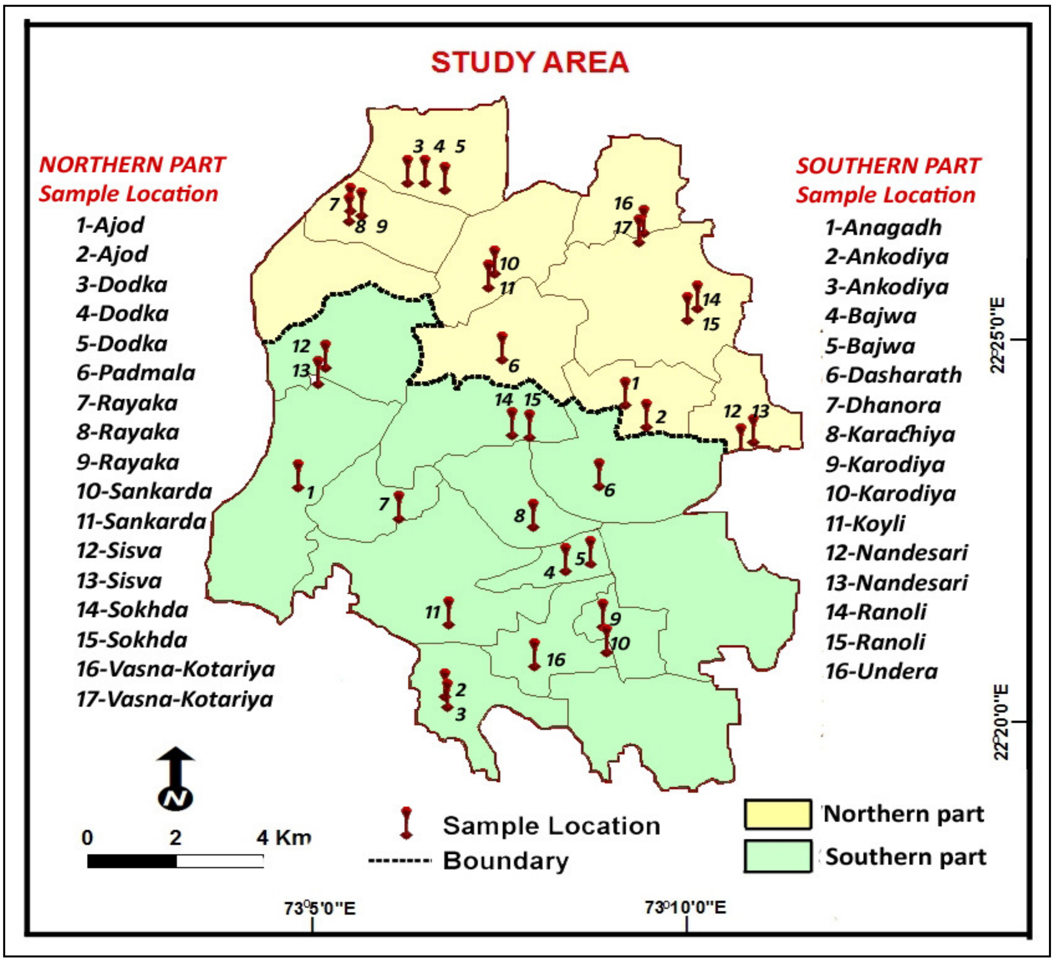

Fig.5.4: Sub-Surface Water Sample Location

5.3 GENERAL CHARACTERISTICS OF SUB-SURFACEWATER

To examine the impact of industrial waste in water, the general characteristics of sub-surface water in the waste disposal sites were observed by collecting water samples in pre and post-monsoon seasons. Characteristics like concentration of *TDS,* *pH, EC, iron* and *nitrite* were analysed from samples collected from northern and southern waste deposals sites.

5.3.1 Pre-monsoon

During the pre-monsoon season the concentration of *TDS* in northern part ranged between 678.40 to 1972.93 mg/l with an average of 1155.91 (Fig.5.5) (Table 5.1). A considerably high variation was observed (390.88) in sub-surface water. The maximum level was noted in the *Sisva* village while the lowest was at *Dodka* village (Fig.5.5).

In southern part, the level of *TDS* varied between 829.80 mg/l to 2838.13 mg/l (Fig.5.5). The mean concentration (1499.00 mg/l) as well as standard deviation (532.82 mg/l) were high denoting a wide range of concentration throughout the time and

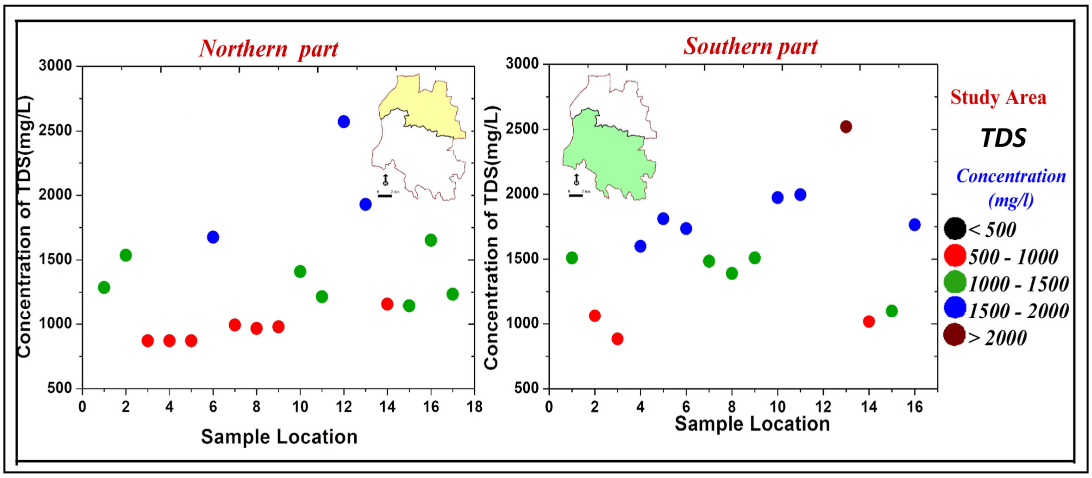

Fig.5.5: Concentration of *TDS* in Sub-Surface Water during Pre-Monsoon Season

space. The maximum level was found at *Nandesari* whereas *Ankodiya* had minimum concentration.

The level of *pH* in northern site varied between 7.05 and 7.88, depicting a slightly alkaline condition (Fig.5.6). The mean of *pH* in sub-surface water was 7.53 indicating a normal condition. A very low standard deviation (0.18) showed the less variability of *pH* level throughout the space. *Sisva* had relatively higher *pH* value while *Sankarda* showed the least level.

In the southern part, the concentration of *pH* ranged between 6.93 to 7.87 (*Ranoli*) with the mean of 7.53. The value of standard deviation was considerably low

(0.23), indicating a lower variation in the level of concentration. *Nandesari* depicted the least level (Fig.5.6) and the highest level was noted in *Ranoli* indicating slightly alkaline condition of the sub-surface water.

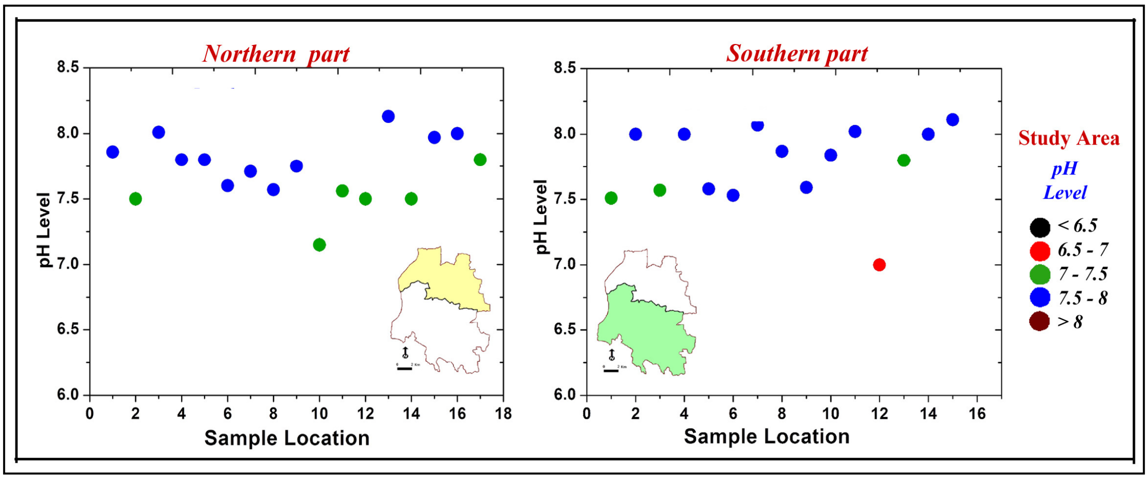

Fig.5.6: Level of *pH* in sub-surface water during pre-monsoon

The concentration of *EC* in northern part ranged between 0.06 s/cm^{-1} x 10^{-3} to 3.08 s/cm^{-1} x 10^{-3}. The mean and deviation values were 1.81 s/cm^{-1} x 10^{-3} and 0.61 respectively. The level of *EC* at *Sisva* was more (Fig.5.7) while *Dodka* had the lowest level.

In southern parts, the concentration of *EC* varied from 1.30 s/cm^{-1}x 10^{-3} to 4.43 s/cm^{-1}x 10^{-3} (Fig.5.7). The mean absorption was 2.31 s/cm^{-1} x 10^{-3} and the deviation from mean was 0.85. The highest and lowest level was observed at *Nandesari* and *Akodiya* respectively.

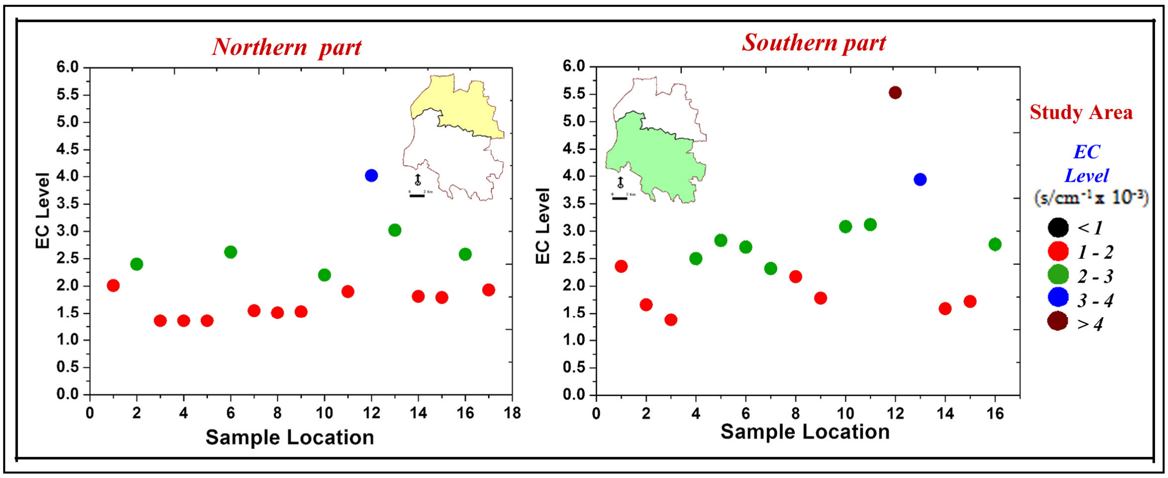

Fig.5.7: Level of *EC* In Sub-Surface Water during Pre-Monsoon

Table 5.1: Statistics of Sub-Surface Water Parameters during Pre-Monsoon in Northern Part					
Parameter	**N**	**Average**	**Min.**	**Max.**	**St. Dev.**
TDS	17	1155.91	678.40	1972.93	390.88
pH	17	7.53	7.05	7.88	0.18
EC	17	1.81	1.06	3.08	0.61
Iron	17	0.93	0.29	1.66	0.32
Nitrite	17	53.17	32.67	118.45	22.68
Source: Computed					

Table 5.2: Statistics of Sub-Surface Water Parameters during Pre-Monsoon in Southern Part					
Parameter	N	**Average**	**Min.**	**Max.**	**St. Dev.**
TDS	16	1499.00	829.80	2838.13	532.82
pH	16	7.53	6.93	7.87	0.23
EC	16	2.31	1.30	4.43	0.85
Iron	16	2.04	1.13	3.59	0.59
Nitrite	16	40.40	26.52	53.21	6.98
Source: Computed					

The concentration of *iron* in northern part had a minimum of 0.29 mg/l and maximum of 1.66 mg/l (Fig.5.8). The mean (0.93 mg/l) was high while the standard deviation was relatively lower (0.32) indicating the less variability in the level of *iron*. The concentration was highest at *Sisva* and lowest in *Sokhda*.

In the southern part, the concentration of *iron* varied from 1.13 mg/l to 3.59 mg/l (Table 5.2). The mean concentration was 2.04 mg/l and the deviation from mean was (0.59) (Fig.5.8). The concentration of the element was greatest at *Nandesari* while *Anagadh* had the lowest.

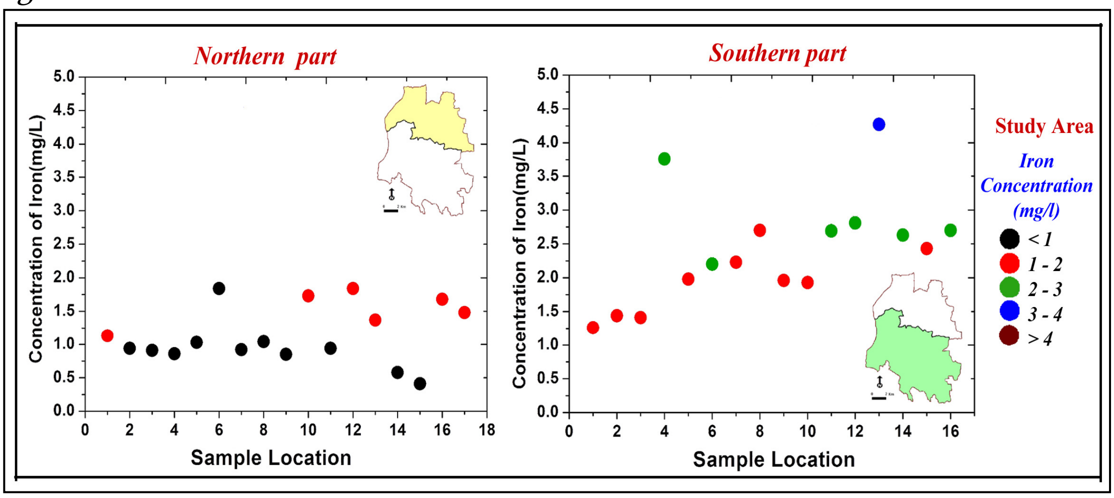

Fig.5.8: Concentration of *Iron* in Sub-Surface Water during Pre-Monsoon

The level of *nitrite* at the northern part, indicated at wide range from 32.67 mg/l to 118.45 mg/l (Fig.5.9). The mean concentration was 53.17 mg/l with high variability of concentration (22.68 mg/l). The maximum value was observed at *Vasna-Kotariya* while *Sisva* had the lowest concentration.

In the southern part, the level of *nitrite* ranged between 26.53 mg/l to 53.21 mg/l with the mean value of 40.40 mg/l. The lower deviation from mean (6.98 mg/l) indicated lesser spatial variability in the concentration (Fig.5.9).

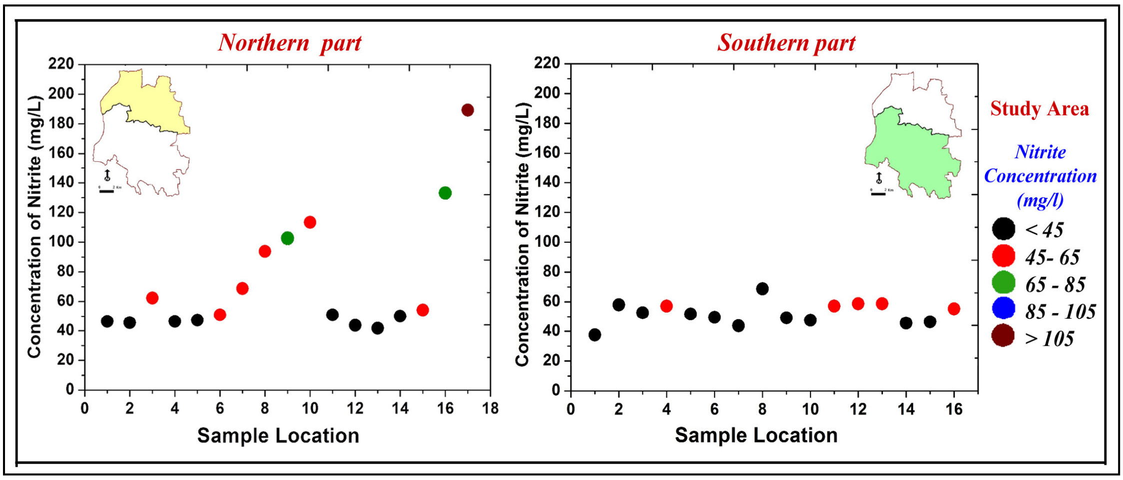

Fig.5.9: Concentration of Nitrite in Sub-Surface Water During Pre-Monsoon

5.3.2 Post-monsoon

During the post-monsoon season, the minimum level of *TDS* in the north was 515.44 mg/l while the maximum was 1408.35 mg/l (Table 5.3). The mean concentration 913.95 mg/l and a relatively high deviation from mean (270.64) was observed throughout the space. The *TDS* value was highest at *Sisva* and lowest at *Rayaka* (Table: 5.3).

Towards south, the concentration of *TDS* varied between 659.15 mg/l to 1994.89 mg/l (Fig.5.10). The mean was 1200.36 mg/l and deviation from mean was 370.28. The highest and lowest *TDS* was found at *Nandesari* and *Ankodiya* respectively.

The level of *pH* in northern part ranged from acidic (6.67) to normal (7.33) condition (Fig.5.11). The mean was 7.04 and standard deviation was 0.14. The level was highest at *Sisva*. The sub-surface water of *Ajod* was relatively more acidic water.

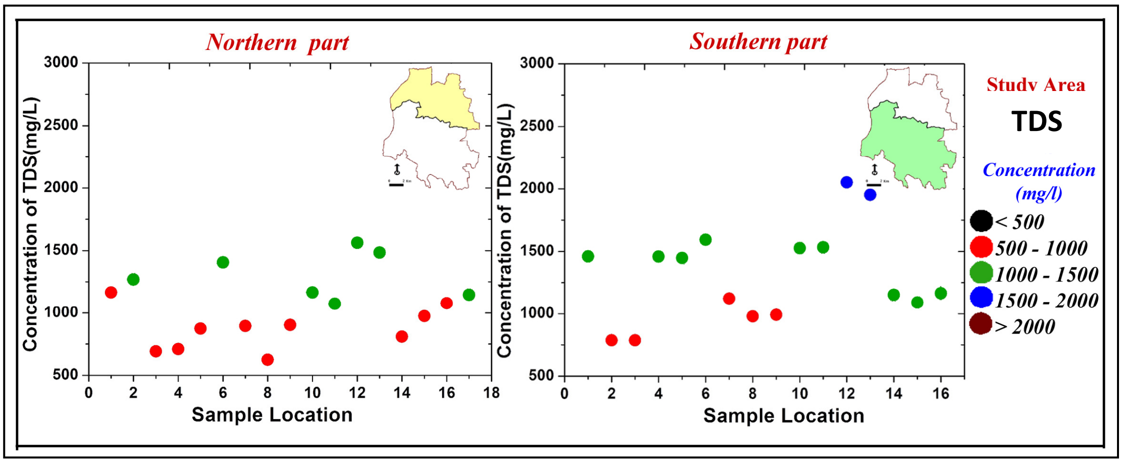

Fig.5.10: Concentration of *TDS* in Sub-Surface Water during Post-Monsoon

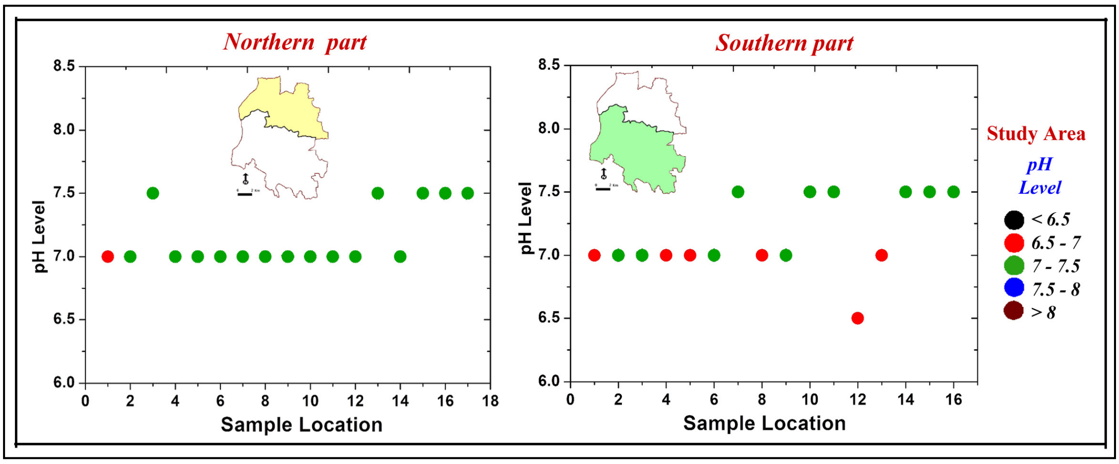

Fig.5.11: Level of *pH* in Sub-Surface Water during Post-Monsoon

The southern part depicted the *pH* between 6.50 to 7.17. The average value was 6.94 denoting the slightly acidic condition. The low deviation from the mean showed the less variability in the level. The maximum value (7.17) was observed at *Ranoli, Undera* and *Karodiya* while the minimum was found only at *Anagadh.*

The concentration of *EC* in northern part varied between 0.81 s/cm^{-1}x 10^{-3} and 2.20 s/cm^{-1}x 10^{-3} (Fig.5.12). The mean value was considerably high (1.43 s/cm^{-1}x 10^{-3}) while standard deviation showed low deviation from the mean (0.43). The highest and lowest was noted at *Sisva* and *Rayaka* respectively.

The southern part had the *EC* ranging from 1.03 s/cm^{-1}x 10^{-3} to 3.12 s/cm^{-1}x 10^{-3}. The mean concentration was 1.88 s/cm^{-1}x 10^{-3} while deviation from mean was 0.58. *Nandesari* depicted the largest value and *Ankodiya* showed the lowest level.

Table 5.3: Statistics of Sub-Surface Water Parameters during Post-Monsoon in Northern Part

Parameter	N	Average	Min.	Max.	St. Dev.
TDS	17	913.95	515.44	1408.35	270.64
pH	17	7.04	6.67	7.33	0.14
EC	17	1.43	0.81	2.20	0.43
Iron	17	0.72	0.19	1.37	0.35
Nitrite	17	95.15	61.19	137.69	22.14

Source: Computed

Table 5.4: Statistics of Sub-Surface Water Parameters During Post-Monsoon in Southern Part

Parameter	N	Average	Min.	Max.	St. Dev.
TDS	16	1200.36	659.15	1994.89	370.28
pH	16	6.94	6.50	7.17	0.20
EC	16	1.88	1.03	3.12	0.58
Iron	16	1.66	0.78	3.90	0.78
Nitrite	16	76.72	50.79	107.70	16.35

Source: Computed

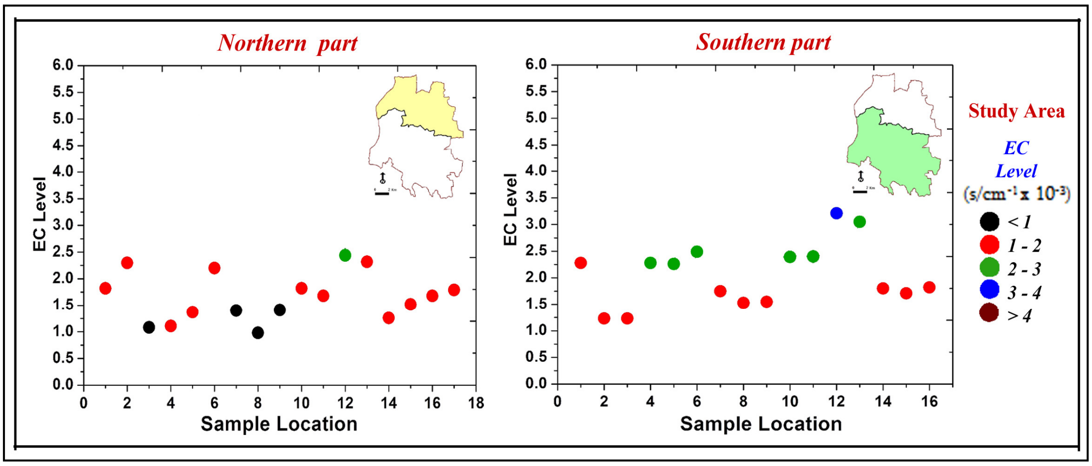

Fig.5.12: Level of *EC* in Sub-Surface Water during Post-Monsoon

The concentration of *iron* in northern part varied between 0.19 mg/l to 1.37 mg/l (Fig.5.13) The mean concentration was 0.72 mg/l. Standard deviation indicated lower deviation from mean (0.35).The concentration was highest at *Sisva* whereas lowest was found in *Sokhda*.

In the southern part, the concentration of *iron* ranged from 0.78 mg/l to 3.90 mg/l (Fig.5.13). The average was 1.66 mg/l and the deviation from mean was 0.78. The variability of concencention in this part was more. The maximum value was observed at *Nandesari* and minimum was noted at *Ankodiya*

The minimum concentration of *nitrite* in north was 61.19 mg/l and the maximum 137.69 mg/l. The mean dilution was 95.15 mg/l and deviation from mean was 22.14 mg/l (Fig.5.13) indicating the higher variation of *nitrite* concentration. *Rayaka* showed the largest value while *Sisva* the lowest.

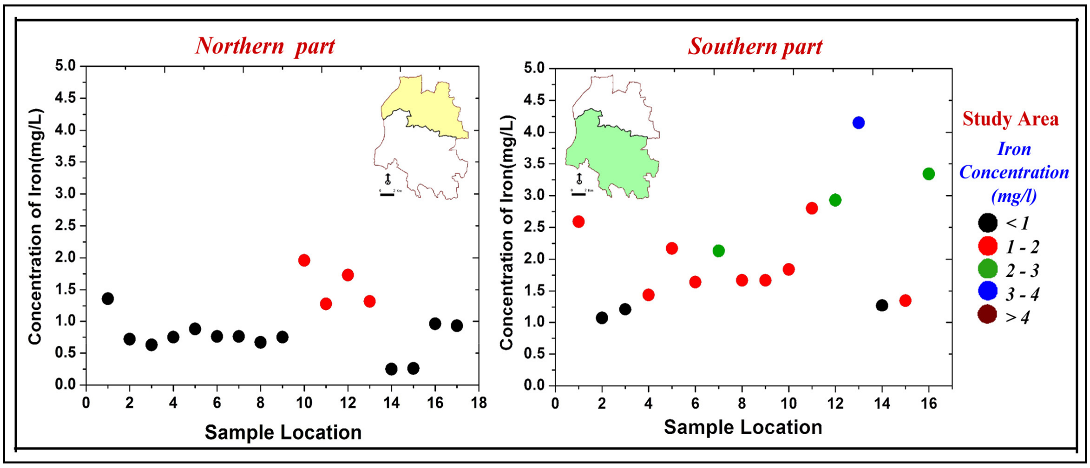

Fig.5.13: Concentration of *Iron* in Sub-Surface Water during Post-Monsoon

In the south the concentration of *nitrite* ranged between 50.79 mg/l to 107.70 mg/l (Fig.5.14). The mean concentration was 76.72 mg/l which is considerably higher than the desirable limit (45 mg/l). The standard deviation was 16.35 indicating a relatively lesser variability. The highest concentration was observed at *Ranoli* and lowest at *Dasharath*.

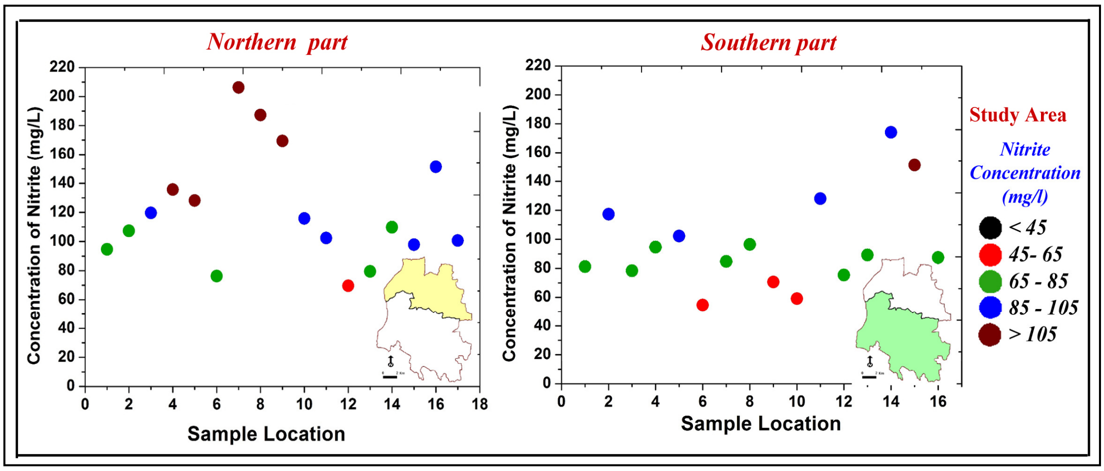

Fig.5.14: Concentration of *Nitrite* in Sub-Surface Water during Post-Monsoon

5.4 SPATIAL DISTRIBUTION OF SUB-SURFACE WATER

During the pre-monsoon season, the maximum concentration of *TDS* (>2000 mg/l) in sub-surface water was noted only in the southern part (near *Nandesari*

GIDC). Maximum waste disposal sites were noted in this section largely with 1500-2000 mg/l *TDS*. A small spot at the southern most part which was distant from the waste sites showed the lowest concentration (<1000 mg/l). In the north, 1500-2000 mg/l of *TDS* was noted at *Fajalpur* and *Sisva* joining the same concentration in the southern part. The northern part depicted the largest area of minimum concentration (<1000 mg/l). This portion was far away from the industries.

In the post-monsoon season, the level of *TDS* decreased in the study area. However, relatively higher concentration was observed where the industrial wastes were dumped (Fig.5.15). In the southern part, highest concentration (1500-2000 mg/l) was restricted near the *Nandesari* GIDC. The maximum area had the concentration of 1000-1500 mg/l, whereas <1000 mg/l was observed at central and southern part. The *northern* part can be divided into two halves, the region with relatively higher concentration (1000-1500 mg/l) near industries and the northern part with lower concentration (500-1000 mg/l).

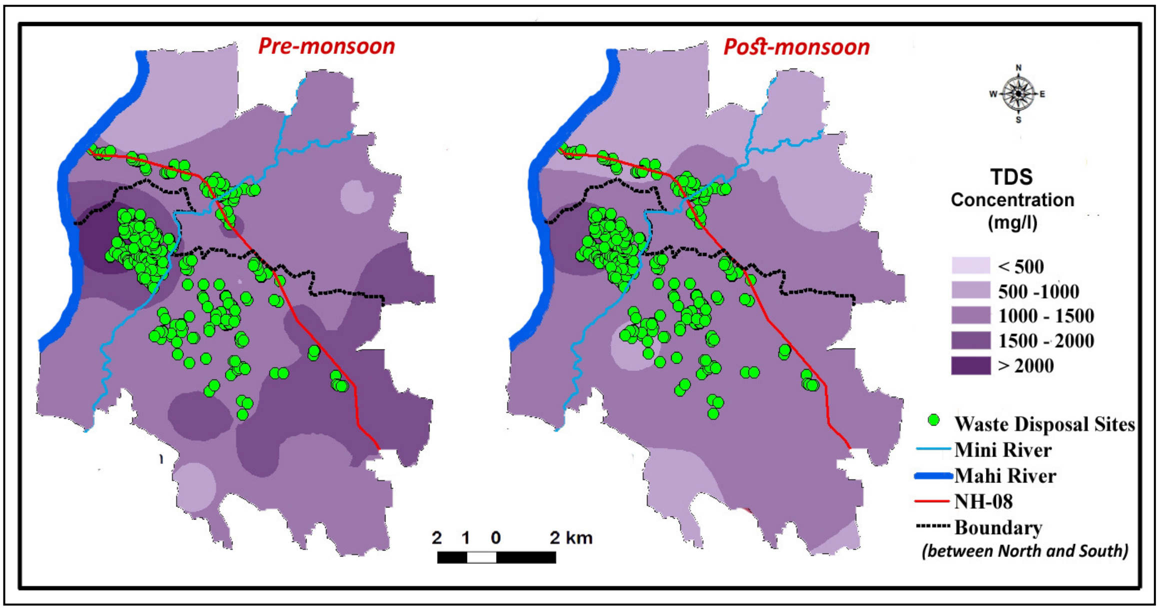

Fig.5.15: Spatial Distribution of *TDS* Concentration in Sub-Surface Water

Before the rainy season, in the southern part the *pH* level was lower (7.00-7.50) near *Nandesari* GIDC and rivers Mini and Mahi. The maximum area of this part had the level between 7.50-8.00. In the northern part, the lower *pH* value (7.00-7.50) was observed nearer to the waste disposal sites (Fig.5.16). On the other hand, *pH* value of 7.50 to 8.00 was noted where there was no industrial waste.

After the monsoon, in the entire study area the level of *pH* was lower (6.50-7.00) particularly in the areas of industrial waste dumping sites and downstream of the river Mini. The areas away from the industries had the *pH* level of 7.00-7.50.

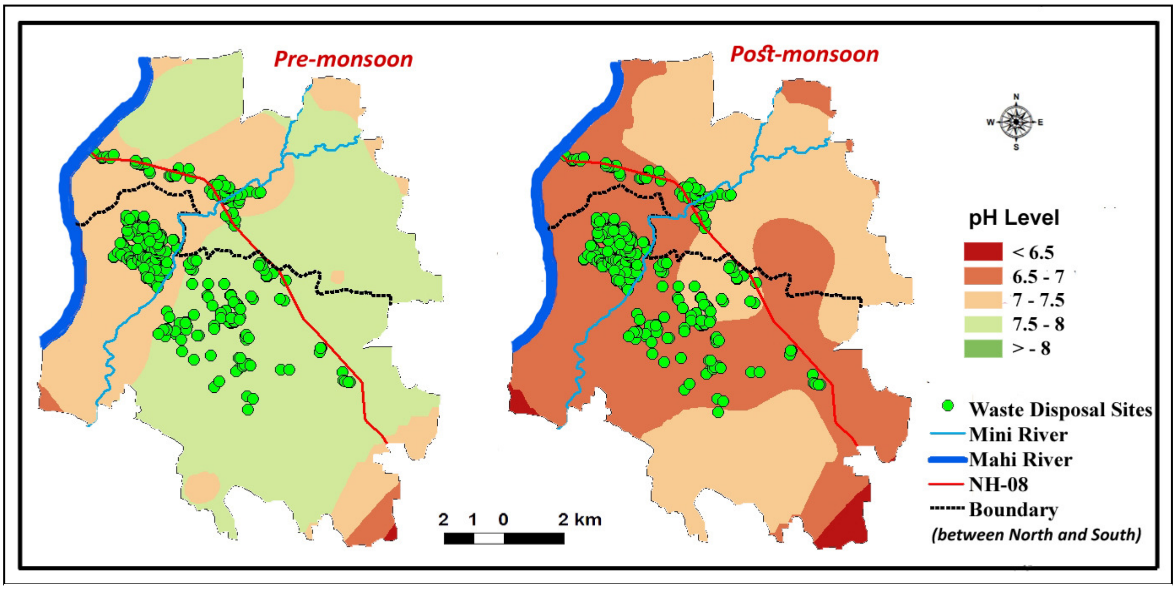

Fig.5.16: Spatial Distribution of *pH* Level in Sub-Surface Water

During the pre-monsoon season, the maximum area in the southern part had >2.00 s/cm^{-1}x 10^{-3} of *EC*. The concentration of 1.50 – 2.00 s/cm^{-1} x 10^{-3} was observed in the central and southern parts. In the north, this concentration was spread over the largest area. While the highest concentration (<2.00 s/cm^{-1}x 10^{-3}) was noted in the adjacent areas of southern part i.e near the industries. In the entire study area, lower level of *EC* (<1.50 s/cm^{-1}x 10^{-3}) was noted away from the dumping sites.

After the rains, the maximum (>2.00 s/cm^{-1}x 10^{-3}) concentration in the southern part was noted as patches near the waste disposal sites. The concentration between 1.50-2.00 s/cm^{-1}x 10^{-3} covered largest area. The lower concentration was 1.00-1.50 s/cm^{-1}x 10^{-3} and was noted in the southern part. In the north, the highest concentration was observed in small area at *Fajalpur* and *Sisva.* 1.5-2.00 s/cm^{-1}x 10^{-3} *EC* was found in and around the waste disposal sites. In the extreme north and north-eastern parts the lower level of *EC* was noted.

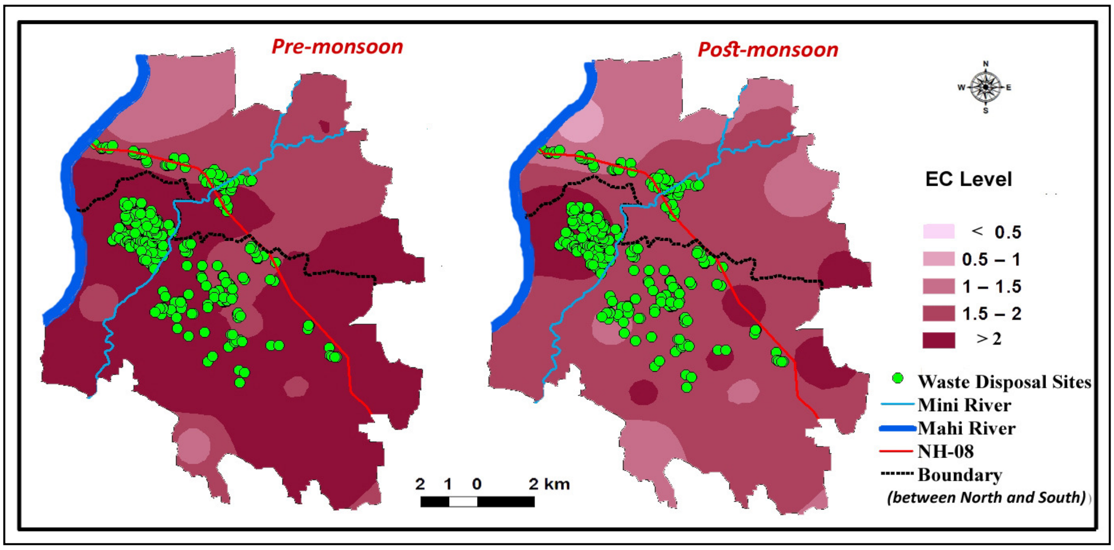

Fig.5.17: Spatial Distribution of *EC* Level in Sub-Surface Water

During the pre-monsoon, high concentration of *iron* (>1.50 mg/l) was observed in the entire southern part except for small patches with 1.00-1.50 mg/l *iron*. In the northern side the maximum concentration (>1.50 mg/l) was noted in a very small area near *Nandesari* which adjoined the same level in the southern site. The level of 1.00 to 1.50 mg/l was observed in the areas of waste disposal sites, along the Mini river and eastern part. The least level of *iron* was noted in the northern site.

After the monsoon, the area of highest concentration (>1.50 mg/l) shrank and

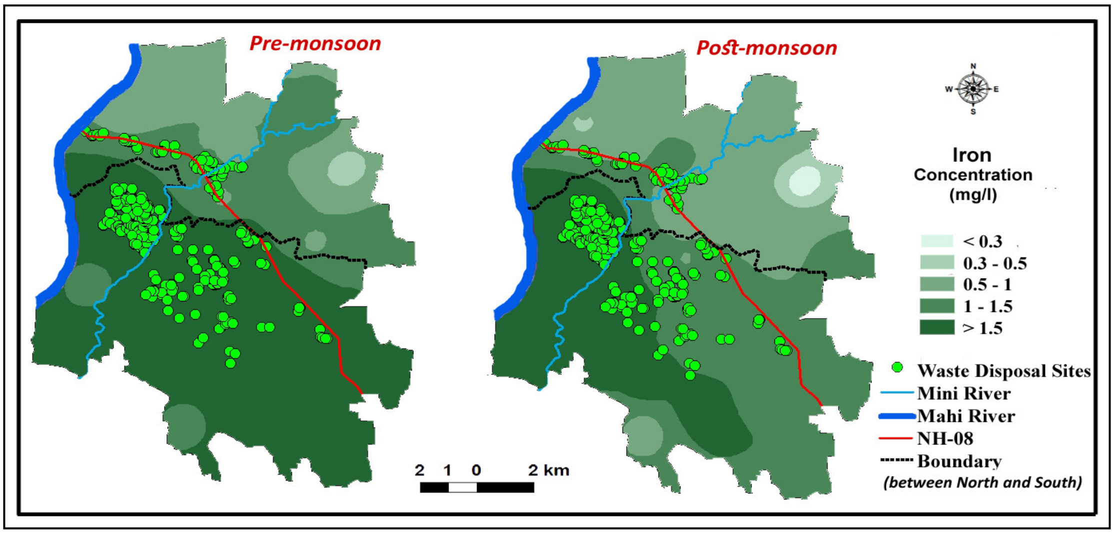

Fig.5.18: Spatial Distribution of *Iron* Level in Sub-Surface Water

was confined near *Nandesari* GIDC, IPCL and along the Mini river. The eastern site of this section showed the concentration of 1.00 to 1.50 mg/l. In the northern part, relatively higher concentration (1.00-1.50 mg/l) was restricted near to dumping sites. Major portion of this site depicted 0.50 mg/l to 1.00 mg/l of *iron* concentration.

During the pre-monsoon season, the absorption of *nitrite* was lower in the southern part. The major portion of this site had the concentration <45.00 mg/l. 45.00 to 65.00 mg/l of *nitrite* was found near the industrial areas. Conversely, the northern part had higher concentration. The highest amount (85-105 mg/l) was observed in the north. The maximum area of this section had the concentration of 45.00-65.00 mg/l.

After the monsoon, the level of *nitrite* increased in the entire area. In the southern part the concentration between 65.00-85.00 mg/l covered the largest area. The area with 85.00-105.00 mg/l overlapped with the waste disposal sites. In the northern part the maximum concentration was observed. In this section the higher level was noted along the NH-08 and Mini river.

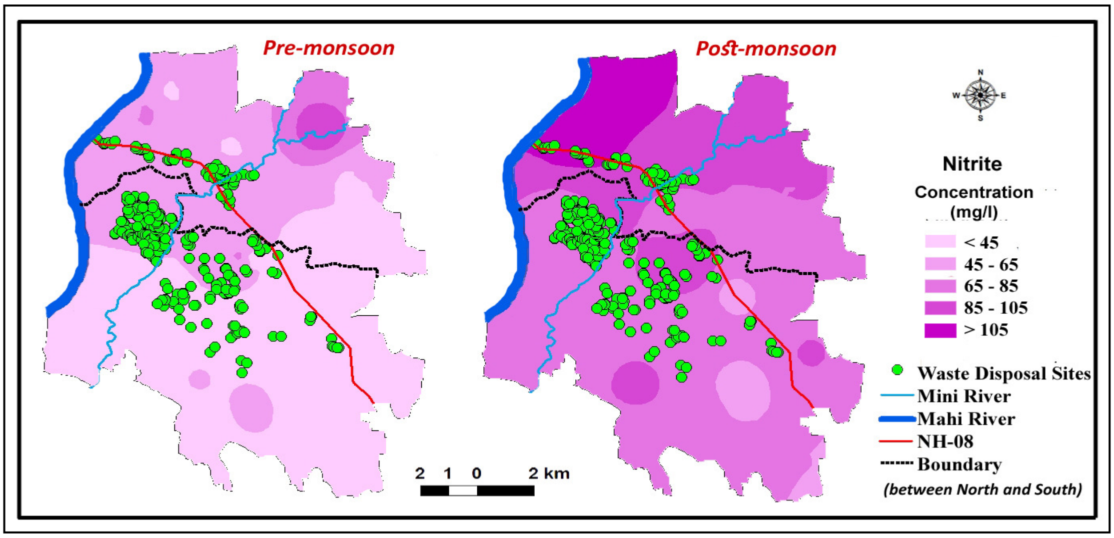

Fig.5.19: Spatial Distribution of *Nitrite* Level in Sub-Surface Water

5.5 SUITABILITY ANALYSIS OF SOLID WASTE DISPOSAL SITE

The suitability of solid waste disposal site was analysed in the study by taking reference to road, railway line, river, pond, residential area and industrial area. After selecting these criteria, the suitable distance from the above criteria were entered and generated the specific zone for IWD sites. These steps were performed individually for all the criteria. Finally, overlay analysis was done considering all the criteria to generate the different waste disposal zones that is unsuitable, marginal suitable, moderate suitable and most suitable zones for solid waste disposal sites

5.5.1 Suitable Distance from Road

The road networks consist of major, minor and pedestrian roads. The national highway NH- 08 which connects Mumbai and Delhi pass through the middle of the study area. It plays an important role in the establishment of industries. Many major and minor industries are located within 5 to 10 kms of the NH- 08. Therefore, it is known as 'Golden Corridor'. While allocating the site for industries the solid waste disposal site should also be selected at a suitable distance from roads to control

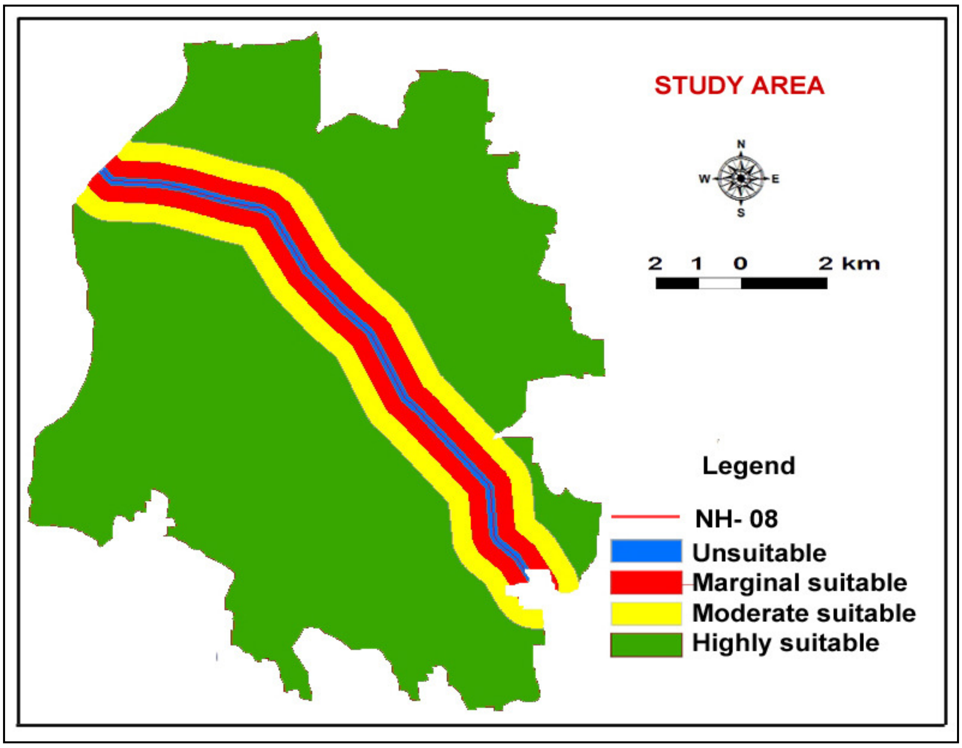

Fig.5.20: Suitable Distance from Road to Waste Disposal Sites

pollution and other environmental issues. As per the universal concept, the waste disposal sites should not be located within 100 meters of road (Berisa and Birhanu 2015, Olusina and Shyllon 2014, Akbari 2008 and Tchobanoglous 1993). Thus, the study preferred a buffer of 100 m distance from the roads by taking only NH-08 into consideration. The area within 100 m of the highway was considered as unsuitable zone. Marginal suitable areas lie between 100 m to 500 m. The distance from 500 m up to 1000 m was considered as moderate suitable zone and most suitable area was at a distance >1000 m. The results revealed that 76.90% of the study area is highly suitable for solid waste dumping site whereas 1.49% is unsuitable for solid waste dumping site is of the total area (Table:5.5 and Fig.20).

Table 5.5: Distance from Road and Area Coverage of Suitability Level

Distance (m)	Level of suitability	Area (sq.km.)	Area in %
<100	Unsuitable	2.22	1.49
100 - 500	Marginal suitable	13.74	9.19
500 - 1000	Moderate suitable	18.57	12.42
>1000	Highly suitable	114.98	76.9
	Total	149.51	100

Source: Calculated

5.5.2 Suitable Distance from Railway Line

Railway Station of Vadodara belongs to the Western Railway zone of Railways. It is a major junction of the Western Railway Main Line and one of the Gujarat's busiest junctions. Vadodara is connected by rail to all important cities and towns of the state as well as the country. Bajwa, Ranoli and Nandesari are the other railway station located in the study area. The waste disposal sites should not be located within 100 m of railway line (Ebistu and Minale 2013). Four different zones were classified considering relative distance from the railroad (Table:5.6). The zone located at the distance more than

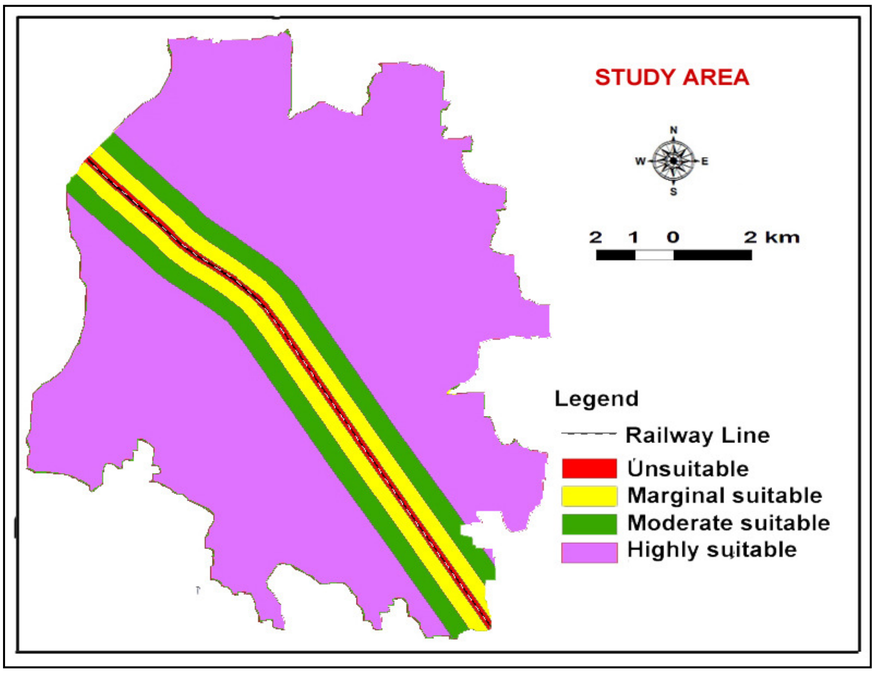

Fig.5.21: Suitable Distance from Railway Line to Waste Disposal Sites

1000 m were selected as highly suitable for solid waste disposal site. The deep green colour area depicted this zone comprised of 75.95%. The moderate and marginal suitable land covered an area of 13.03% and 9.66% respectively. While 1.36% of the study area (red colour) is unsuitable for disposal of waste.

Table 5.6: Distance from Railway and Area Coverage of Suitability Level

Distance (m)	Level of suitability	Area (sq.km.)	Area in %
<100	Unsuitable	2.03	1.36
100 - 500	Marginal suitable	14.45	9.66
500 - 1000	Moderate suitable	19.48	13.03
>1000	Highly suitable	113.55	75.95
	Total	149.51	100

Source: Calculated

5.5.3 Suitable Distance from River

It is preferable to dump the solid waste away from the river banks. In the study area, the river Mahi flows from north to south in the western border and river Mini from northern towards southern. To maintain the environmental condition of the river water at least 200 m buffered distance should be considered (Ebistu and Minale, 2013).

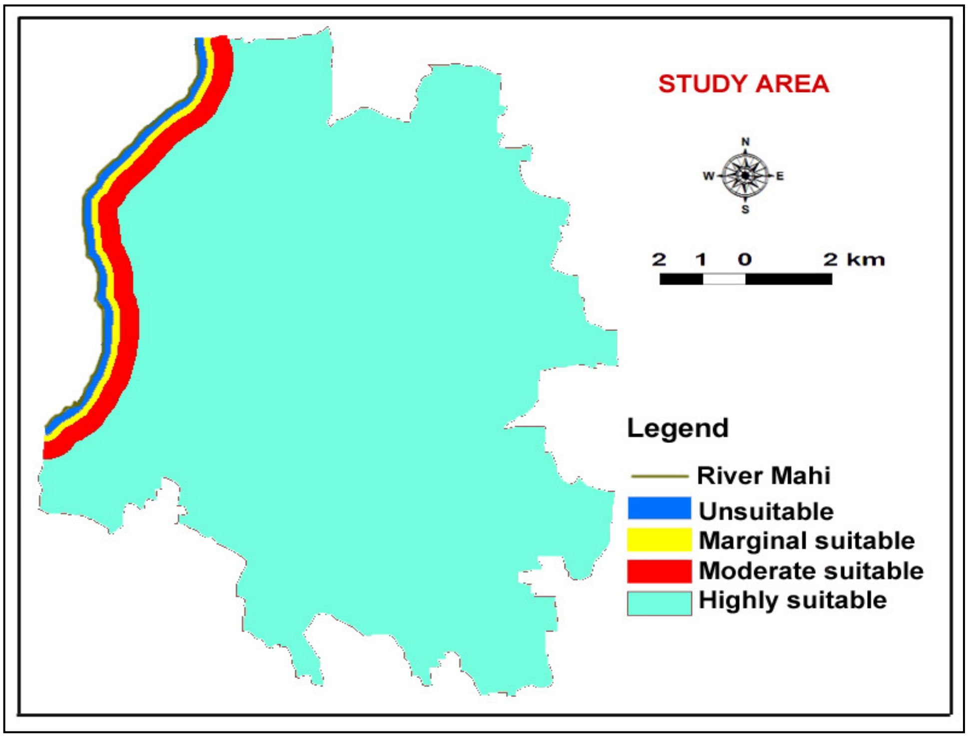

Fig.5.22: Suitable Distance from Mahi River to Waste Disposal Sites

Accordingly, four different zones of each river were categorised. In reference to Mahi river, the light blue shade (Tables:5.7 and Fig.5.22) indicated the highly suitable land for solid waste dumping site covering an area of 86.54% of the study area. The orange and yellow colour represented moderate (8.00% of the total area) and marginal suitability (2.48%) respectively. The unsuitable area covered an area of 4.44 sq.km. (2.97%) which is represented by blue colour. In regard to Mini river, 7.18% land is unsuitable (yellow shade). The marginal and moderate suitability land covered 5.69% and 16.61% of the total area. The deep green colour depicted the most suitable area for solid waste disposal (70.52%).

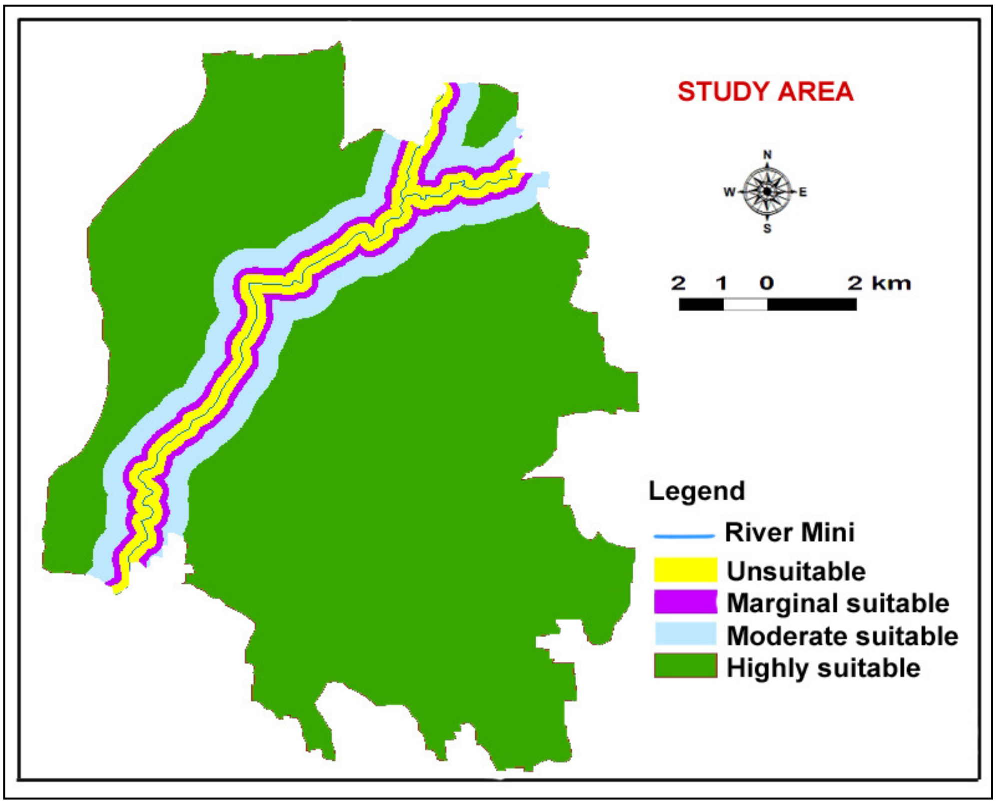

Fig.5.23: Suitable Distance from Mini River to Waste Disposal Sites

Table 5.7: Distance from Mahi River and Area Coverage of Suitability Level

Distance (m)	Level of suitability	Area (sq.km.)	Area in%
<200	Unsuitable	4.44	2.97
200 - 350	Marginal suitable	3.71	2.48
350 - 800	Moderate suitable	11.96	8
>800	Highly suitable	129.4	86.55
	Total	149.51	100

Source: Calculated

Table 5.8: Distance from Mini River and Area Coverage of Suitability Level			
Distance (m)	Level of suitability	Area (sq.km.)	Area in%
<200	Unsuitable	10.74	7.18
200 - 350	Marginal suitable	8.5	5.69
350 - 800	Moderate suitable	24.83	16.61
>800	Highly suitable	105.44	70.52
	Total	149.51	100

Source: Calculated

5.5.4 Suitable Distance from Surface-Water (Pond)

Small lake and pond were scattered in the study area (Fig.5.23) and are mostly situated near the residential areas. The waste should not be disposed in the vicinity of these water bodies (Babalola and Busu, 2011).The area within 200 m showing in red colour is unsuitable zone and is spread over 5.14% of the total area. Marginal suitability is between 200-350 m (6.10%) and 350-800 m is moderate suitable (26.86%). The dark green shaded denoted the highly suitable zone for waste disposal site.

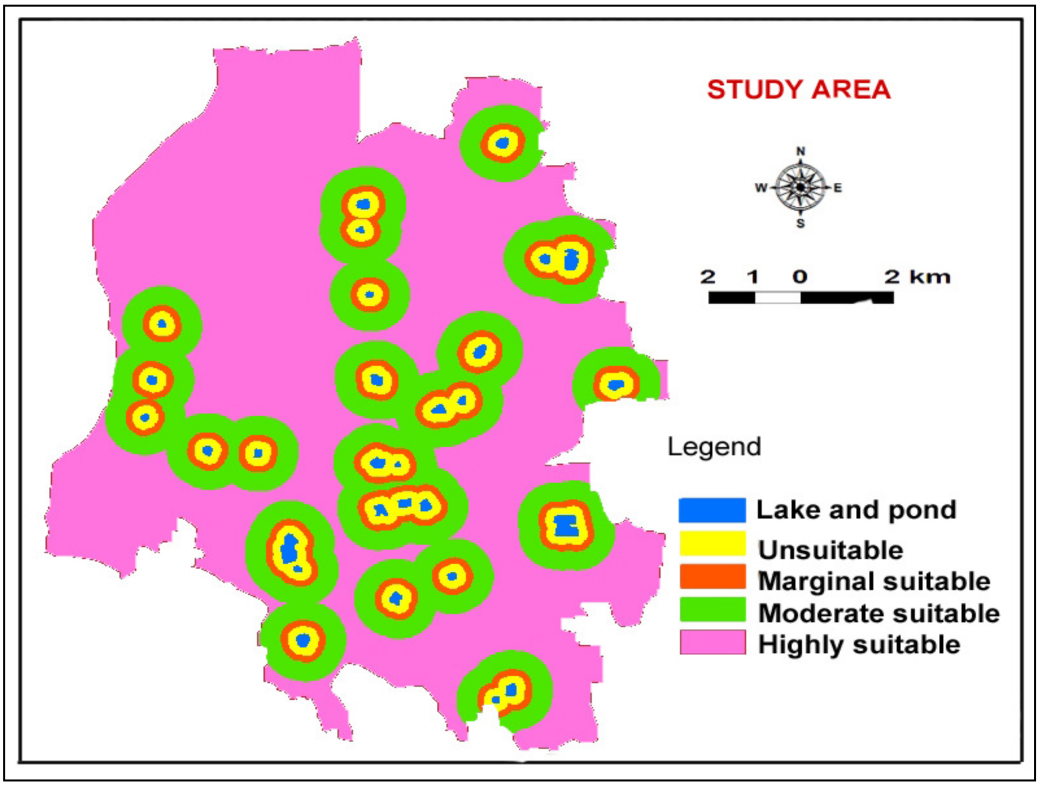

Fig.5.24: Suitable Distance from Lake and Pond to Waste Disposal Sites

Distance (m)	Level of suitability	Area (sq.km.)	Area in%
<200	Unsuitable	7.69	5.14
200 - 350	Marginal suitable	9.13	6.1
350 - 800	Moderate suitable	40.17	26.87
>800	Highly suitable	92.52	61.89
	Total	149.51	100

Table 5.9: Distance from Pond and Area Coverage of Suitability Level

Source: Calculated

5.5.5 Suitable Distance from Residential Area

The southern part of the study area showed the maximum concentration of settlements. The other residential areas are scattered all over the area. The suitable distance for solid waste dumping site from residential has been determined as >300 m. The study considered the distance <300 m as unsuitable (28.77%). The area of 300-700

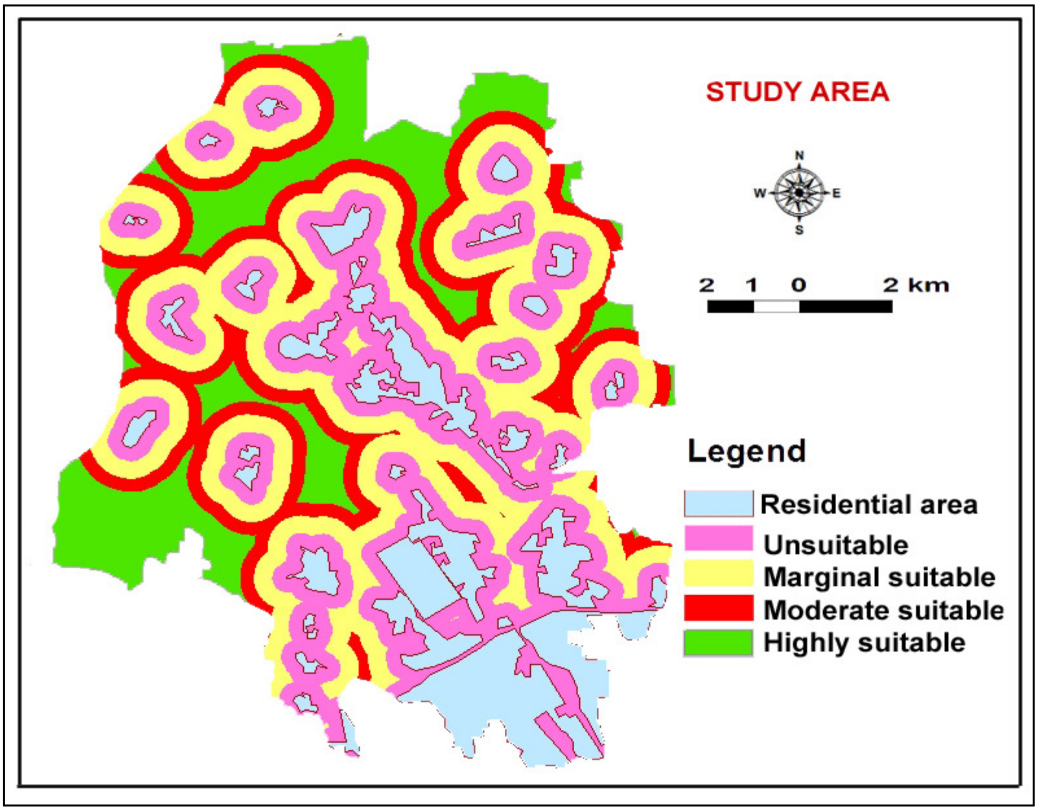

Fig.5.25: Suitable Distance from Residential Area to Waste Disposal Sites

m distance depicted the marginal suitability (33.83%) shown in yellow colour. 50.58 sq.km. (21.58%) is the zone of moderate suitability (700-1000 m) and the most suitable is above 1000 m distance from the residential area. It covered 15.82% of the total area. The highly suitable zone covered lowest share as compared to other levels of suitability.

Table 5.10: Distance from Residential Area Coverage of Suitability Level

Distance (m)	Level of suitability	Area(sq.km)	Area in%
<300	Unsuitable	43.02	28.77
300 - 700	Marginal suitable	50.58	33.83
700 - 1000	Moderate suitable	32.27	21.58
>1000	Highly suitable	23.64	15.82
	Total	149.51	100

Source: Calculated

5.5.6 Suitable Distance from Industrial Area

It is well known that waste should not be dumped at a very close proximity to the industrial areas. The highly suitable solid waste dumping sites from industrial areas in this study include *Nandesari* GIDC, Indian Petro-Chemical Limited and Gujarat State Fertilizer Cooperation. The area greater than 1000 m was selected as highly suitable for solid waste dumping site (79.22% of the total area). About 94.70 sq.km. (6.33%) is situated at the distance of 700-1000 m and was considered as moderately suitable. The red colour depicted the marginal suitability and the land which is unsuitable for dumping accounts for about 88.89 sq.km. (5.95% of the total).

Table 5.11: Distance from Industrial Area Coverage of Suitability Level

Distance (m)	Level of suitability	Area (sq.km)	Area in%
<300	Unsuitable	8.89	5.95
300 - 700	Marginal suitable	12.71	8.5
700 - 1000	Moderate suitable	9.47	6.33
>1000	Highly suitable	118.44	79.22
	Total	149.51	100

Source: Calculated

5.6 DISCUSSION

Industrial activities generate waste products which are considered as useless and harmful to environment and human beings. With the increase in the number of industries the generation of waste products also tend enhance. Proper management of

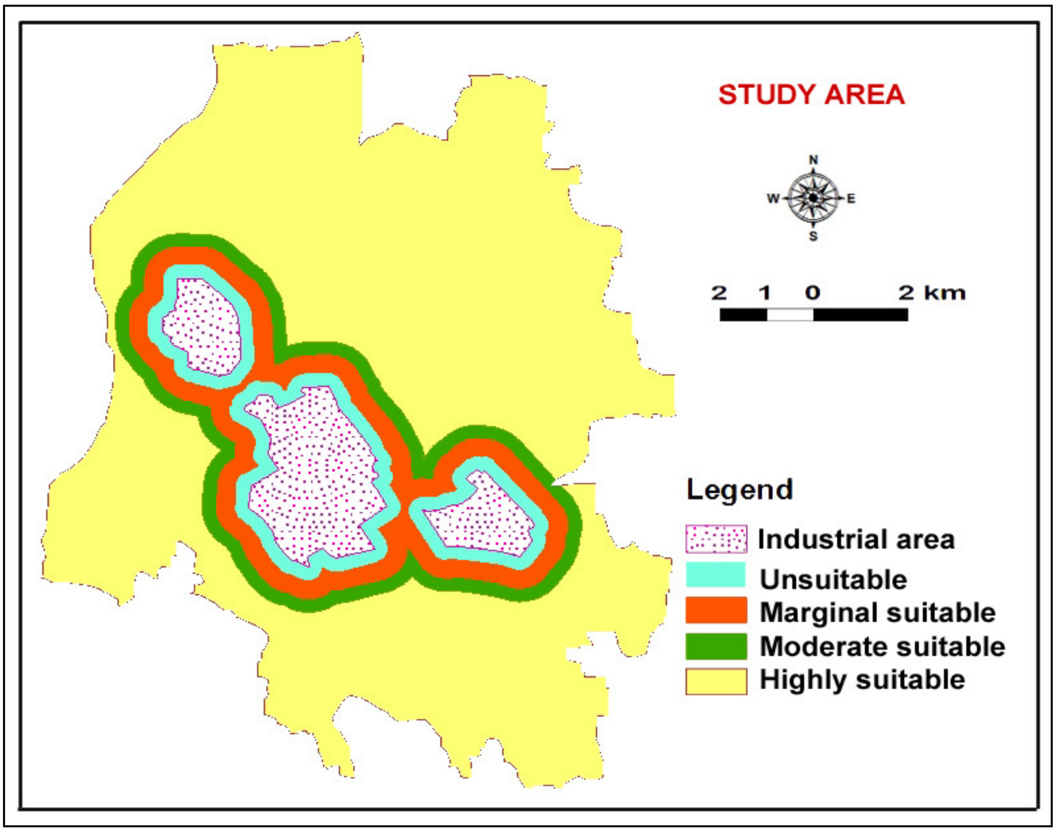

Fig.5.26: Suitable Distance from Residential Area to Waste Disposal Sites

such waste is essential as improper management have adverse impact on environment quality, human health and water quality. The number of waste disposal site increased from 42 in 2007 to 159 in 2011. However, a slight decreased (151) was observed in 2015. Though the number of waste disposals sites decrease in 2015 but the area covered was increased (from 0.49 sq km in 2011 to 0.58 sq km in 2015). The waste disposals sites increased mostly in the southern part as it was nearer to the industrial areas but some increasing trend in the northern segment away from industrial area was also observed. In the southern part, number of waste disposal sites in *Nandesari* GIDC and Indian Petro Chemical Limited remarkably increased. In the case of northern part *Fajalpur, Rayaka, Sankarda* and *Padmala* villages were noted as new places for waste disposal sites.

The impact of the waste disposal site on the sub-surface water quality was undertaken. The concentration of *TDS*, *pH, EC*, *iron* and *nitrite* in sub-surface water was found fluctuating in pre and post-monsoon seasons. The level of *TDS*, *pH*, *EC* and *iron* were higher during pre-monsoon season whereas *nitrite* concentration increased after the monsoon season. The south-western part depicted the higher concentration of *TDS*, *EC* and *iron* where the waste disposal sites were noted.

One way of proper management of industrial waste is to dispose industrial waste judiciously. In the study, factors like road, railway line, river, pond, residential and industrial areas were considered and demarcation of distance was made base on the level of suitability of solid waste disposal site. The results revealed that about 70-79% of the study area is highly suitable for solid waste dumping site by referring to road, railway, industries, pond and river. But in the case of residential area only 15% of the study area is highly suitable for solid waste dumping site.

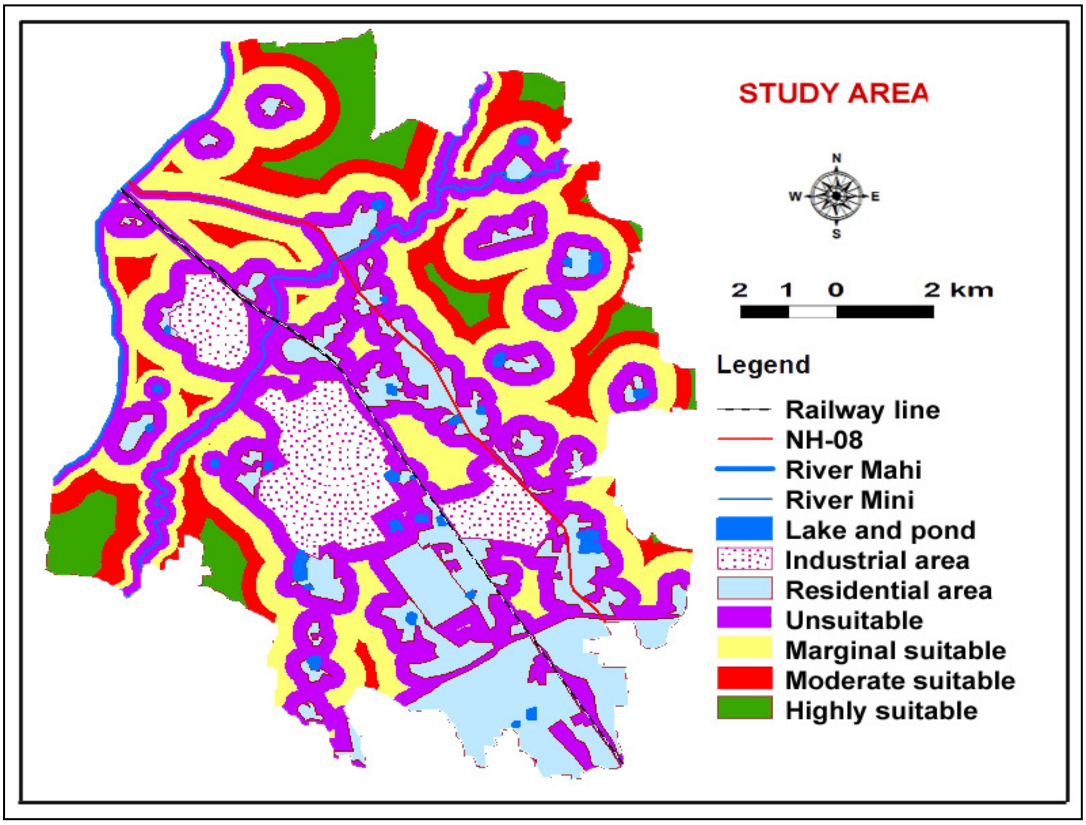

Fig.5.27: Identified Suitability Sites

By considering the study area in totality, the suitability of solid waste dumping site was analysed. Based on the distance and all the criteria overaly analysis was done (Table: 5.12). The results from the overlay analysis in the Arc GIS produced the map of suitable solid waste disposal sites (Fig.5.27). The map depicted four classes which are shown in green, red, yellow and violet. The highly suitable zone of waste disposal sites is represented by green colour. About 6.65% of the total study area is occupied by this category. The red shade denoted moderate suitable area and it spreads over an area of 16.41 sq.km.(10.64%). Marginal suitable zone is represented by violet (24.49%) and the remaining 57.89% falls under unsuitability zone. Taking this into consideration, the highly suitable area for waste disposal sites was selected on the northern and south-western part. These areas will be the optimum distance from settlements, industrial areas, surface water, roads and railway network.

Table 5.12: Suitability Area and Percentage of Area Coverage

Level of Suitability	Area in km	Area in%
Built up area	37.95	25.38
Unsuitable	48.85	32.67
Marginal	36.73	24.57
Moderate	16.41	10.98
Highly suitable	9.57	6.40
Total	149.51	100.00

Source: Calculated

Resume

In this chapter, industrial waste disposal (IWD) sites were identified and it was observed that the IWD sites were more near the Nandesari GIDC. The number and area of IWD sited significantly increased from 2007 to 2015. Sub-surface water was more contaminated where the IWD sites were located. The overlay analysis in GIS showed that the most suitable IWD sites are located in the northern and south-western part of the study area. The next chapter focuses upon the impact of industrial activities and socio-economic factors on human health.

Fig.5.28: Industrial Waste in Different Parts of the Study Area
Source: Photograph during Field Visit

Fig.5.29: Industrial Waste in Different Parts of the Study Area
Source: Photograph during Field Visit