Published Research Paper

ISSN : 2231-1726

Studies in Geography | Vol. 24, 2013
University of Rajasthan, Jaipur

Assessment of Water Quality near Chemical and Petrochemical Industries of Vadodara Taluka, Gujarat

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Abstract

Water is an important resource which is essential for survival of all the organisms including human beings. With the increasing population, urbanization and industrialization there is an increased pressure on all the natural resources including water resources. As a result serious increasing pressure on it, the quality and quantity of water is becoming a major issue of concern. The present study has been carried out to assess water quality near the Chemical and Petro-chemical industries of Vadodara taluka, Gujarat. For the study 58 water samples from the surface and subsurface water were collected for both the pre and post monsoon seasons of 2011. The water parameters like total dissolved solids (TDS), pH, iron and nitrite were chemically analyzed. Pair 't' test was successfully applied to analyse the seasonal variability of water parameters. It was found that pH level was within the desirable limit (BIS, 1991) while the TDS, iron and nitrite were above the desirable limits. Thus the study concludes that the surface and subsurface water near the chemical and petrochemical industries is contaminated. Hence for future sustainability it is essential to control the contamination of water in this region.

Key Words : *Surface and subsurface, Water quality, Seasonal variability, Pre monsoon and Post monsoon.*

Introduction

Water is an important 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 elements in it. Their presence is essential but the deviation from the permissible as well as desirable limit affects human health (Kanchan and Roy, 2009). Indiscriminate overexploitation of water results into its restricted availability and deterioration of quality. (Kanchan and Ghosh 2012, Villaescusa and Bollinger 2008, Harvey, et al. 2005 and Choudhury, 2000). Further, natural factors like leaching of minerals, chemical reactions of various organic and inorganic elements, weathering and erosion etc affect the surface and subsurface water characteristics (Ghosh and Kanchan, 2014). The quality is more adversely affected by anthropogenic factors and human intervention in the ecosystem. The injudicious discharge of industrial affluent and excessive use of fertilizer and pesticides in agricultural fields are the main sources of man-made contaminants of water (Fawell and Nieuwenhuijsen, 2013).

Industrialisation is the major thrust of economic and social development. It helps to build a self reliant country and enhances the living standards of human being. But, an uncontrolled industrialisation might turn into a major source of environmental issues (Reddy and Behera, 2006). Many a times, when the industries injudiciously discharge their effluents it gets accumulated in nearby open pits or in the depressions and low lying areas. Subsequently, the accumulated water percolates and contaminates the subsurface water quality (Purandara, et al. 2003). Phiri, et al. (2005) examined the impact of industrial effluents on river water quality in Malawi, Africa. It was observed that the effluents were acidic with high level of total dissolved solids (TDS), electrical conductivity (EC) and chloride. Similarly, Teng, et al. (2011) discussed the impact of industrialisation and urbanisation on surface water quality in Panzhihua mining town in China. The results revealed that the effluents bearing Chemical Oxygen demand (COD) and Biological Oxygen demand (BOD) were released into the river water which caused degradation of the surface water quality. Studied the ground water quality in industrial zone of Visakhapatnam, India. It was observed that both the wastes generated by industrial and domestic activities polluted the subsurface water. Bikkad and Mirgane, (2009) and Hassan, et al. (2013) worked on the ground water quality in industrial areas of Aurangabad district, Maharashtra. The high level of EC, TDS, thorium, chloride, calcium and COD in water were noticed in this belt. From these studies it can be concluded that water quality directly depends on the quality and quantity of the discharge from the plant and on its dilution rate. Gadhia, et al. (2012) studied the seasonal variations in physico-chemical characteristics of Tapi estuary in Hazira industrial area, Gujarat. The study revealed that the water quality of estuary has been affected by industrial and domestic effluents.

The rapid pace of industrialisation in the Gujarat state is the need for developmental processes but if the wastes discharged from the industries are not disposed judiciously then it might turn into a source of surface and subsurface water contamination. The present paper is an attempt to assess the water quality near Chemical and Petro Chemical Complex Industrial Area, Gujarat Industrial Development Corporation (GIDC) and Gujarat State Fertiliser Co-operation limited (GSFC) encompassing the Golden Corridor Belt (No.-08) lying on the northern part of Vadodara Taluka, Gujarat State, India.

Study Area

The present study focuses on a selected segment which is an industrialized belt of Vadodara taluka in Gujarat, India. The area encompasses many chemical and petro chemical industries. Geographically, the region extends between 22°19'2. N and 22°28'12" N latitude, and from 73°3'35." E to 73°11'29." E longitude covering an area of 149.52 sq. km (Fig.1). In the north, this area is bounded by Savli taluka of Vadodara district while Vadodara Urban Agglomeration is towards the south. In the west the area extends upto Mahi River. A national highway (NH- 08) connecting Delhi and Mumbai traversing through the region plays an important role in the establishment of industries known as 'Golden Corridor'. The majar industrial complexes include (i) Gujarat Industrial Development Corporation (GIDC) located at Nandesari is a major industrial estate of the area which spread is over 2.06 sq. km. streching along the River Mini, a tributary of river Mahi. There are about 250 small and medium industrial units in the estate which largely produce chemicals, pharmaceuticals, dyes, pesticides, plastics etc. (ii) Gujarat State Fertilzer Co-operation Limited (GSFC) at Jawharnagar, is another important large scale industry situated in the southern part of the study region. It produces chemicals, petrochemicals, fertilizers, agricultural and biotechnological products. (iii) Indian Petrochemical Complex Limited (IPCL), Jawaharnagar is now known as Reliance Industries and produces benzene, carbon fibre, caustic soda, chlorine, poly butadiene, (iv) Gujarat Refinery at Jawaharnagar is the largest refinery of Indian Oil Corporation Limited (IOCL). It generates liquefied petroleum gas, auto and natural gas, petrol, gasoline, gas oil, jet and marine fuel, bitumen, petrochemical special product and crude oil.

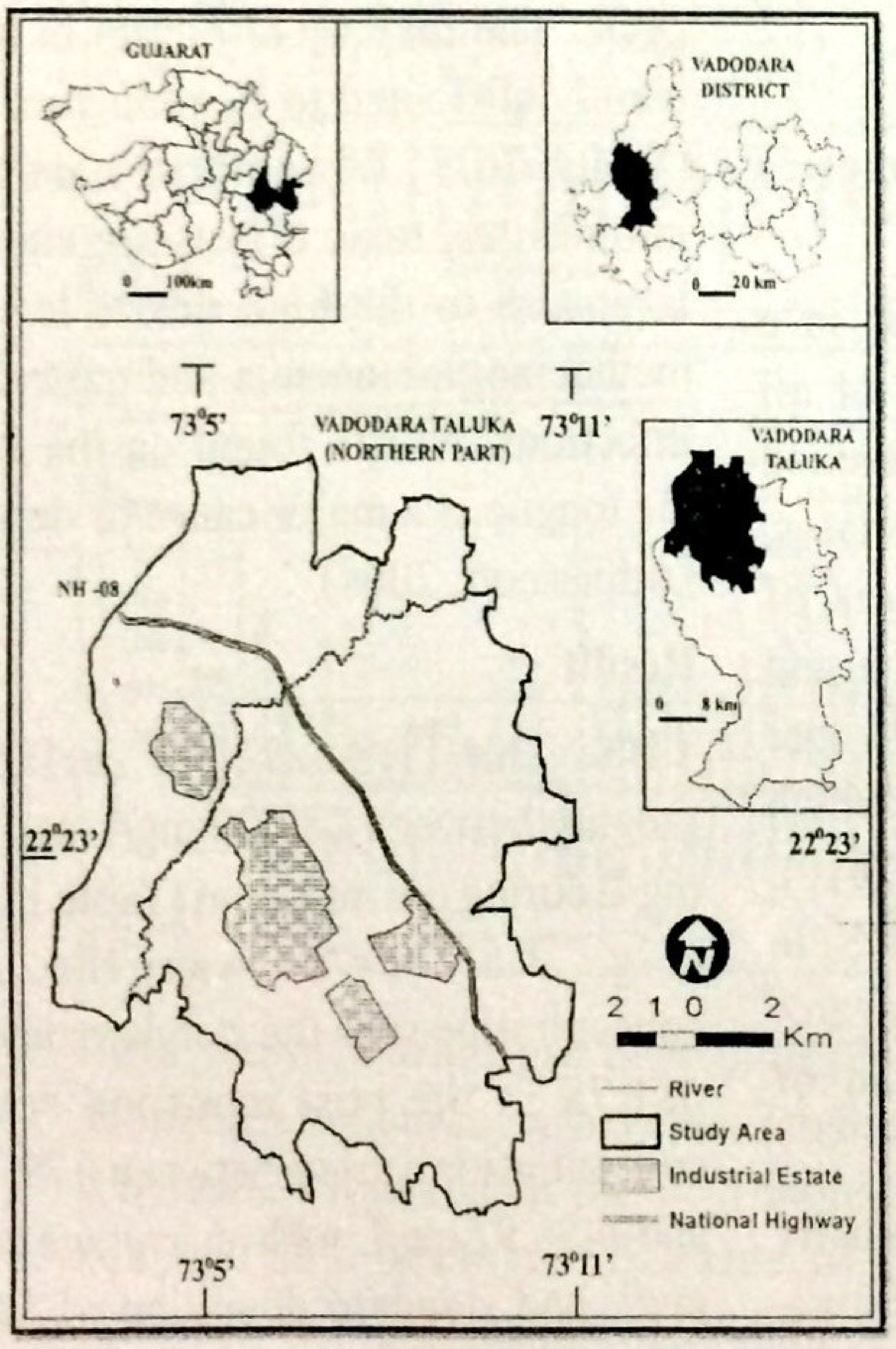

Fig. 1. Location of study area

Methodology

Fifty-eight water sampies [twenty-three surface and thirty five subsurface] were collected through random sampling method for the pre-monsoon and post-monsoon seasons of 2011.(Fig.2) The pre monsoon samples were collected in the month of April while the post monsoon samples were taken in the month of November. Garmin E-trex Vista HCx handheld GPS was used for

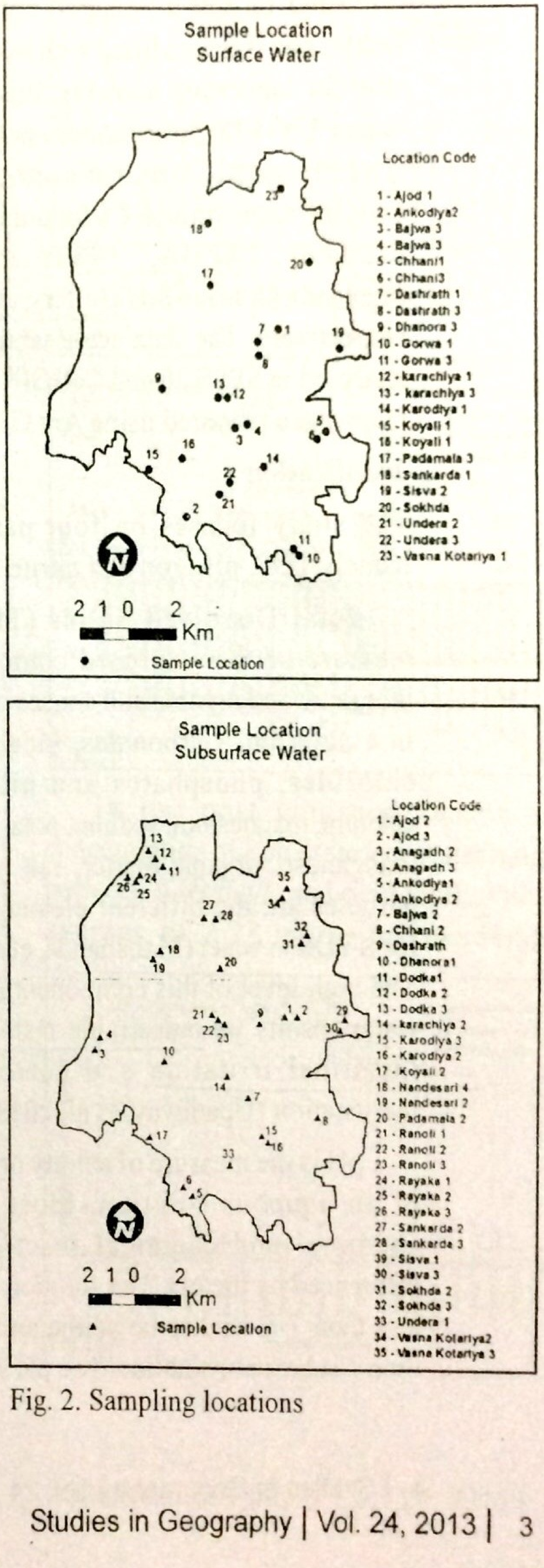

Fig. 2. Sampling locations

marking the location of surface as well as subsurface water samples and data were tripped through Mapsource Software. Total dissolved solids (TDS) and pH was measured in the field itself. TDS metre (Henna Dist. 4, HI 98304) was used for TDS while pH was measured by pH indicating paper (Merk Made). The water samples were collected in 250 ml capped polyethylene bottles and were acidified with hydrochloric acid for laboratory analysis. Elico Double Beam UV-VIS Spectrophotometer Model S1-210 was used to measure nitrite and iron concentration through Cadmium Reduction Methods (APHA, 1989) and 1,10 Phenanthroline method (Jeffery, et al. 1989) respectively. The data were tabulated and analysed in SPSS 20 and ORIGIN 8 and the maps were prepared using Arc GIS 10.1.

Justification

The study focuses on four parameters namely TDS, pH, iron and nitrite.

Total Dissolved Solids (TDS) is a measure of the combined content of all inorganic and organic substances contained in a solution. Carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles are the different elements which form TDS in water (Mahananda, et al. 2010). The high level of this component (TDS) in water results in undesirable taste, gastro-intestinal irritation and corrosion or incrustation (Upadhyay, et al. 2013).

pH is the measure of acidity or basicity of an aqueous solution. Most of bio-chemical and chemical reactions are influenced by the pH. The solution with pH less than 7 is said to be acidic and greater than 7 is basic or alkaline. The pH ± 7.35 to 7.45 in the blood may cause health problems. Headache, nausea, fever, skin infection, osteoporosis are some of the symptoms due to lower level of pH (Kanchan, et al. 2012). However, the desirable pH range essential for drinking water is between 6.5-8.5 (BIS 1991).The pH of water affects the solubility of many toxic chemicals. When acidity increases, most metals become more water soluble and more toxic (Patel and Parikh, 2013).

Iron is commonly found in both surface and subsurface waters (Casey, 2009). It is an essential element in human nutrition, but presence of excess iron in water may lead to tissue damage (Lieu, et al. 2011).

Nitrate and nitrite are the naturally occurring ions and are parts of nitrogen cycle. The toxicity of nitrate in humans is mainly attributed to its reduction to nitrite (WHO, 2011).When nitrates are converted into nitrites, toxic effects are encountered. Exposure to the high nitrite level causes methaemoglobinaemia and gastrointestinal infections. Nitrite found on the surface of the tongue is a major cause of dental caries (Addisscott, 2004).

Result

TDS: The TDS level in surface water ranging between 282.00 mg/L and 2910.00 mg/L during pre monsoon (Table 1). 1261.83 (Fig. 3.a) mg/L was the average concentration with the standard deviation of 681.75 In the post monsoon season the concentration varied between 179.15 mg/L and 2456.92 mg/L with an average of 867.66 mg/L and standard deviation of 547.84. In subsurface water, the minimum concentration before the rains was 377.00 mg/L while the maximum was 4540.00 mg/L (Table 2) with an average of 1236.94 mg/

L (Fig. 3.b) and high standard deviation of 740.53. In post monsoon, the concentration ranged between 339.11 mg/L and 1951.46 mg/L. 958.09 mg/L and 424.92 were the mean and standard deviation respectively (Tabl 1 & 2, Fig. 3.a & b).

pH: In the pre monsoon season pH value of the surface water ranged from 7.47 to 9.45. The average value was 8.15 (Fig 4.a) with lower standard deviation of 0.58 (Table 1) whereas in the post monsoon season it decreased and varied between 6 to 8. The mean was 7.02 while 0.38 was the deviation from mean. During pre monsoon, pH in subsurface water ranged between 7 to 8 (Fig 4.b) which reduced in the post monsoon season. The average pH value of pre monsoon and post monsoon seasons were 7.68 and 7.09 respectively and 0.38 and 0.28 were the standard deviations (Tab. 2).

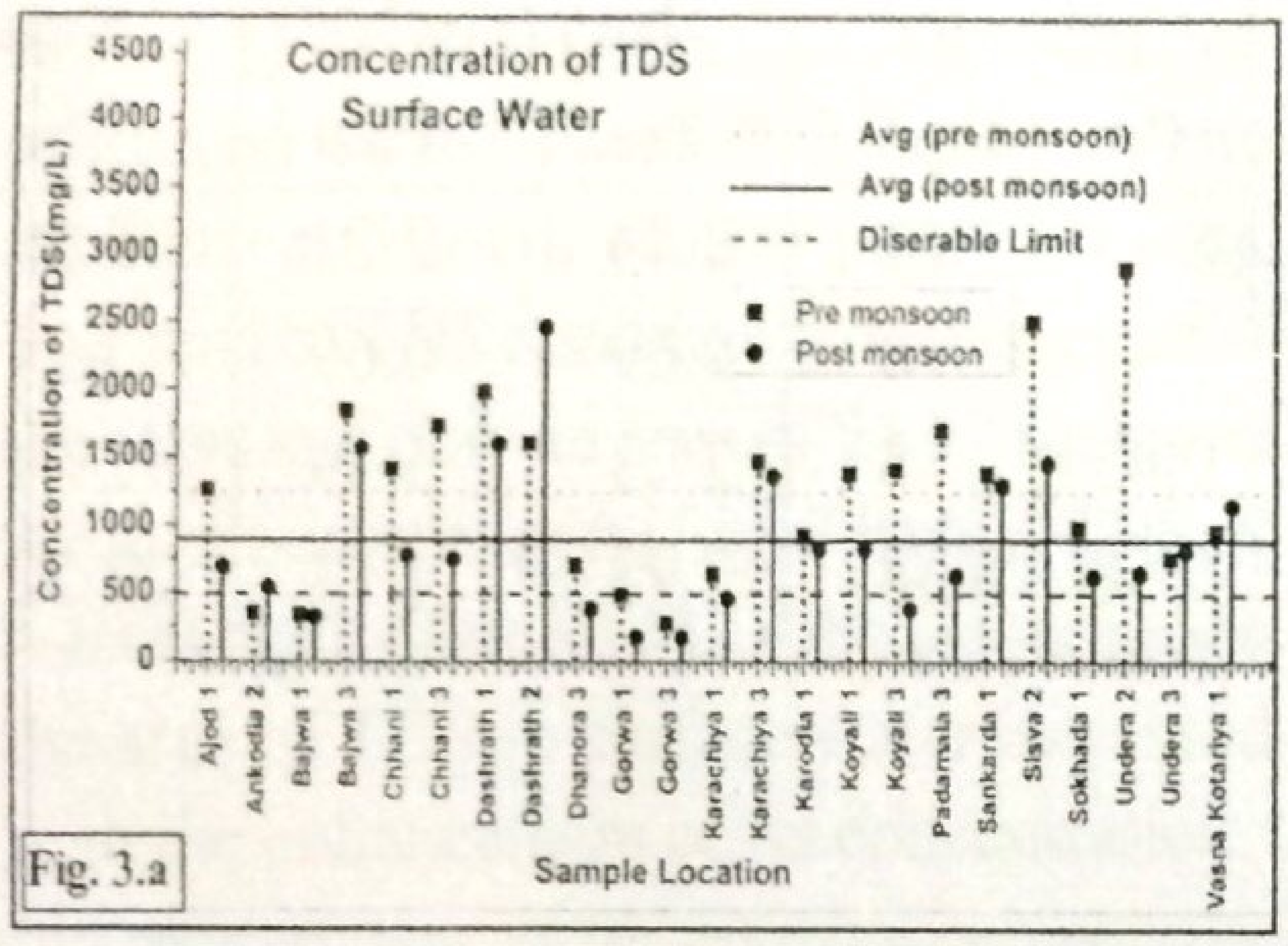

Fig. 3.a

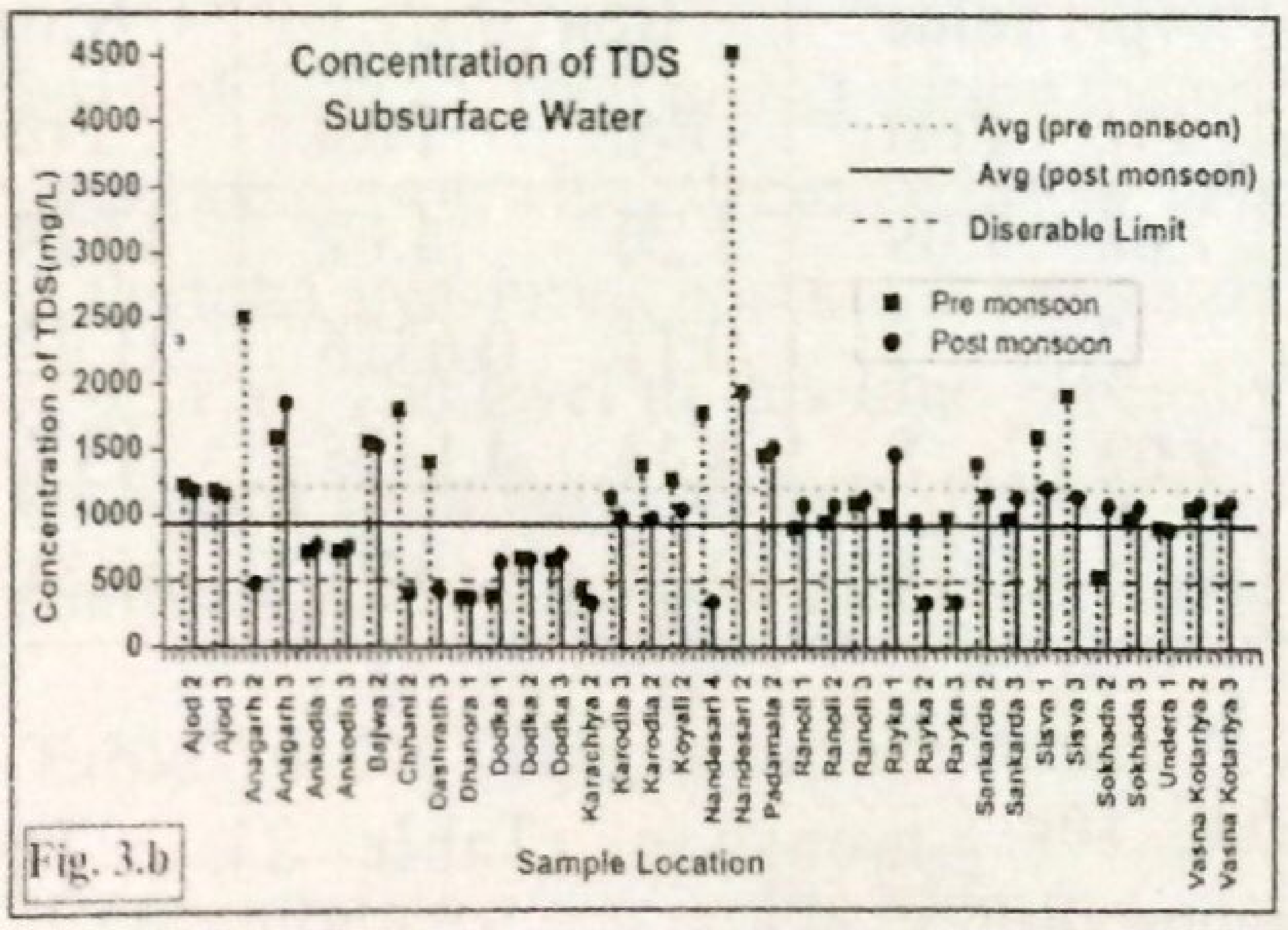

Fig. 3.b

Iron: The concentration above the desirable limit of iron was observed in the entire region throughout the year. It was higher in pre monsoon season (Fig 5.a) when the maximum amount in surface water was 27.3 mg/L with an average of 8.44 mg /L and standard deviation 7.75 (Table 1).

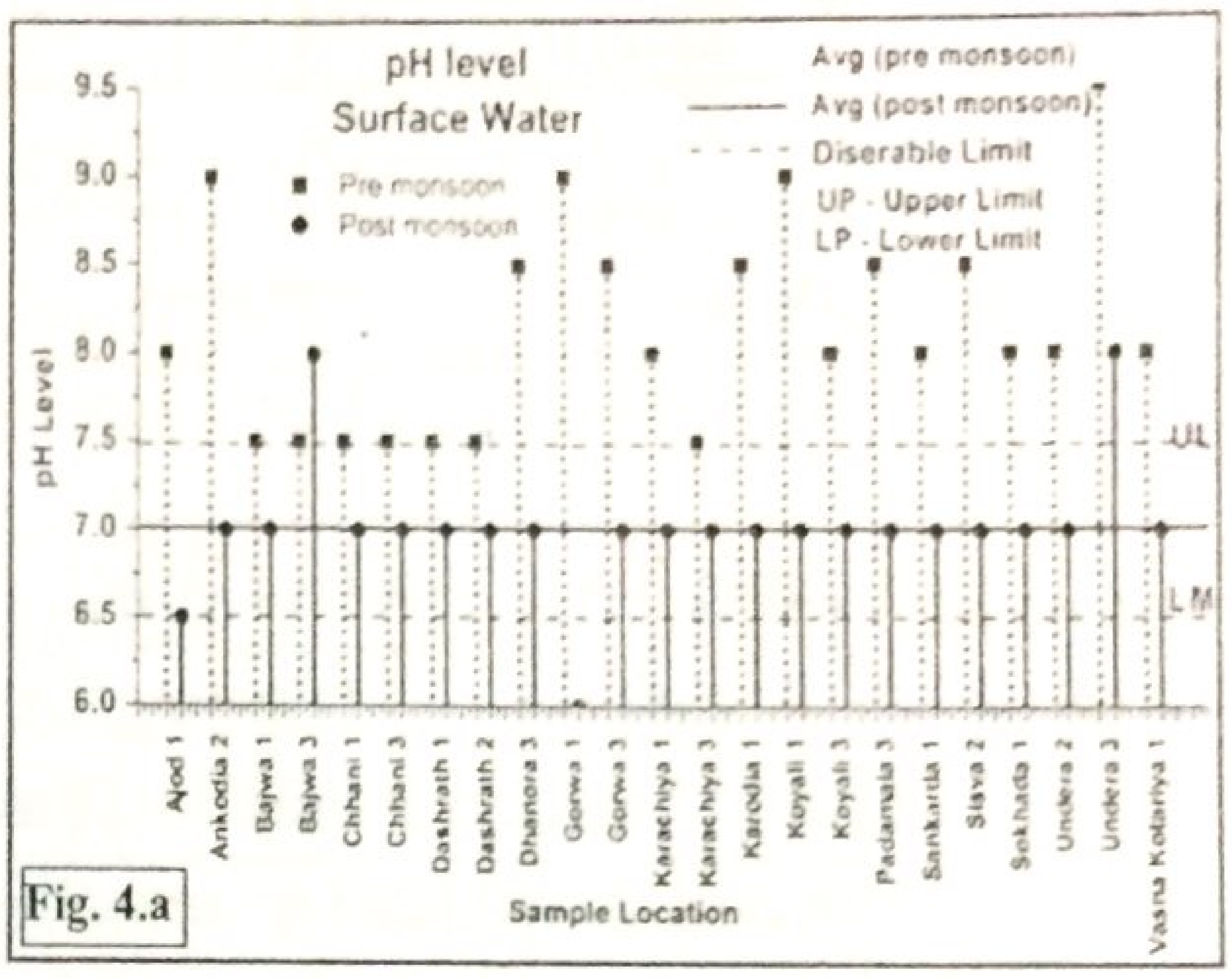

Fig. 4.a

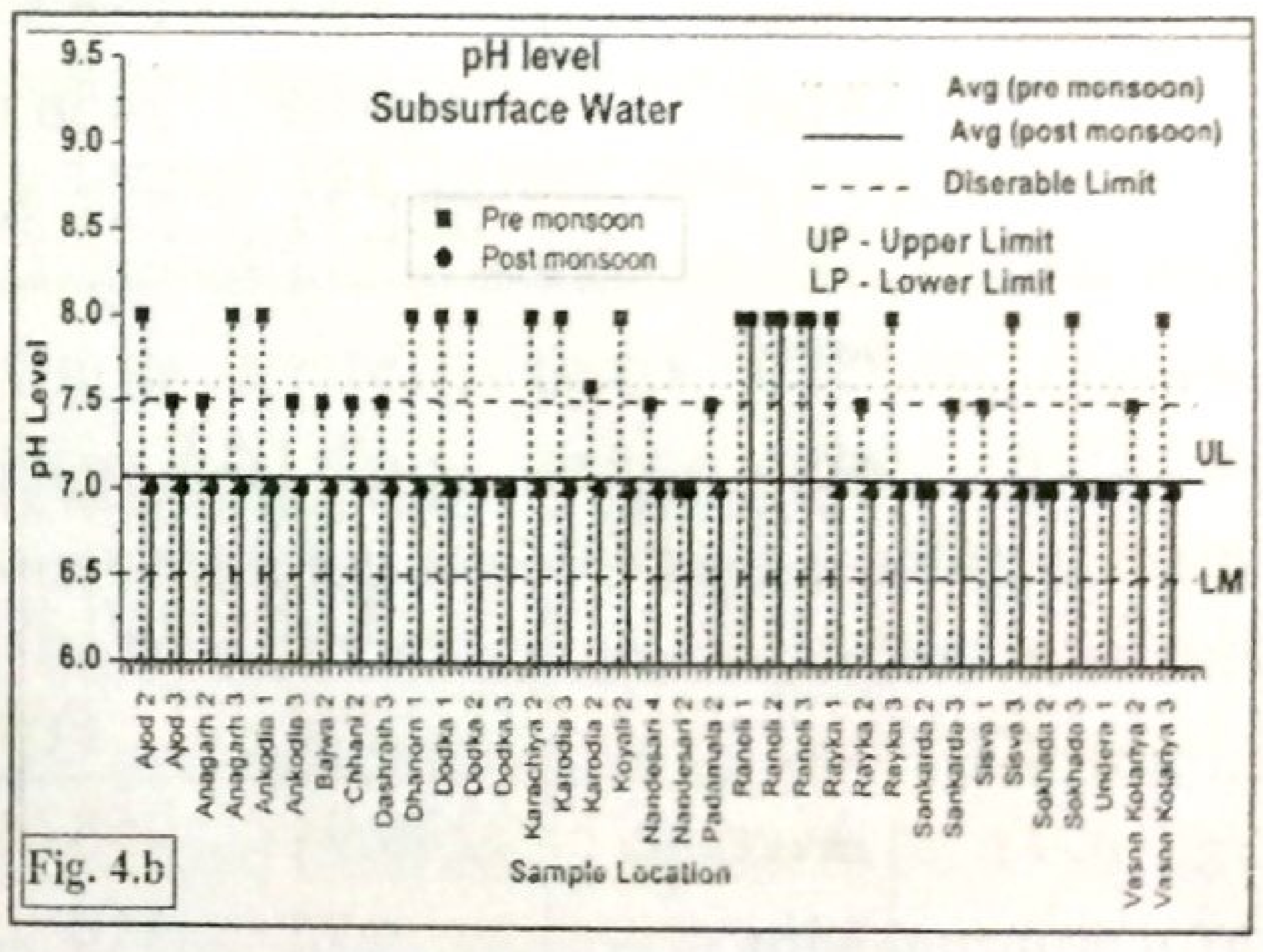

Fig. 4.b

In the post monsoon season the concentration of iron in surface water ranged between 0.69 mg/L and 5.59 mg/L with an average of 2.23 mg/L. A considerable

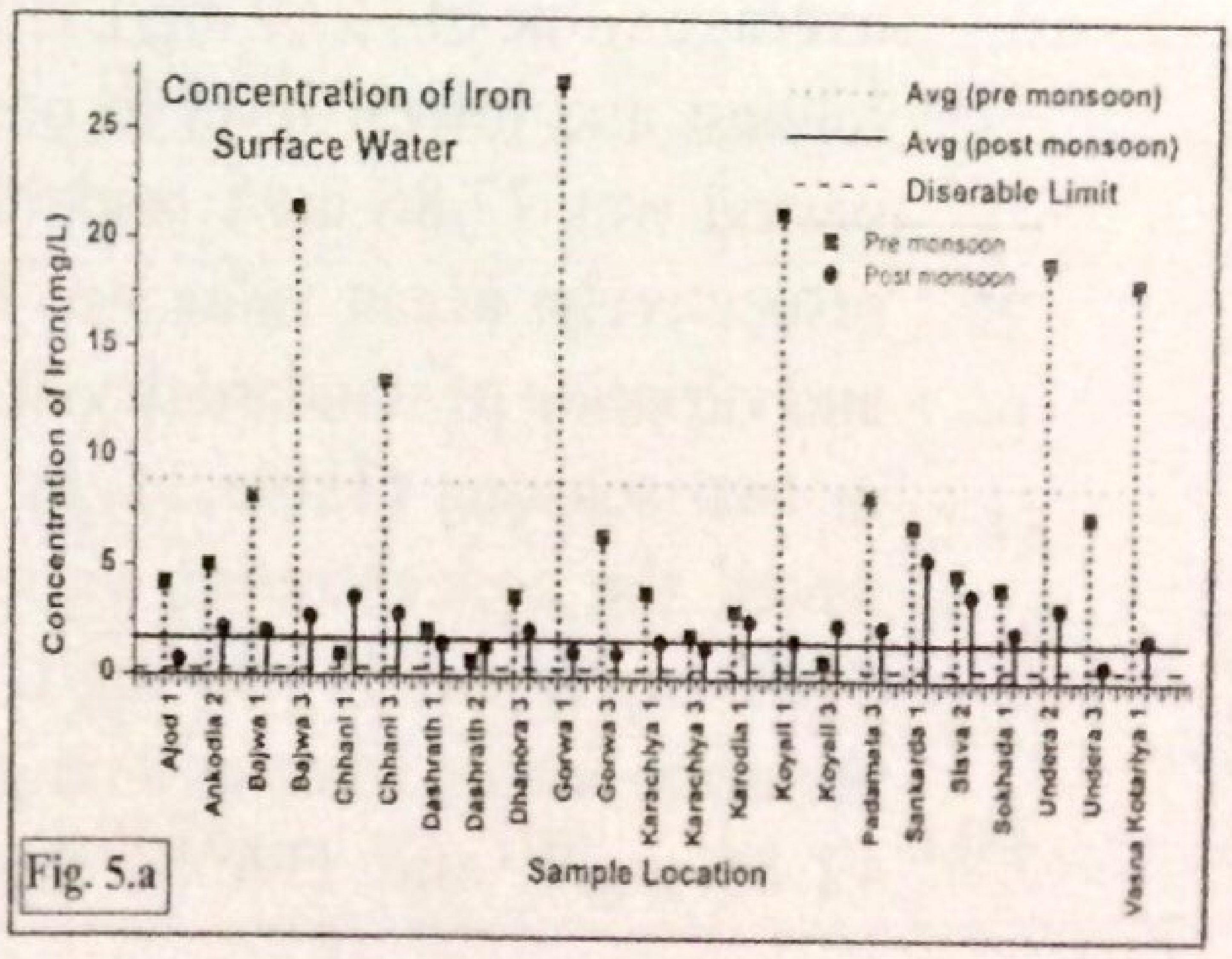

Fig. 5.a

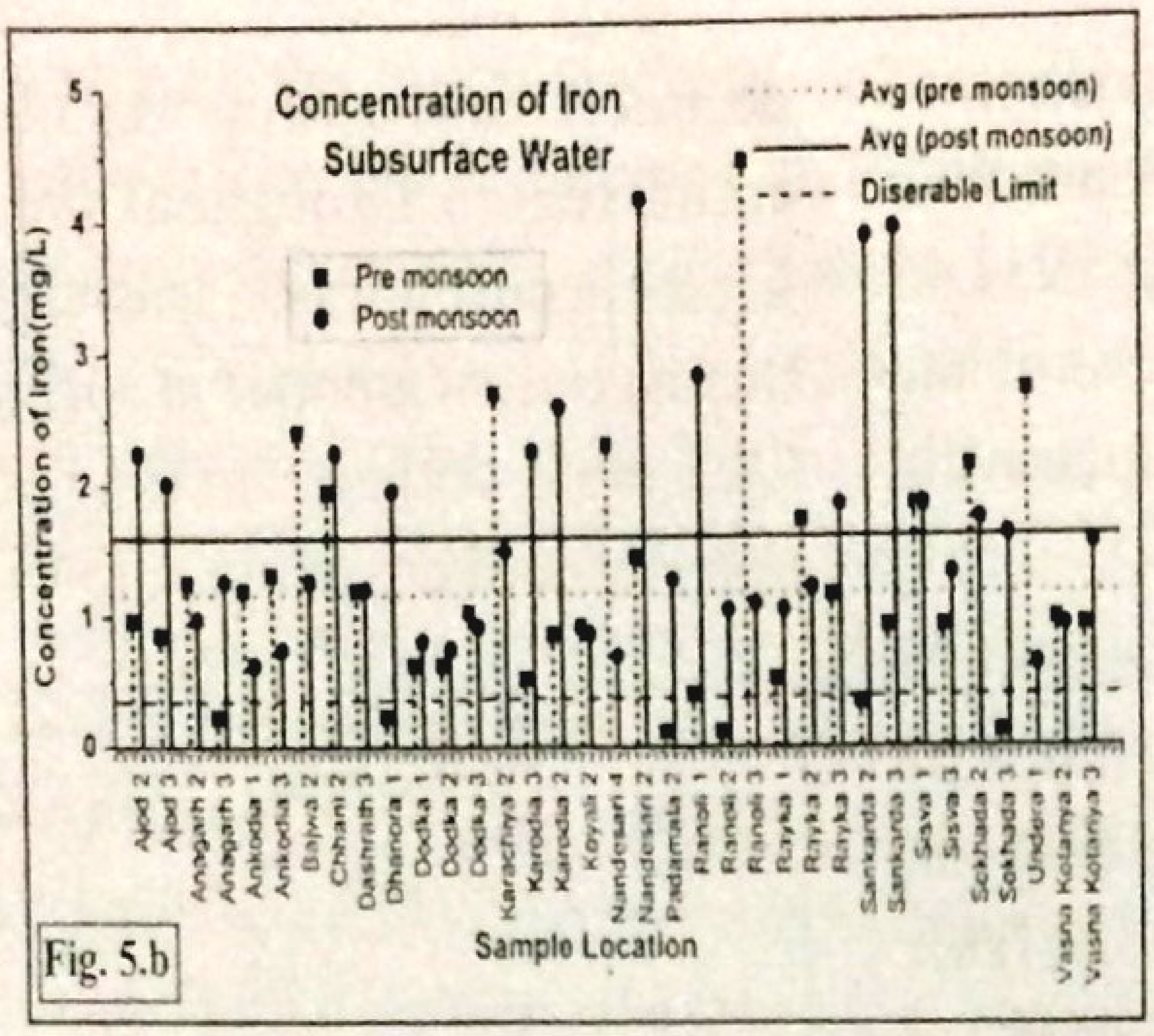

Fig. 5.b

decrease was observed in standard deviation (1.13). The minimum and maximum concentration in subsurface water was 0.11 mg/L and 4.43 mg/L (Table 2). While in post monsoon season it varied from 0.63 mg/L to 4.15 mg/L. The level of iron increased in post monsoon (1.62 mg/L) which was (1.20 mg/L) prior to rains. The values of standard deviation were almost the same in both the seasons.

Table No. 1 : Surface Water

	TDS (mg/L)		pH value		Iron (mg/L)		Nitrate (mg/L)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Average	1261.8	867.66	8.15	7.02	8.44	2.23	35.59	69.88
Min	282	179.15	7.47	6	0.69	0.69	13.39	17.86
Max	2910	2456.9	9.45	8	27.3	5.59	129.4	116.07
S.D	681.75	547.84	0.58	0.38	7.75	1.13	22.22	22.18

Source

Table No. 2 : Sub Surface Water

	TDS (mg/L)		pH value		Iron (mg/L)		Nitrate (mg/L)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Average	1236.94	958.09	7.68	7.09	1.20	1.62	47.29	81.20
Min	377	339.11	7	7	0.11	0.6336	21.42	42.85
Max	4540	1951.46	8.02	8	4.43	4.1475	113.3	196.43
S.D	740.53	424.92	0.36	0.28	0.92	0.93	23.81	34.97

Source

Nitrite: The range of nitrite in surface water during pre monsoon season was between 13.39 mg/L and 129.4 mg/L with an the average value of 35.59 mg/L (Fig. 6.a). The highest and lowest level in post monsoon period was 17.86 mg/L and 116.07 mg/L respectively. Mean value was 69.88 mg/L and variation of standard deviation was low in two seasons (Table 1). In subsurface water, the concentration varied between 21.42 mg/L and 113.30 mg/L during pre monsoon season whereas it ranged between 42.85 mg/L and 196.43 mg/L in post monsoon (Table 2). The average concentrations in pre monsoon and post monsoon were 47.29 and 81.20 mg/L respectively (Fig.6.b). It showed an increase of nitrite concentration in subsurface water during post monsoon season. The values of standard deviation in pre and post monsoon seasons were.23.81 and 34.97 respectively.

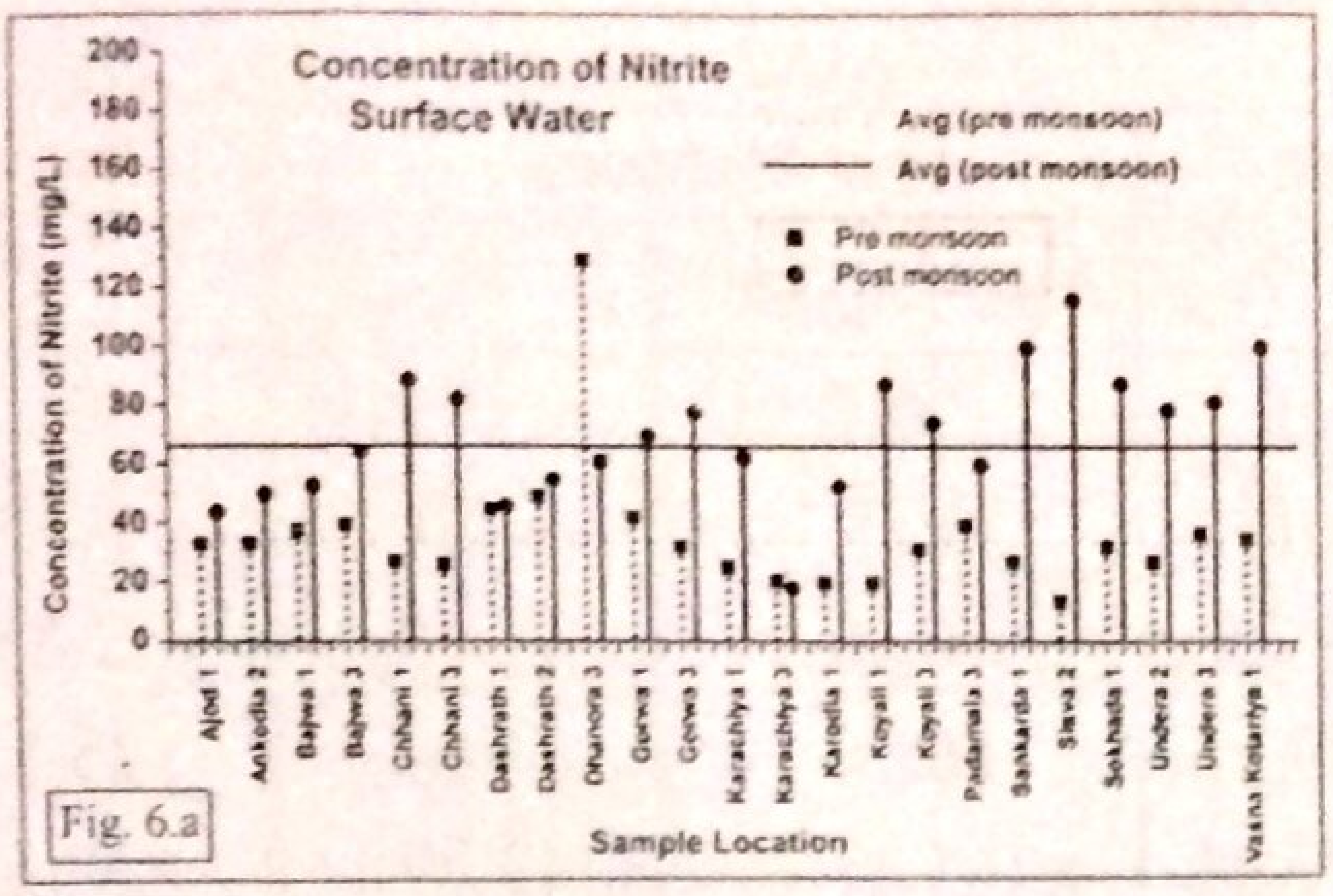

Fig. 6.a

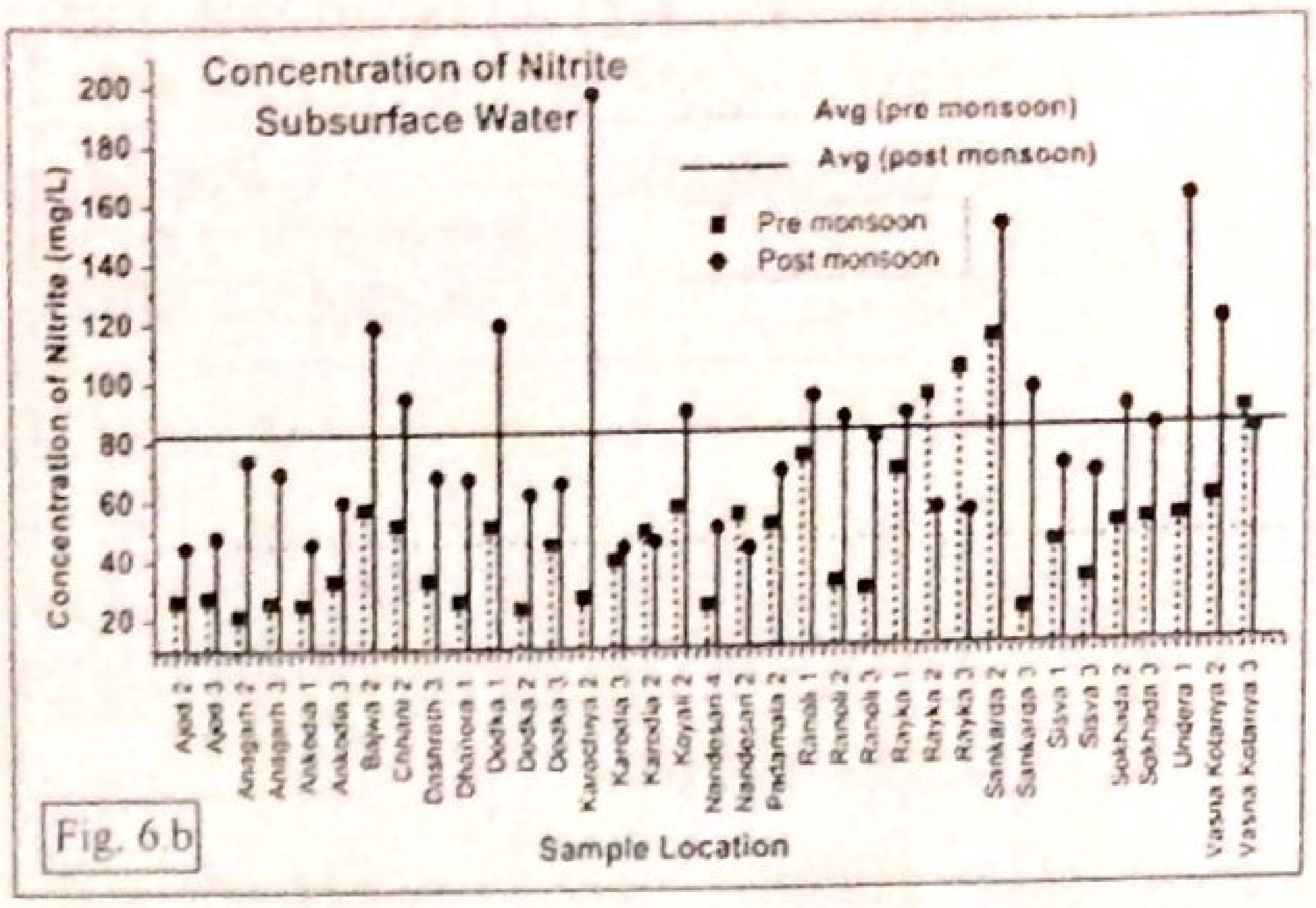

Fig. 6 b

Spatial Pattern and Seasonal Variability

TDS: The amount of TDS in both the surface and subsurface water declined after the rains. In the premonsoon season, the higher level was noticed in surface water in the entire region (133.39 sq. km) except in some scattered small patches located in the southern and south central parts (Fig.7.a). The level of TDS remarkably decreased after the rains and only an area of 54.67 sq. km in the north eastern part (Fig. 7.b) had TDS of > 1000 mg/L (Table 3.1). In the pre monsoon the area of TDS in surface water increased with the enhancement of its concentration.

The 89.21% of the total area had higher level of TDS (> 1000 mg/L) during the pre monsoon season which decreased to 34.54% of the total area during post monsoon season (Fig. 7.a). The level in this time gradually decreased from north eastern side towards southern part. In the post monsoon period patches of comparatively lower concentration was observed in the north western and the central part (Fig.7.a).

In subsurface water, 116.09 sq. km of area had > 1000 mg/L of TDS during pre monsoon season (Table 3.2). 750-1000 mg/L of TDS was spread over 28.57 sq. km of area. After the rains, the segment extending from the western to the north eastern region had the highest concentration whereas the lower concentration was observed in the north western, central and south eastern parts of the region (Fig.7.b).The area with highest concentration (>1000 mg/L) reduced from 116.09 to 65.47 sq. km in post monson the area of concentration of 750-1000 mg/L increased from 28.57 sq. km to 66.43 sq. km in post monson.The lower concentration was confined only to a smaller patch once.

pH: In the pre monsoon season, pH

Table No. 3.1 : TDS in Surface Water

Concentration mg/L	Pre Monsoon		Post Monsoon		Change
	Area (sq. km)	%	Area (sq. km)	%	%
<250	0	0	1.61	1.08	1.08
250 - 500	1.85	1.24	6.16	4.13	2.89
500 - 750	4.65	3.11	35.12	23.53	20.42
750 - 1000	9.63	6.44	54.81	36.72	30.28
> 1000	133.39	89.21	51.56	34.54	-54.67
Total	149.52	100	149.26	100	0.00

Table No. 3.2: TDS in Sub Surface Water

Concentration mg/L	Pre Monsoon		Post Monsoon		Change
	Area (sq. km)	%	Area (sq. km)	%	%
<250	0	0	0	0	0
250 - 500	0	0	0.75	0.50	0.50
500 - 750	4.86	3.25	16.56	11.08	7.83
750 - 1000	28.57	19.11	66.74	44.64	25.53
> 1000	116.09	77.64	65.47	43.79	-33.86
Total	149.52	100	149.26	100	0.00

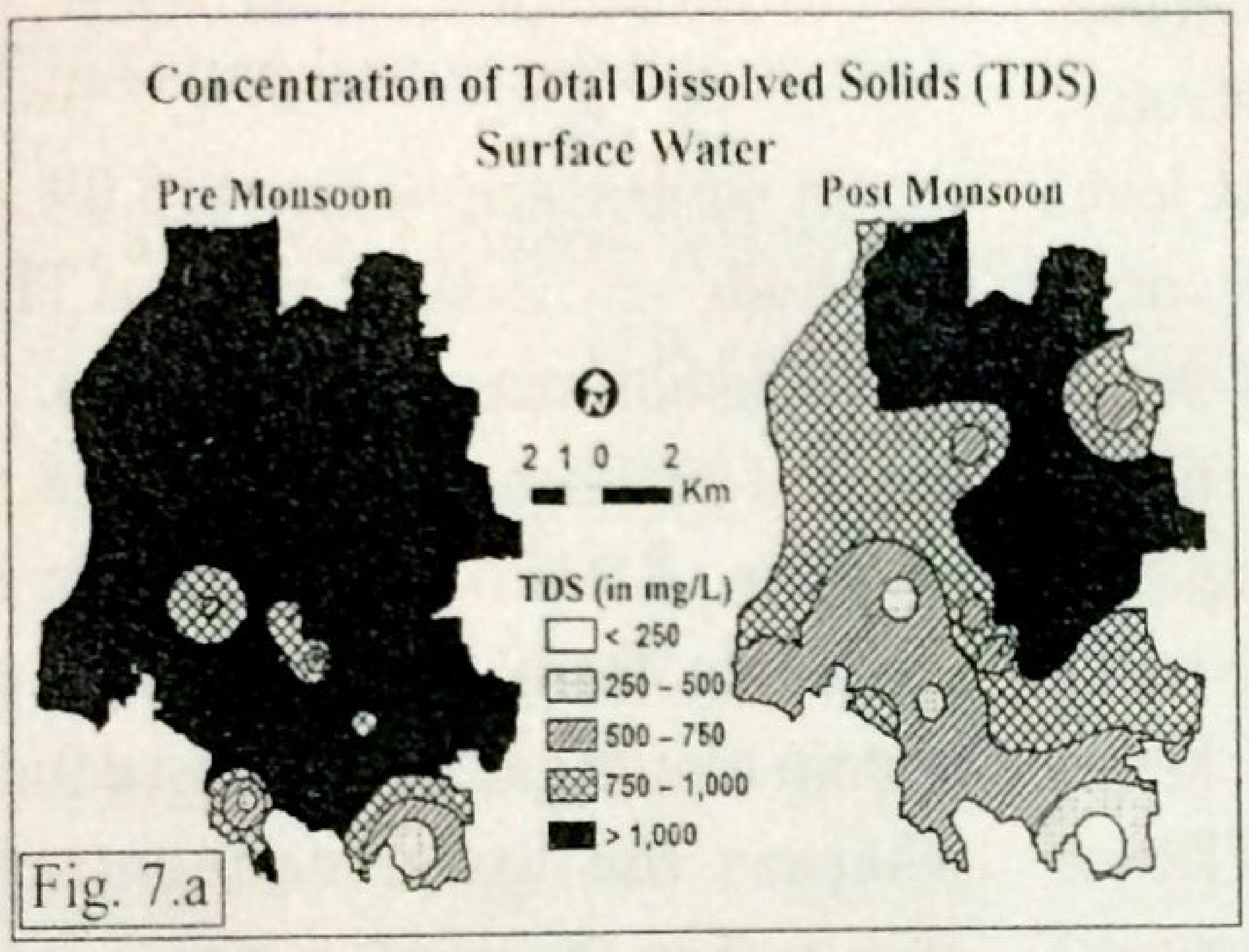
Concentration of Total Dissolved Solids (TDS)
Surface Water

Fig. 7.a

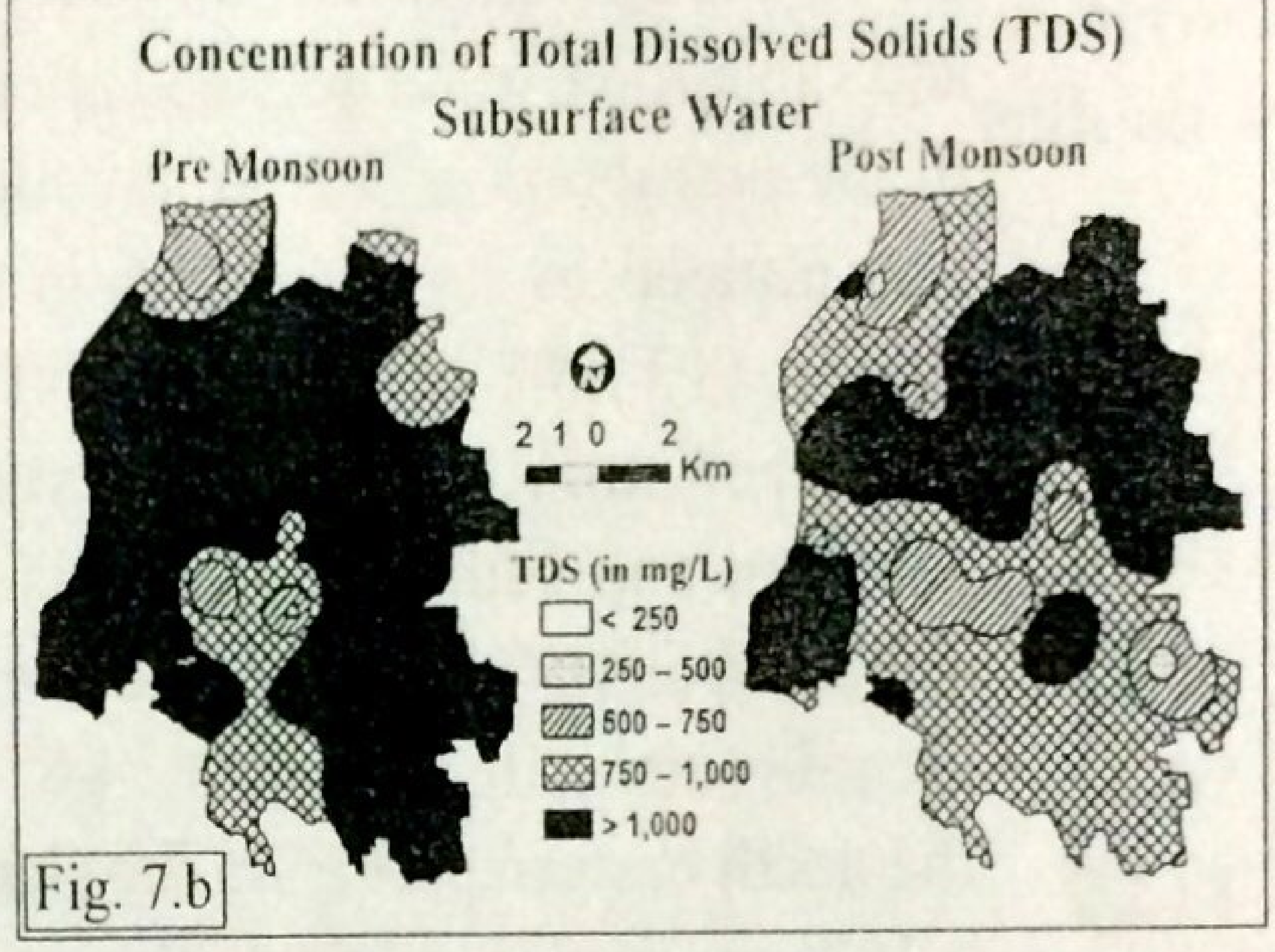
Concentration of Total Dissolved Solids (TDS)
Subsurface Water

Fig. 7.b

value of the surface water showed slightly alkaline condition. Only a small patch (10.61 sq. km) of higher alkalinity(> 8.5 pH) was observed in the southern part. In this season, 92.90% (Fig.8.a) area of the surface water (138.91 sq. km) had the pH level between 7.5 to 8.5,. After the rainfall, pH in surface water reduced in the entire region except a patch in the central part (Fig.8.a). In an area of 145.92 sp km pH value was 6.5-7.5. The pH value of surface water indicated an increse of 83.18% of the area in level between 6.5-7.5 in pre and post monson while a remarkable decrease (-81.54%) was observed in an area (4.96 sq. km) with pH value of 7.5- 8.5 (Fig. 8.a and Table 4.2). After the rain the level decreased in the region (Fig. 8.a). In subsurface during the premonsoon water the level between 6.5 to 7.5 was observed in 144.56 sq. km. Tab 4.2 reveals that in the pre monsoon season the pH level between 7.5 – 8.5 was recorded in 129.23 sq. km (86.50%) of subsurface area. In the premonsoon pH value of 6.5-7.5 was recorded only in 13.5% of the total area which increased to 96.68% in the postmonsoon period (Fig. 8b).

Iron: High concentration (1.2 mg/L) of iron in surface water was noticed in the entire region throughout the year (Table 5.1). The concentration in subsurface water the pre monsoon season shows the highest concentration covering 72.11 sq. km (48.23%) in north western and southern parts (Table 5.2). In the post monsoon season the concentration > 1.2 mg/L was spread over in 88.63 % of the area (Table 5.2). An area of 55.38 sq. km (37.04%) had iron concentration between 0.9 – 1.2 mg/L in the subsurface water during pre monsoon season

Table 4.1: pH in Surface Water

Level	Pre Monsoon		Post Monsoon		Change
	Area (sq. km)	%	Area (sq. km)	%	%
< 6.5	0	0	2.01	1.34	1.34
6.5 -7.5	0	0	145.92	97.59	97.59
7.5 - 8.5	138.91	92.90	1.59	1.06	-91.84
> 8.5	10.61	7.10	0	0	-7.10
Total	149.52	100	149.26	100	0.00

Table 4.2: pH in Sub Surface Water

Level	Pre Monsoon		Post Monsoon		Change
	Area (sq. km)	%	Area (sq. km)	%	%
< 6.5	0	0	0	0	0
6.5 -7.5	20.19	13.50	144.56	96.68	83.18
7.5 - 8.5	129.33	86.50	4.96	3.32	-81.54
> 8.5	0	0	0	0	0
Total	149.52	100	149.26	100	0.00

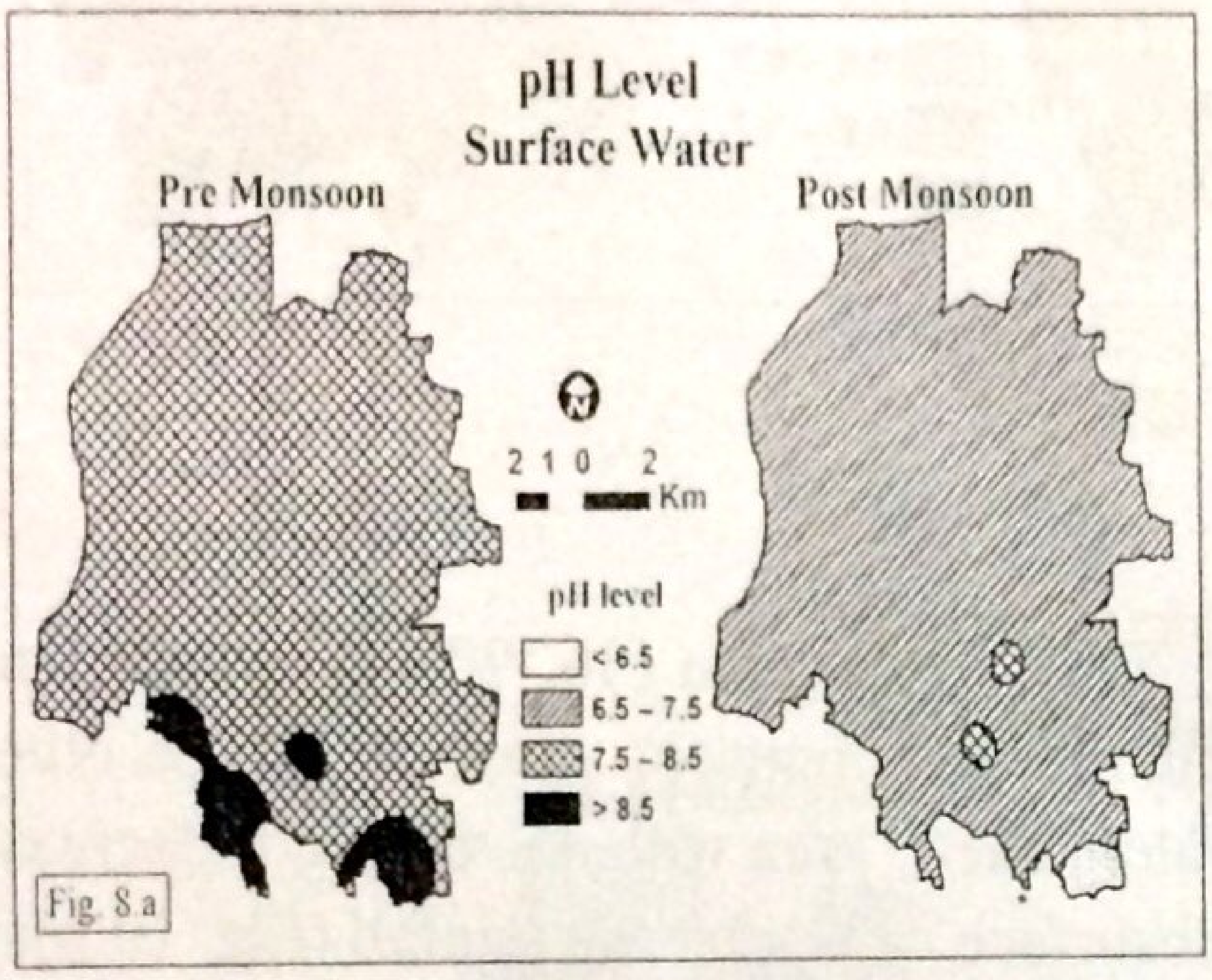

Fig. 8 a

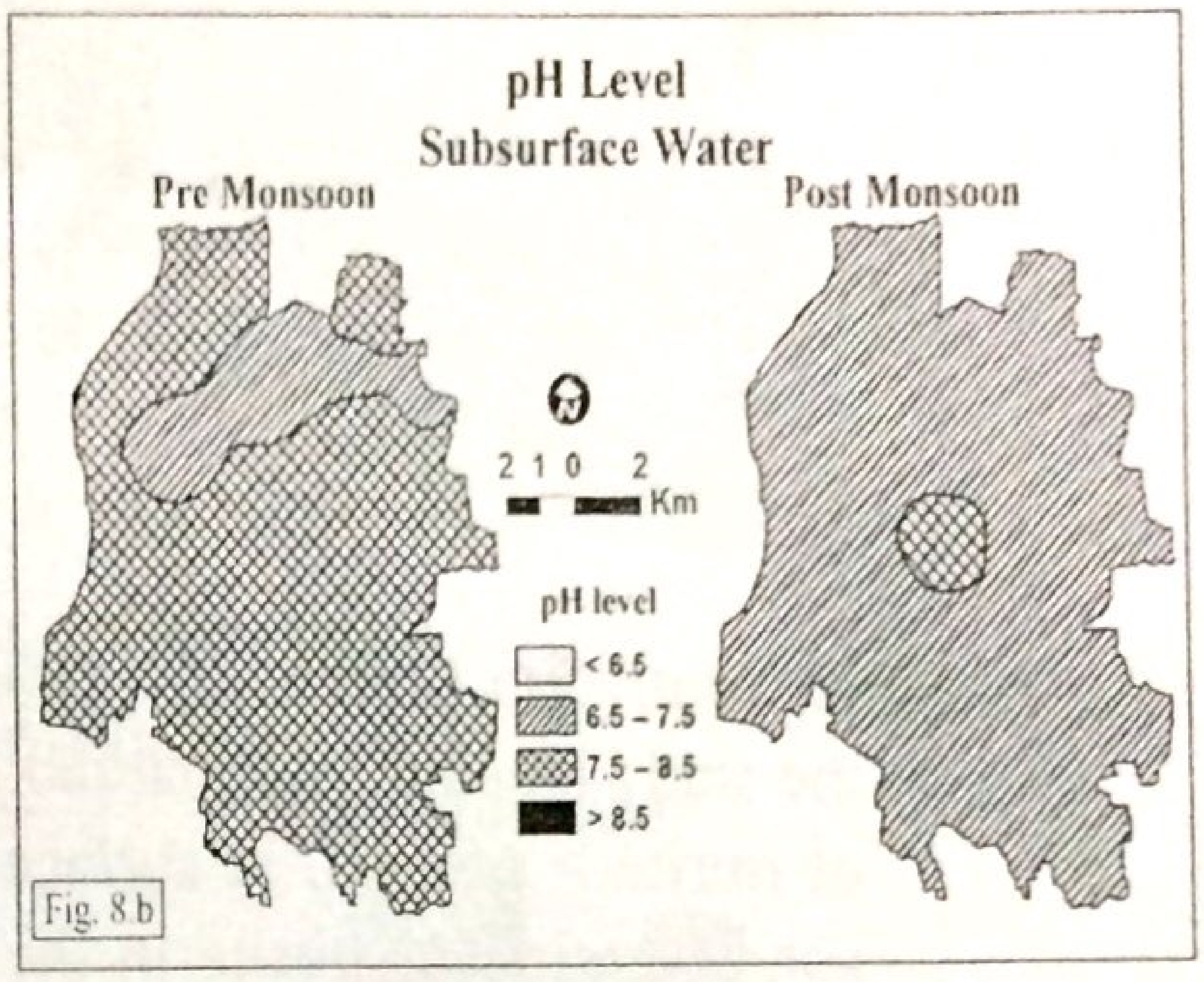

Fig. 8 b

(Table 5.2 and Fig. 9.a.). However, after the rains the area declined tremendously to 37 sq. km. (Fig.9.b)

- **Nitrite:** In the pre monsoon season high nitrite concentration in surface water was observed in the western part (Fig.10.a). In surface water prior to rains 123.81 sq. km (82.81%) of the area had nitrite concentration of < 45 mg/L while 2.5 sq. km had >85 mg/L of nitrite. A remarkable change in < 45 mg/L of nitrite concentration in the two seasons was evident where a decline of -82.17% was noted. In the post monsoon season, the level of nitrite in surface water increased tremendously. 65.04 sq. km (43.50%) of the area had nitrite concentration between 45-65 mg/L while 70.10 sq. km (46.88%) had 65-85 mg/L

Table No. 5.1: Iron in Surface Water

Concentration	Pre Monsoon		Post Monsoon		Change
	Area (sq. km)	%	Area (sq. km)	%	%
< 0.3	0	0	0	0	0
0.3-0.6	0	0	0	0	0
0.6-0.9	0	0	0	0	0
0.9-1.2	0	0	0	0	0
> 1.2	149.52	100	0	100	0
Total	149.52	100	149.26	100	0.00

Table No. 5.2: Iron in Sub Surface Water

Concentration	Pre Monsoon		Post Monsoon		Change
	Area (sq. km)	%	Area (sq. km)	%	%
< 0.3	0.21	0.14	0	0	-0.14
0.3-0.6	2.72	1.82	0	0	-1.82
0.6-0.9	19.10	12.77	4.92	3.29	-9.48
0.9-1.2	55.38	37.04	12.08	8.08	-28.96
> 1.2	72.11	48.23	132.52	88.63	40.40
Total	149.52	100	149.26	100	0.00

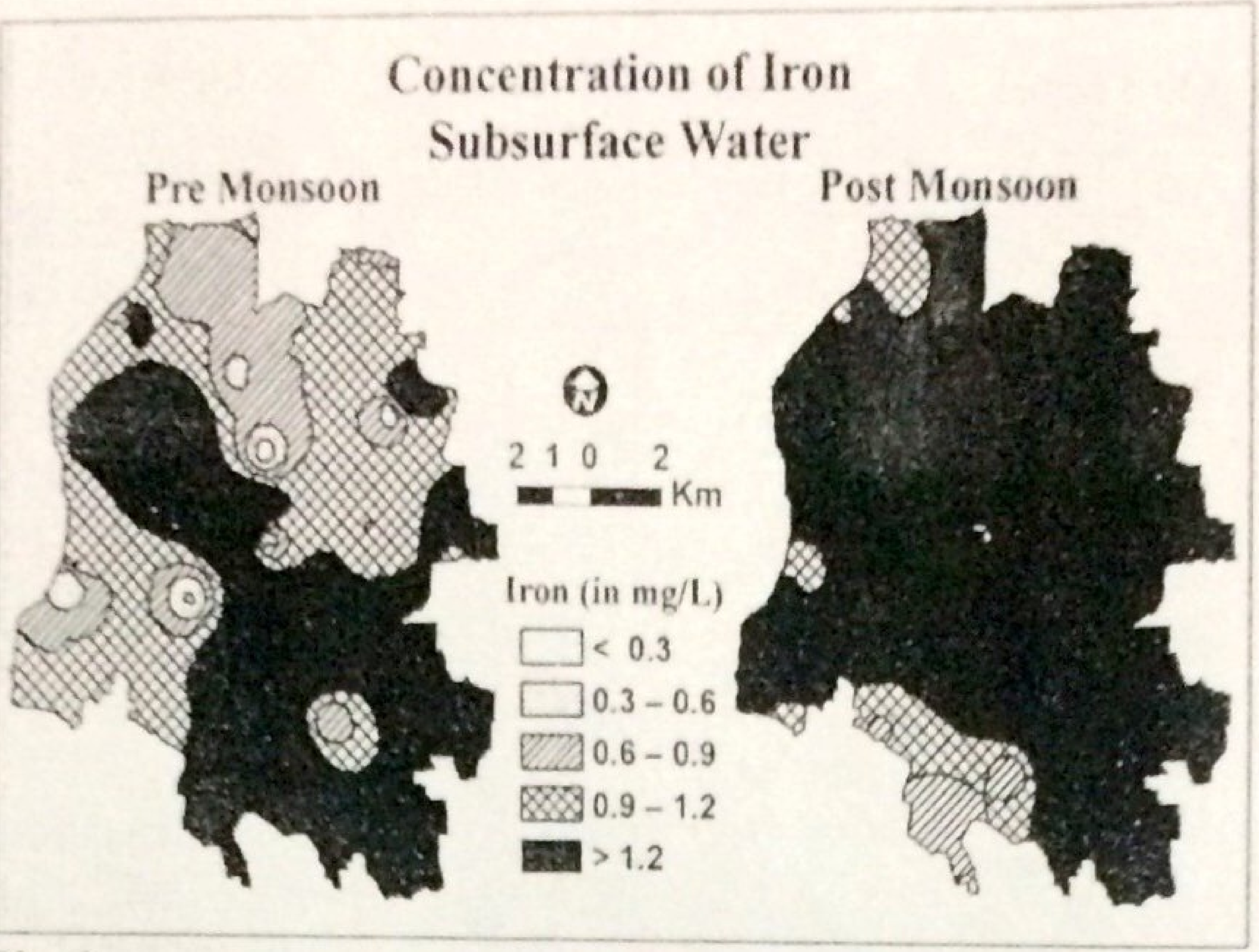

Fig. 9.a

Fig. 9.b

concentration (Table 6.1). Thus > 55% of the study area had a remarkably high level of nitrite > 65mg/L in surface water. The concentration of nitrite in the subsurface water in pre monsoon was also low. 81.11 sq. km (54.25%) of the southern part of the study area had less than 45 mg/L of nitrite (Table 6.2).

In terms of subsurface water the study region can be divided into two halves viz. northern with > 45 mg/L of nitrite and southern with < 45 mg/L. The concentration between 45- 65 mg/L extended in 59.15 sq. km area of the region. The area of 8.47 and 0.79 sq. km showed the concentration of 65- 85 mg/L and > 85 mg/L of nitrite level respectively in pre monsoon (Table 6.2). During post monsoon season, the level increased tremendously (>65 mg/L) in the northern and southern parts (Fig. 6). In 53.14% of the area lying in eastern and western parts of the region (79.44 sq. km) the concentration between 65- 85 mg/L was noticed (Fig. 10.b). Area with > 85 mg/L of nitrite increased from 0.79 sq. km to 55.97 sq. km (36. 90 %) in between pre & post monsoon seasons. On the other hand , the area with 45- 65 mg/L decreased by 30.14 % after the rainfall (Fig. 10.b).

Table No. 6.1 : Nitrite in Surface Water

Conce-ntration (mg/L)	Pre Monsoon		Post Monsoon		Change
	Area (sq. km)	%	Area (sq. km)	%	%
< 45	123.11	82.81	0.96	0.64	-82.17
45 - 65	19.42	12.99	65.04	43.50	-30.51
65 - 85	3.78	2.53	70.01	46.88	44.36
> 85	2.50	1.67	13.42	8.98	7.30
Total	149.52	100	149.26	100	0.00

Table No. 6.2 : Nitrite in Sub Surface Water

Conce-ntration (mg/L)	Pre Monsoon		Post Monsoon		Change
	Area (sq. km)	%	Area (sq. km)	%	%
< 45	81.11	54.25	0	0	-54.25
45 - 65	59.15	39.56	14.09	9.42	-30.14
65 - 85	8.47	5.67	79.46	53.14	47.48
> 85	0.79	0.53	55.97	37.43	36.90
Total	149.52	100	149.26	100	0.00

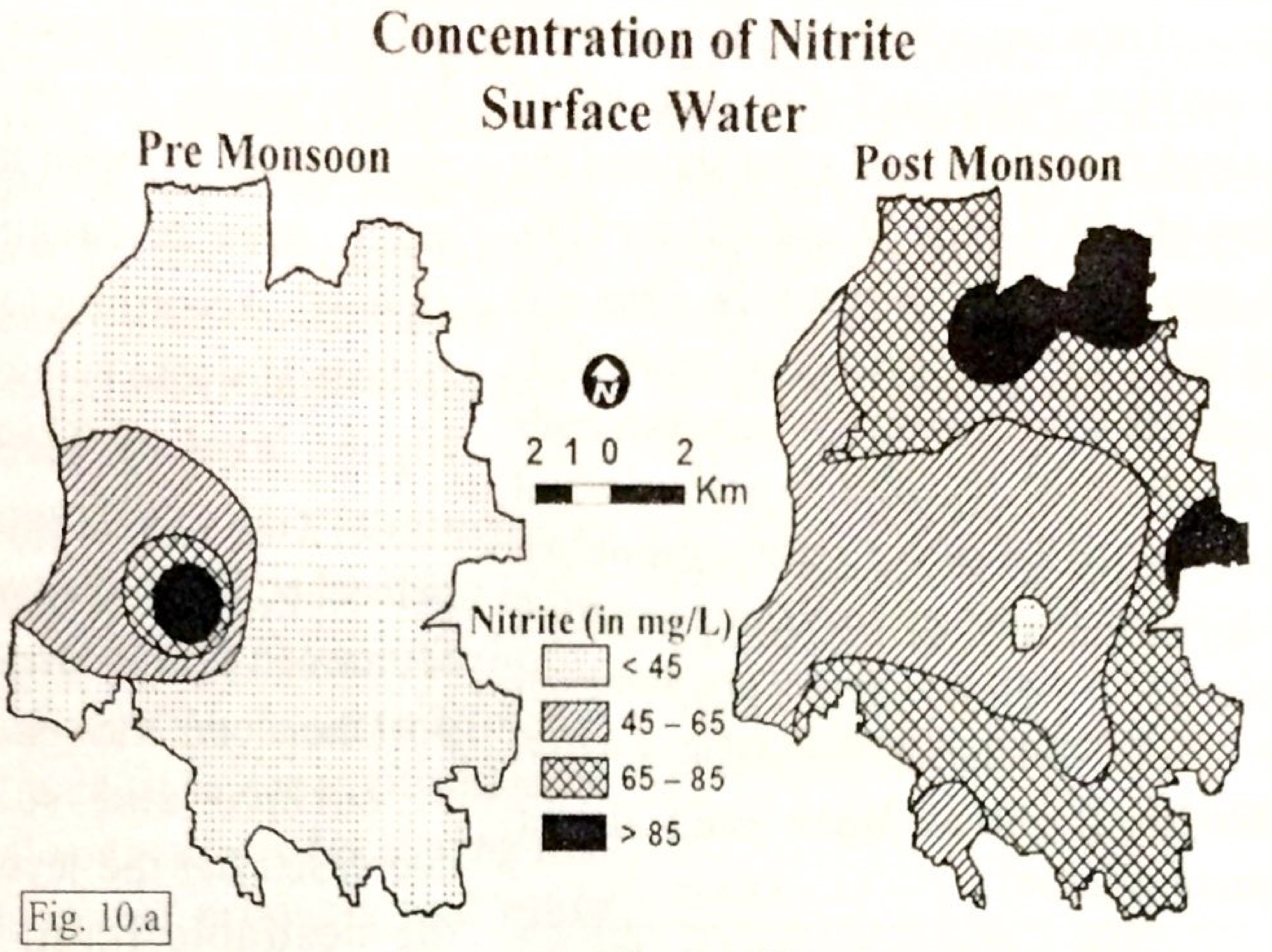
Concentration of Nitrite
Surface Water

Fig. 10.a

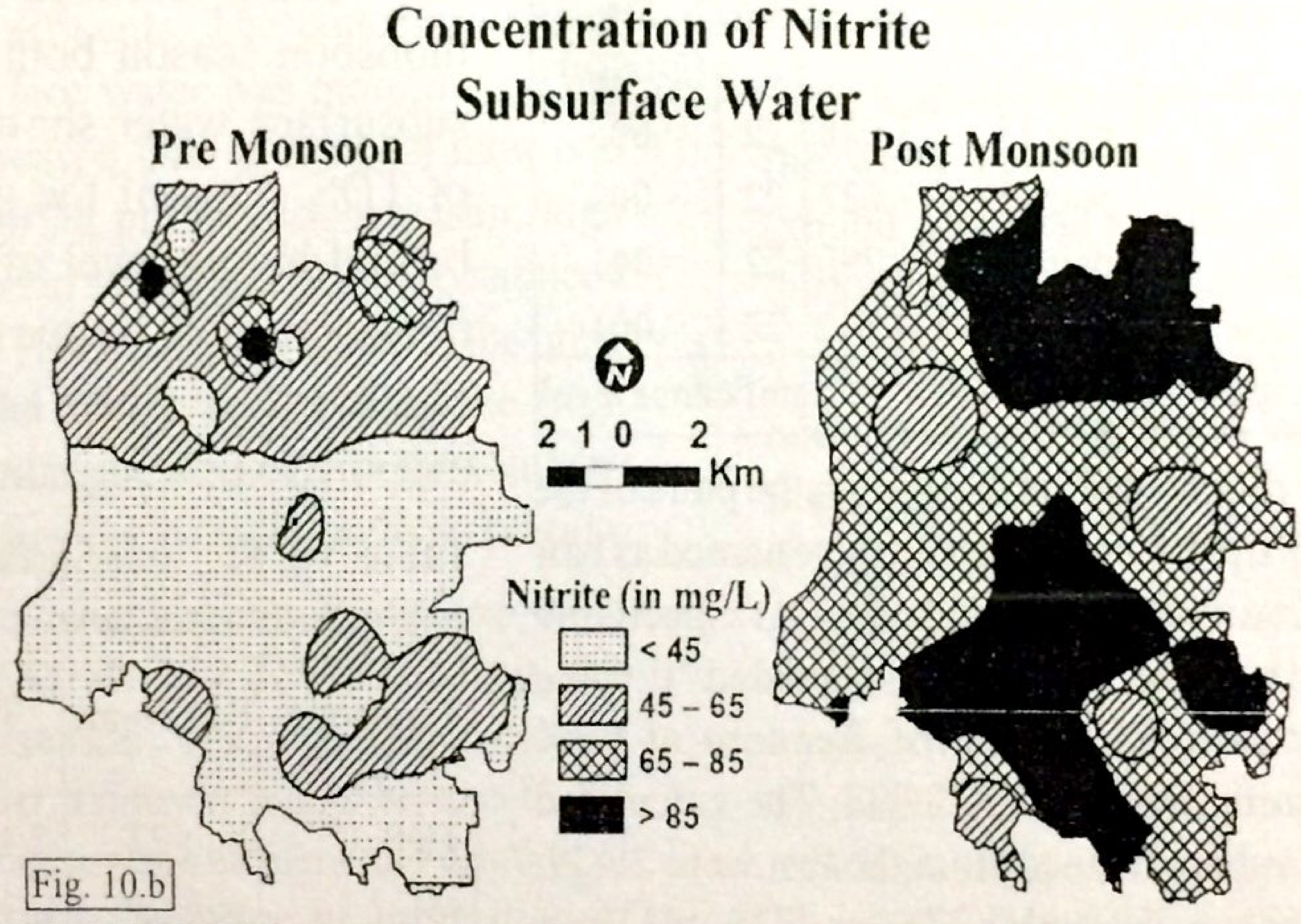
Concentration of Nitrite
Subsurface Water

Fig. 10.b

Seasonal Variability

Pair 't' test is a statistical technique for hypothesis testing which is used to determine the changes in the mean of the same sample in different time period. In this test, two hypotheses are initially proposed. 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 the test. If the test value is more then the tabulated 't' value then the alternative hypothesis is accepted i.e there is a significant variation in the mean of the sample.

Paired t-test was performed on the both the data sets of pre monsoon and post monsoon seasons. All the parameters of surface and subsurface water viz- TDS, pH, iron and nitrite were incorporated in the test. These pairs for surface water were designated as pair 1T, pair 1P, pair 1F and pair 1N respectively for pre monsoon. (Table

7). The tabulated value of pair t-test with 22 degree of freedom at 95 % significance level for surface water is 2.074. The result obtained from the paired t test showed the values of 3.08, 7.62, 3.79, and 4.01 for TDS, pH, iron and nitrite respectively. Thus it is concluded d that the calculated value of 't' is higher than the tabulated value which leads to rejection of the null hypothesis and acceptance of the alternative hypothesis. All the parameters showed significant variation in mean concentration during pre monsoon and post monsoon seasons in surface water.

Table No. 7: Surface Water (pre and post monsoon season)

Perameters	Pair Name	T	Df	Sig. (2-tailed)
TDS	pair 1T	3.088	22	.005
pH	pair 1P	7.627	22	.000
Iron	pair 1F	3.795	22	.001
Nitrite	pair 1N	-4.012	22	.001
Result of pair t test with 95% significance level				

For the subsurface water, the pairs of the TDS, pH, iron and nitrite were named as pair 2T, pair 2P, pair 2F and pair 2N respectively for both the season. The tabulated 't' value with the 34 degree of freedom at 95% significance level is 2.032. The calculated 't' value obtained from the test were 2.424, 9.769, 1.759 and 5.273 for TDS, pH, iron and nitrite respectively. It showed that the calculated 't' values of TDS and pH were greater than the tabulated 't' value. The null hypothesis is rejected and the alternative hypothesis is accepted. It leads to conclude that there was variation in the mean concentration of parameters in subsurface water during pre and post monsoon season.

Discussion

The level of TDS in 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. 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 reasons 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 post monsoon, the concentration of TDS in surface and subsurface water decreased but the level was still above the desirable limit. During the pre monsoon season both the surface and subsurface water showed higher levels of TDS. One of the governing factors behind higher level of TDS during pre monsoon might be due to lowering down of subsurface water level as a result of evaporation during summer season.

Table No. 8: Sub Surface Water (pre and post monsoon season)

Perameters	Pair Name	T	Df	Sig. (2-tailed)
TDS	pair 2T	2.424	34	.021
pH	pair 2P	9.769	34	.000
Iron	pair 2F	-1.759	34	.088
Nitrite	pair 2N	-5.273	34	.000
Result of pair t test with 95% significance.				

The pH level of surface and subsurface water was under the desirable limit. During the pre monsoon season the pH level of surface water showed slightly alkaline condition particularly near IPCL. During post monsoon season, the whole region has lower level of pH in subsurface water except for a small patch in the central portion near the Nandesari industrial estate and Jawarhar Nagar. The surface water had more alkaline condition than the subsurface water during pre monsoon season. During the post monsoon season there was a considerably lower level of pH which might be due to the influence of rain water.

The level of iron in surface water is much higher than the desirable limit in the entire region rhroughout the year. The higher concentration indicates the presence of iron in the area. It might be due to the influence of industrial units such as discharging iron containing waste products and other industrial effluents. The concentration of iron in surface water was more during pre monsoon season than in the post monsoon season. During pre monsoon season, high level of iron in subsurface water was noticed near GIDC, IPCL and GSFC. After the rainy season, the whole region had the high concentration of iron except in the southern part and a small patch in the northern portion.

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 and due to application of nitrogenous fertilizers to agricultural land which drains during the rainy season and mixes with the surface water. During the field visit it was observed that in most of the villages there was lack of proper sanitary system and animal rearing is practicised 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.

The concentration of nitrite in subsurface water increased during post monsoon season. High nitrite concentration was observed near GSFC which is a major industry producing fertilizers, chemicals, petrochemicals and agricultural products. The increasing use of chemical fertilizers and the disposal of the generated wastes in the vicinity are the main factors responsible for the progressive increase of nitrate level in (Fig.10.b) groundwater. The nitrites containing industrial waste being dumped into the barren land, easily percolate down. The nitrate detected in well water samples might have originated from decaying organic matter.

Conclusion

1. The result of Pair t test showed that all the water parameters of surface and ground water had significant variations during pre and post monsoon seasons.
2. TDS concentration in both the surface and sub surface water was higher during the pre monsoon season. On an average, the northern and eastern part of the region had higher concentration while southern part had the lower concentration. The area of TDS increased with the enhancement of its concentration during pre monsoon season. But in post monsoon a decrease in highest concentration (>1000 mg/L) was observed.
3. pH level in both the surface and sub surface water was within the desirable limit which slightly decreased during the post monsoon season. In pre monsoon season the pH level between 6.5 - 7.5 covered the maximum area while after the rains 7.5 – 8.5 pH level was spread over in most of the area.
4. High iron concentration was observed

in both surface and subsurface water. The concentration in surface water was more during pre monsoon than the post monsoon season. The concentration of iron in surface water was high throughout the year. In subsurface water, the maximum concentration was spread over in most of the area.

5. Subsurface water had higher concentration of nitrite than in the surface water in both the seasons. Level of nitrite increased in the post monsoon. The northern and southern parts had higher concentration while the lower level was observed in the central portion. During pre monsoon season, the lowest level of nitrite covered most of the area whereas the highest concentration was spread over in a very limited area. The concentration between 45 -85 mg/L was noticed in the maximum area of surface water during post monsoon season. In subsurface water, large area was having the concentration > 65 mg/L.

Acknowledgment

One of the authors, Roolee kanchan is thankful to Indian Council of Social Science Research, New Delhi for funding the Major Research Project (ICSSR No F. No. RP 02/120/2009/RP dated 23.02.2010).

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Received on 14.10.14 Accepted on 22.01.15

*International Research Journal of Environment Sciences*______________________________ ISSN 2319–1414
Vol. **4(7),** 7-16, July **(2015)** *Int. Res. J. Environment Sci.*

Grain Size Distribution and Its Relation to the Geochemical Parameters in the Chemical and Petrochemical Complex of Vadodara District of Gujarat, India

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Available online at: www.isca.in, www.isca.me
Received 4th April 2015, revised 9th May 2015, accepted 13th June 2015

Abstract

Grain size of sediments has an important relationship with the infiltration rate of water and rate of surface run off. Hence, it is essential to analyze the connection between different textures and geochemical parameters. In the present study, numbers of shallow cores of soil samples were taken along the river Mini flowing in the northern part of Vadodara district of Gujarat, India. Ground water samples were also acquired from the same region. Parameters like iron and nitrite were analysed both in different layers of the shallow cores and groundwater. It was inferred from the analysis that location of industries and the path of river Mini had important contribution in the pattern of the concentration of parameters both horizontally and vertically.

Keywords: Grain size, geochemical parameter, correlation.

Introduction

The grain size of the sediments is an important aspect because it determines the rate of runoff and capacity of infiltration of water. With the increasing grain size, the rate of infiltration increases and rate of surface runoff decreases, while decreasing grain size restricts higher rate of infiltration and supports greater surface runoff. The concentration of different parameters in the grains depends upon their size apart from the depositional environment, anthropogenic and lithologic sources and mineralogical composition of the sediment[1]. The infiltration rate is particularly affected by grain size of the sediments, amount of rainfall and aquifer condition[2,3]. Surface, subsurface water and soil quality is much susceptible to solid wastes and effluents in the industrial region which is also controlled by sediment size distribution to a great extent. Grain size distribution and its impact on the concentration of elements have been undertaken by many scientists. Heavy metals like Zn, Cd, Al, Mg, Ba, Pb, Mo, Fe, Cu, Co, Ni, Cr and As were analysed in surface sediment of the Ismit Bay, Turkey and it was found that, the northern coast was heavily polluted by industrial and domestic wastes[4]. Study on level of major elements in sediments of Ria de Vigo in Galice in north western Spain showed that, particle size as well as industrial, urban and rural waste dumping sites plays an important role in the level of metal concentration in the sediment[5]. The effect of grain size distribution on heavy metal content in the soil through factor analysis and correlation in Chebachji Lake in south of western Siberia of Russia depicted an inverse relationship between the sediment particle size and element content in the soil[6]. In the study of concentration of toxic heavy metals (Ni, Cu, Cd, and Pb) in the sediments of Dongping Lake in China it was found that the absorption of substances increased with the decrease in grain size[7]. The study on the concentration of the Cu, Cr, Pb, Zn and Ni in <63 µm grain size in urban areas of southern Brazil inferred that heavy metals could be transferred quite rapidly on the impermeable surfaces[8]. Suspended material concentration in grain size distribution and their association with heavy metal concentration on the left bank of Kojour River, Iran was analysed by using multivariate regression analysis and bivariate[9]. High concentration of Pb, Cd, Zn and Cr were observed in coastal sediments of the Bay of Bengal, India[10]. The concentration of trace metals in sediments was analysed in Ennore Creek of Chennai, India and high level of Fe, Cr, Cu, N, Pb and Zn was noted in finer sediment [11]. Si, Al, Fe, Mn, Cu, Zn and Cr concentration in the sediments of Damodar River, India were analysed and it was observed that the level of heavy metals tended to increase as the size of the grains got finer[12]. The core sediment in Achankovil river basin of India showed that concentration of heavy metal increases with an increase in depth[13]. Geochemical parameters of groundwater like pH, conductivity, TDS, total hardness, alkalinity, Na, K, Ca, Mg, Cl, Cu, Zn, Fe and As were analysed in the Budhi Gandak belt in Muzaffarpur district, India. It was found that iron and arsenic were found above the permissible limit of WHO[14]. Similar kind of studies showed concentration of different parameters was above the permissible limit[15-18].

Vadodara district of Gujarat, India, has a number of chemical and petrochemical industries. A number of such chemical industries are located in the northern part of Vadodara City and on the south of river Mini which is a tributary of river Mahi. These chemical and petrochemical industries encompass Nandesari Gujarat Industrial Development Corporation (GIDC), Indian Petro Chemical Complex Limited (IPCL), Jawahar Nagar and Gujarat State Fertilisers and Chemical Limited (GSFC). The industrial wastes generated by these industries, is dumped in the open space and the effluents are released in the effluent channels from IPCL and Nandesari GIDC to river Mini which finally find its path to Gulf of Cambay[19]. Thus, it is necessary to evaluate the relationship between the grain size distribution and concentration of chemical parameters in groundwater and soil. In the present study, such attempt has been made and the relationship is evaluated near the chemical and petro chemical complex of Vadodara district of Guajrat.

Material and Methods

Study Area: The present study focuses upon a selected part along the river Mini which is nearer to the industrialized belt of Vadodara district of Gujarat, India. The area encompasses many chemical and petrochemical industries. In the north, it is bounded by Savli taluka of Vadodara district while Vadodara Urban Agglomeration is towards the south. In the west, the area extends upto river Mahi. Nandesari GIDC is spread over an area of 2.06 sq. km[20]. There are about 250 small and medium units which largely produce a number of chemicals, pharmaceuticals, dyes, pesticides, plastics etc.[21]. Deepak Nitrite Limited in Nandesari produces sodium nitrate, sodium nitrite, calcium nitrate, calcium nitrite, potassium nitrate and potassium nitrite etc.[22]. GSFC is another major complex and is spread over 3.21 sq. km.[20]. Rock phosphate, sulphur and liquid sulphur, ammonia, phosphoric acid, benzene, methyl, ketones, sulphuric acid, hydrochloric acid, potassium nitrate and sodium nitrate etc. are some of the other finished products produced by GSFC[23]. IPCL (now owned by Reliance Industries) produces benzene, carbon fiber, caustic soda, chlorine etc.[24]. Gujarat Refinery in Jawaharnagar is the largest refinery of IOCL and generates liquefied petroleum gas, auto and natural gas, petrol, gasoline, gas oil, jet and marine fuel, bitumen, petrochemical special product and crude oil[25].

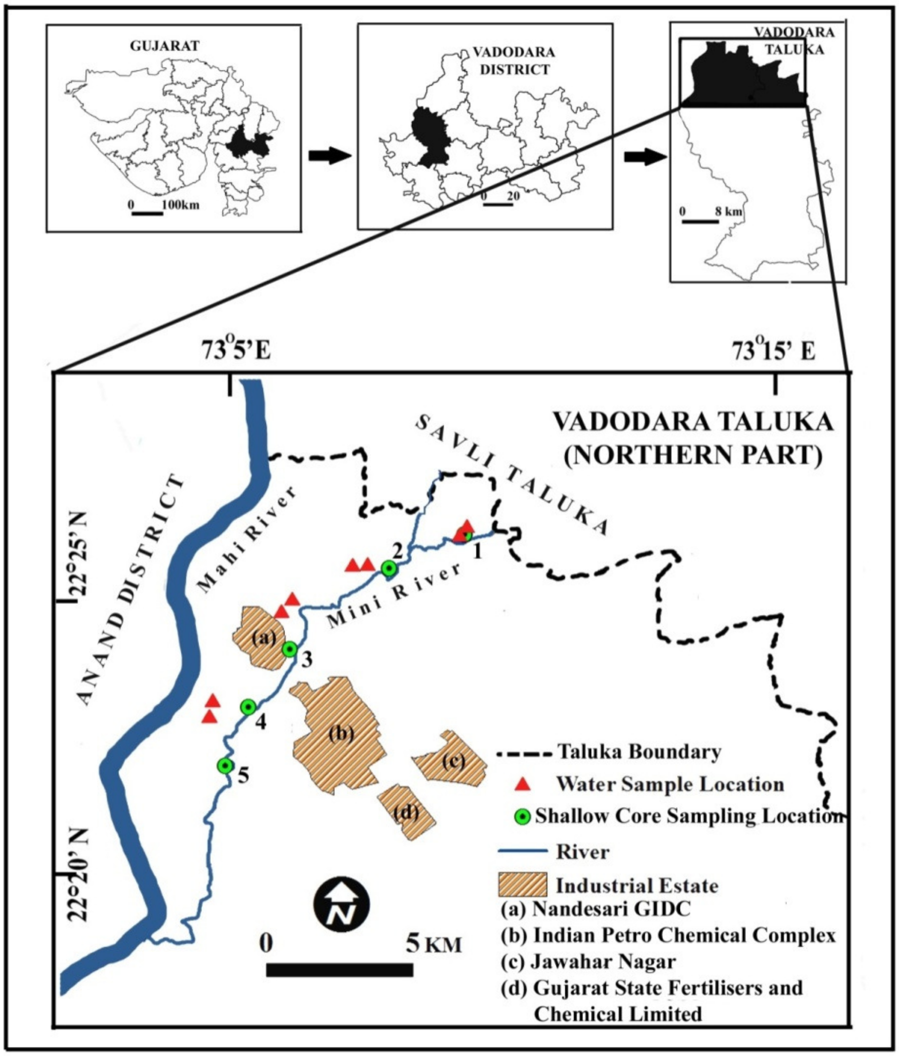

Figure-1
Study Area

Methodology: Sample collection and analysis: Five sampling locations were selected along the path of river Mini. During the selection of the sampling locations, equal distance between the samples was taken into consideration. The sampling locations were marked by using handheld GPS (Garmin eTrex Vista). PVC (Polyvinyl Chloride) pipes with 3 inch diameter were used for coring (figure-2). Initially, the surface area was cleared and the pipe was held vertically. At the top of the pipe, a thick piece of wood was kept and continuous hammering has been done on it so that the pipe can penetrate into the subsurface. After collection of the sample, the pipe was capped from both the sides to restrict its contact with the air. The pipe was cut longitudinally along with the core by using stainless steel saw. One portion of the core was kept along with the pipe by wrapping it tightly using high grade clean film under low temperature for future purpose. Other portion was sub-sampled by using stainless steel saw latitudinally at 1 inch interval. Each of the portions of the sub-samples was retained in the zipped polytheline bag. The sample of 0-1 inch, 4-5 inch and 8-9 inch of depth were selected for grain size analysis through the standard wet sieving method[26]. Groundwater samples were collected from the open tube well (table-4). 500 ml polyethelene bottle tied with weight on one end and a rope on the other end was used to collect the samples from the wells. After the collection of the samples, it was acidified with HCl and kept in the capped polyethelene bottles. Iron and nitrite were analysed by standard colourimetric technique through the 1,10 Phenanthroline method[27] and Cadmium Reduction Methods[28] using Elico Double beam UV/Vis spectrophotometer (Sl-210) in the laboratory of Department of Geography, Faculty of Science, The M. S. University of Baroda. The results obtained from the analysis were used in the statistical software of Origin for diagrammatic representation and ARC GIS 10 was used for the mapping.

Figure-2
Coring for soil sample collection

Results and Discussion

Grain size Distribution: On an average, clay comprised of more than 50% of the total quantity of samples. However, the average percentage of clay was slightly less (44.90%) in the intermediate zone. Thus, clay was found dominantly in the entire region (table-1). One-third of the sediments consisted of silt (36.53 %). But the zone between 4-5 inch, where the percentage of clay was low, the proportion of silt was higher (41.26%). Clay and silt together contributed to more than 90% of the total sediments. The percentage of the sand was least (~10%). Spatial variations were observed in the characteristics of sediments. The percentage of clay in the immediate layer (0-1 inch of depth) increased from 60-76 % downstream (table-1. a). A volte-face was observed with silt where a decrease in the percentage (31.87% to 13.85%) was evident downstream. In this direction, point 2 was the only exception where the proportion of the clay (27.35%) was much lower than that of the silt (65.55 %). Although dominance of clay was evident in the intermediate layer but some variations were spotted. The average clay percentage was lower (44.90%) and decreased downstream from 65.37% to 56.43% (table- 1.b). However, some fluctuations were observed in the intermediate parts. The average silt amount increased (41.26%) in the intermediate layer. Never the less, fluctuations were observed in the proportion of silt (table-1b). The maximum intensity of clay (80.58%) was noted in sampling location 2 and the minimum (11.84%) at the adjacent point (sampling location 3). Later, it again increased to 55.91% in sampling location 4. The lowest layer of the soil (8-9 inch of depth) was characterised by higher percentage of clay (56.28%) while silt and sand percentages were lesser (34.86% and 8.86%) (table-1.c). The maximum clay percentage (85.18%) of the lowest layer was observed downstream while the percentage of silt was lowest in this layer. The highest percentage of silt (56.69%) was noted in sampling location 3. Its percentage decreased from this point both downstream and upstream. The sand percentage was least (~10%) in all the layers of the region with middle layer of the sampling location 3 being the only exception.

Distribution of Iron in Subsoil: In all the three layers the concentration of iron in subsoil along the river increased downstream (table-2). In the upper most layer (0-1 inch of depth) the level of iron gradually increased from 2.13 to 55.64 mg/kg with the average concentration of 43.39 mg/kg. The concentration of iron ranged between 5.87 mg/kg to 43.14 mg/kg in the intermediate layer (4-5 inch of depth).While the average iron level (24.75 mg/kg) in this layer was lower than average iron level of upper layer (0-1 inch depth) as well as bottom layer (8-9 inch of depth). In the deepest layer, the level of iron varied between 3 mg/kg to 21 mg/kg with an average concentration of 29.18 mg/kg.

Table-1a
Distribution of grain size immediate layer (0-1 inch)

Sample Location	Sand%	Silt%	Clay%
1	8.10	31.87	60.03
2	7.10	65.55	27.35
3	6.22	29.35	64.43
4	5.16	26.81	68.03
5	10.11	13.85	76.04
Average	7.34	33.49	59.18

Table-1b
Distribution of grain size intermediate Layer (4-5 inch)

Sand%	Silt%	Clay%
7.22	27.41	65.37
6.08	80.58	13.34
34.80	11.84	53.36
8.07	55.91	36.02
13.03	30.54	56.43
13.84	41.26	44.90

Table-1c
Distribution of grain size Bottom (8-9 inch)

Sand%	Silt%	Clay%
10.29	29.01	60.70
6.23	48.41	45.36
11.29	56.69	32.02
2.83	39.01	58.16
13.67	1.15	85.18
8.86	34.86	56.28

Source: Computed

In sampling locations 2, 4 and 5, the maximum level of iron in subsoil was observed at the upper most layer (0-1 in of depth). Here, the concentration of iron was 21.83 mg/kg, 52.64 mg/kg and 55.64 mg/kg respectively (table-2). Lowest concentration was found at the deepest layer except sampling location 3 with concentration of 101.15 mg/kg at 8-9 inch of depth. In the entire region sampling location 1 had the least concentration of iron but comparatively higher concentration was observed at the intermediate layer while bottom layers had lower concentration of iron except sampling location 3.

Table-2
Concentration of iron in sediments

Sample Location	Immediate Layer	Intermediate Layer	Bottom Layer	Average
1	2.13	5.87	3.16	3.72
2	21.83	7.71	4.43	11.32
3	84.44	50.51	101.15	78.70
4	52.93	16.53	15.58	28.35
5	55.64	43.14	21.6	40.13
Average	43.39	24.75	29.18	32.44

Source: Computed

Distribution of Nitrite in Subsoil: Among all the sampling locations, average concentration of nitrite was noted in the immediate layer (table-3). In the upper most layer (0-1 inch of depth) the highest average concentration of nitrite was 62.67 mg/kg and lowest 27.67 mg/L was observed at the bottom most layer. The concentration of nitrite in immediate and the bottom most layer of subsoil increased downstream along the river (table-3). The average concentration of nitrite in the intermediate layer was 36.96 mg/kg.

Table-3
Concentration of nitrite in sediments

Sample Location	Immediate Layer	Intermediate Layer	Bottom Layer	Average
1	56.25	50	12.5	39.58
2	63.39	31.25	16.07	36.90
3	51.78	36.6	39.28	42.55
4	77.67	50.89	33.03	53.86
5	64.28	16.07	37.5	39.28
Average	62.674	36.962	27.676	42.44

Source: Computed

Sampling location wise concentration of nitrite depicted that sampling location 4 had highest average concentration (53.86 mg/kg). In all the sampling locations, immediate layer showed highest concentration of nitrite while in the bottom most layer, concentration was less except in the sampling locations 3 and 5.

Concentration of Iron and Nitrite in Groundwater: The dilution of nitrite in ground water ranged between 20.54 mg/l to 113.3 mg/l with an average concentration of 57.56 mg/l and standard deviation of 44.18. Highest absorption of nitrite was observed (113.30 mg/l) at sampling location 2 while the lowest level was recorded at sampling location 3 (20.54 mg/l). The level of iron in groundwater ranged between 0.34 mg/l to 2.33 mg/l (table-4). 1.10 mg/l was the average concentration with high standard deviation of 0.89. Sampling location 3 had maximum level of iron (2.33 mg/l) in groundwater whereas least was noted in sampling location 2 (0.34 mg/l).

Correlation between Grain size Distribution and Groundwater Parameters: Karl Pearson correlation was used to calculate the relationship between the parameters (iron and nitrite) and grain size distribution. Strong positive correlation existed between the iron and nitrite concentration in the subsoil (table-5). Sampling location 2 and 4 depicted correlation values of +0.99 and +0.93 respectively. While sampling locations 1, 3 and 5 showed relatively lower positive correlation (+0.12, +0.35, and +0.42 respectively). Negative correlation existed between percentage of sand and concentration of iron in all the sampling locations except sampling location 2 (table-6.a). Nitrite concentration had strong negative relationship with sand percentage particularly at 1, 3 and 5 sampling locations (-0.92, -0.76 and -0.81 respectively). On the other hand, positive correlation was noted at sampling locations 2 and 4. No specific pattern was observed between the groundwater parameters and silt percentage (table-9). At sampling location 3 (near Nandesari) the correlation between silt percentage and iron concentration was strong and positive (+0.95). On the other hand, soil sample location 1 and 4 showed negative relationship between silt percentage and iron concentration viz. -0.91 and -0.80. A reverse pattern was observed between iron concentration and clay percentage. The concentration of nitrite and silt percentage from sampling locations 4 and 5 depicted negative correlation (-0.51 and -0.52) whereas, the sample location 1, 2 and 3 had positive correlation (+0.28, +0.34 and +0.04). A positive relationship existed between clay percentage and nitrite concentration except for the sampling location 2 with correlation value of -0.38 (table-7c). Layer wise correlation between grain size and concentration of parameters in the sediments depicted some of the important facts. In the immediate layer, correlation between sand percentage and concentration of iron and nitrite was negative and weak (-0.24 and -0.28). In the layer of 4-5 inch, the sand fraction and iron concentration showed strong positive relation with the value of +0.83 while at the same depth the value was weak and negative (-0.16) between sand fraction and nitrite. In the other two layers, the correlation values of sand fraction with sand nitrite was positive (+0.35 and +0.24 respectively). The correlation between silt and parameters (iron and nitrite) in all the layers were negative and weak except between silt percentage and iron content at 4-5 inch depth which is negative but strong (-0.66) Silt and iron content correlation value at 8-9 inch depth was positive (+0.45). The correlation between clay percentage and both the parameters was positive in all the layers (table-8).

Table-4
Concentration of water parameters in ground water

Sample Location	**Concentration**				**Clay % in sediment**	**Geographical Location**
	Iron	Iron (Average)	Nitrite	Nitrite (Average)		
1	0.97	0.95	58.03	72.77	62.03	N22.44078 E73.15444
1	0.92		87.5			N22.44153 E73.15482
2	0.34	0.34	113.3	113.30	28.68	N22.43244 E73.12254
2	Nil		Nil			N22.43166 E73.12439
3	1.2	2.33	22.32	20.54	49.94	N22.41758 E73.09970
3	3.45		18.75			N22.41910 E73.10239
5	1.26	0.79	21.42	23.66	72.55	N22.38728 E73.07896
5	0.23		25.89			N22.38658 E73.07603

Source: Computed

Table-5
Correlation between iron and nitrite level in sediments

	Location 1		Location 2		Location 3		Location 4		Location 5	
	Iron Level	Nitrite Level	Iron Level	Nitrite Level	Iron Level	Nitrite Level	Iron Level	Nitrite Level	Iron Level	Nitrite Level
Iron Level	1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.
Nitrite Level	+0.12	1	+0.99	1	+0.35	1	+0.93	1	+0.42	1

Source: Computed, N.A.-Not Applicable

Table-6
Correlation of grain size and concentration (conc.) of iron in sediments

		Location 1		Location 2		Location 3		Location 4		Location 5	
Table 6.a		Sand %	Iron Conc.	Sand %	Iron Conc.	Sand %	Iron Conc.	Sand %	Iron Conc.	Sand %	Iron Conc.
	Sand %	1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.
	Iron Conc.	-0.51	1	+0.95	1	-0.88	1	-0.04	1	-0.87	1
Table 6.b		Silt %	Iron Conc.	Silt %	Iron Conc.	Silt %	Iron Conc.	Silt %	Iron Conc.	Silt %	Iron Conc.
	Silt %	1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.
	Iron Conc.	-0.91	1	+0.21	1	+0.95	1	-0.80	1	+0.56	1
Table 6.c		Clay %	Iron Conc.	Clay %	Iron Conc.	Clay %	Iron Conc.	Clay %	Iron Conc.	Clay %	Iron Conc.
	Clay %	1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.
	Iron Conc.	+0.99	1	-0.25	1	-0.49	1	+0.72	1	-0.45	1

Source: Computed, N.A.-Not Applicable

Table-7
Correlation between grain size and concentration (conc.) of nitrite in sediment

		Loction 1		Loction 2		Loction 3		Loction 4		Loction 5	
Table 7.a		Sand%	Nitrite Conc.	Sand%	Nitrite Conc.	Sand%	Nitrite Conc.	Sand%	Nitrite Conc.	Sand%	Nitrite Conc.
	Sand%	1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.
	Nitrite Conc.	-0.92	1	+0.90	1	-0.76	1	+0.34	1	-0.81	1
Table 7.b		Silt%	Nitrite Conc.	Silt%	Nitrite Conc.	Silt%	Nitrite Conc.	Silt%	Nitrite Conc.	Silt%	Nitrite Conc.
	Silt%	1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.
	Nitrite Conc.	+0.29	1	+0.35	1	+0.04	1	-0.52	1	-0.51	1
Table 7.c		Clay%	Nitrite Conc.	Clay%	Nitrite Conc.	Clay%	Nitrite Conc.	Clay%	Nitrite Conc.	Clay%	Nitrite Conc.
	Clay%	1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.
	Nitrite Conc.	+0.27	1	-0.38	1	+0.64	1	+0.41	1	+0.62	1

Source: Computed, N.A.-Not Applicable

Table-8
Depth wise correlation between grain size and concentration of parameters in sediment

0-1 Inch Depth		0-1 Inch Depth		4-5 Inch Depth		4-5 Inch Depth		8-9 Inch Depth		8-9 Inch Depth	
Sand%	Iron Conc.	Sand%	Nitrite Conc.	Sand%	Iron Conc.	Sand %	Nitrite Conc.	Sand%	Iron Conc.	Sand%	Nitrite Conc.
1		1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.
-0.24	1	-0.28	1	+0.83	1	-0.16	1	+0.35	1	+0.24	1
Silt	Iron Conc.	Silt	Nitrite Conc.	Silt %	Iron Conc.	Silt	Nitrite Conc.	Silt%	Iron Conc.	Silt%	Nitrite Conc.
1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.
-0.45	1	-0.07	1	-0.66	1	+0.02	1	+0.45	1	-0.12	1
Clay%	Iron Conc.	Clay %	Nitrite Conc.	Clay	Iron Conc.	Clay	Nitrite Conc.	Clay%	Iron Conc.	Clay%	Nitrite Conc.
1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.	1	N.A.
0.48	1	+0.10	1	+0.38	1	+0.07	1	+0.38	1	+0.07	1

Source: Computed, N.A.-Not Applicable

Table-9
Correlation between grain size and concentration of parameters in ground water

Sand %	Iron Conc.	sand%	Nitrite Conc.
1	N.A.	1	N.A.
+0.91	1	-0.90	1
Silt%	Iron Conc.	silt%	Nitrite Conc.
1	N.A.	1	N.A.
-0.35	1	+0.84	1
Clay%	Iron Conc.	clay%	Nitrite Conc.
1	N.A.	1	N.A.
+0.15	1	-0.71	1

Source: Computed, N.A.-Not Applicable

Discussion: Clay was dominantly found in the immediate layer (figure-3) followed by silt and sand, that constituted the least percentage. Thus, it can be said that the clayey type of soil is dominant along the river Mini which comes under alluvial soil category. The presence of such type of soil in the north-western part of the district is mainly due to the fluvial processes[29]. The concentration of nitrite was higher in the immediate layer which decreased with the increasing depth (figure-4). Significant concentration of iron was also observed in the immediate layers where the clay percentage was maximum (figure-5). As the percentage of grain size gets finer the infiltration rate decreases significantly. Thus, the rate of infiltration from the surface to the subsurface also decreases and concentrates mainly in the upper most layers[2,30]. Sampling location 3 showed the maximum concentration of iron in all the layers (figure-5). Nandesari is an Industrial Notified Area and many chemicals are used which are related to iron and nitrite in the industries. The solid industrial wastes generated from the industries are also dumped in the nearby areas (figure-6). These ongoing industrial activities may be one of the reason for higher concentration of iron. Sampling location 1 or upstream point had lowest concentration of iron which is far away from the industrial estate (table-2). But, at sampling location 5 (downstream) which is also far from the industries the concentration was higher. It may be due to the downstream flow of river Mini. When the river is crossing the industrial estate (sampling location 3) the level of iron and nitrite in the sediment increase (table-2 and 3). Therefore, the downstream points showed higher concentration than the upstream ones. Consequently, the significance of river Mini is clearly observed in the study area. During the rainy season, the wastes get mixed with rainwater and flow southwards resulting into the high level of iron and nitrite in the sediment particularly in the downstream. The concentration of nitrite in groundwater is negatively correlated with the clay percentage in the sediment (-0.70). A considerably higher concentration of nitrite was observed at sampling location 2 where the silt percentage is high with lowest percentage of clay (table-4) whereas, lowest level of nitrite was noted at sampling location 4 where the clay percentage is highest. The level of iron in ground water and the percentage of clay in the sediment did not show any specific correlation (+0.15) which indicated the natural occurrence of iron in the surface and subsurface soil.

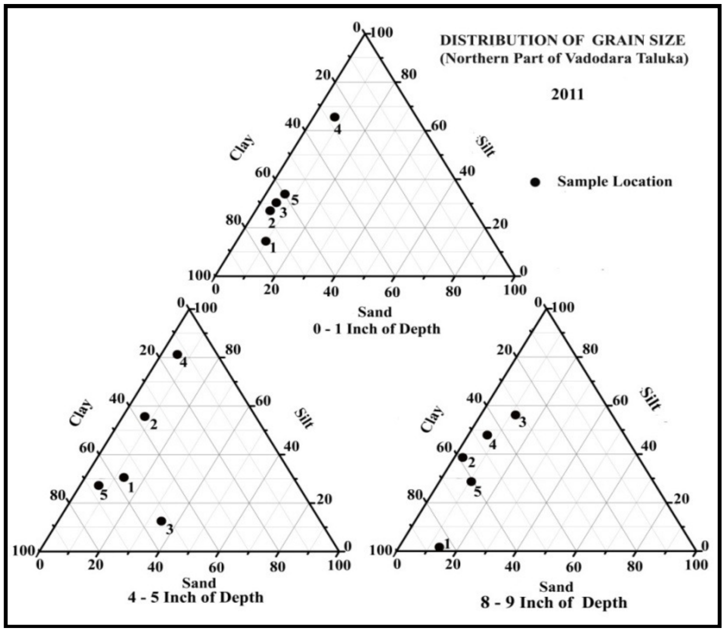

Figure-3

Ternary diagram showing distribution of grain size

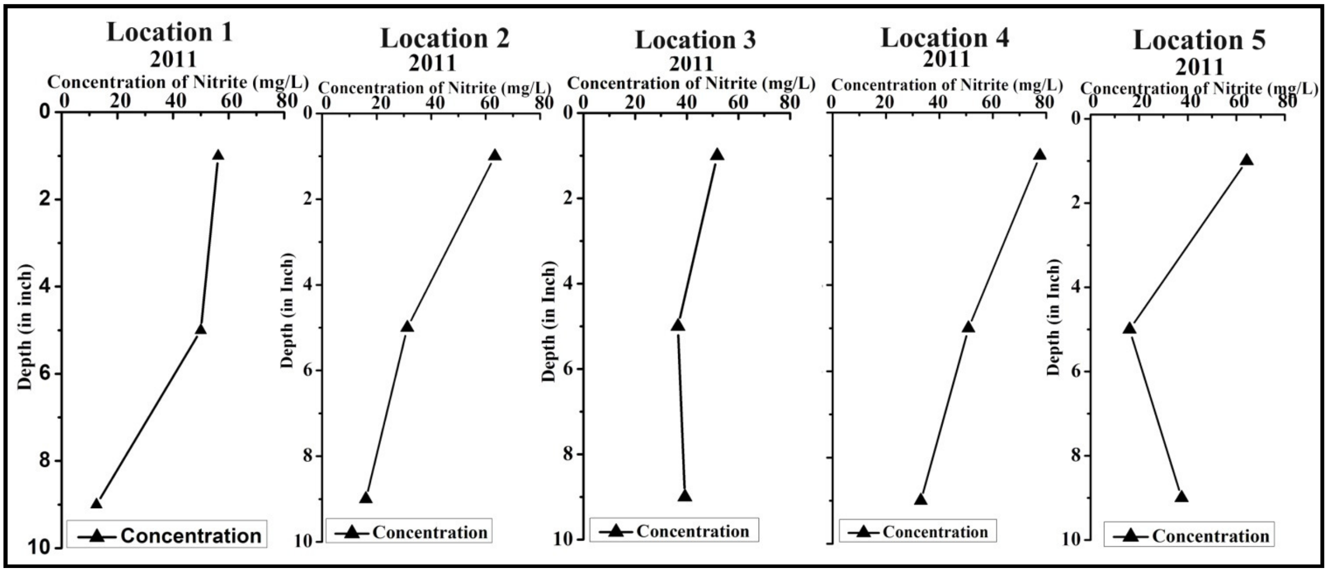

Figure-4

Concentration of nitrite in sediment

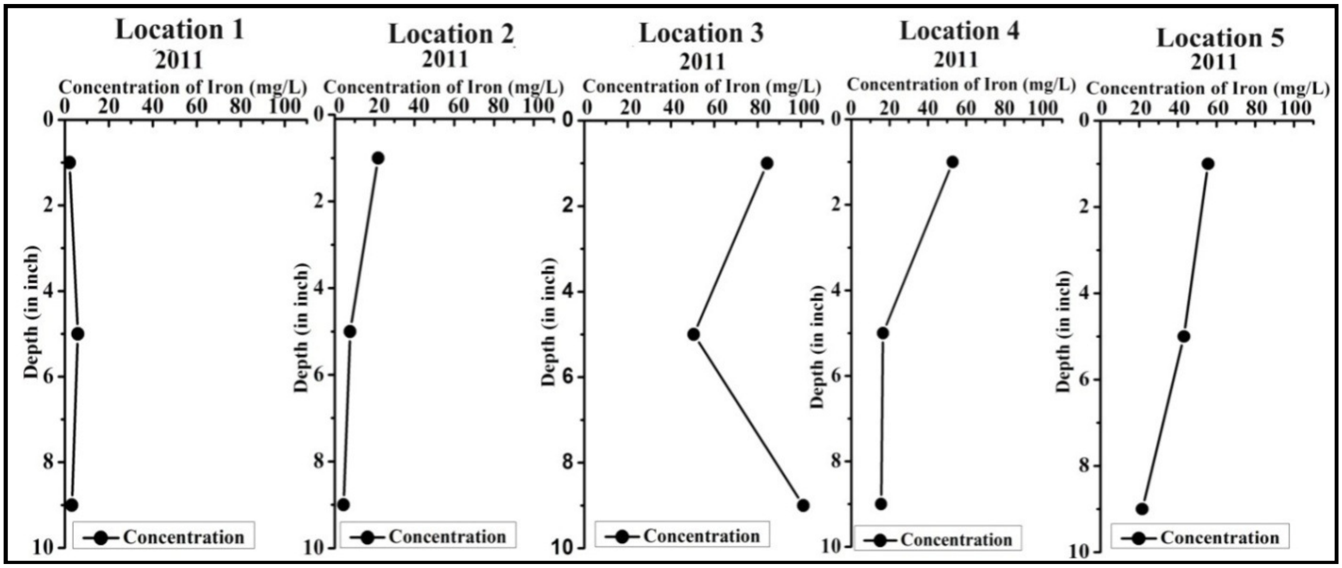

Figure-5
Concentration of iron in sediment

Figure-6
Dumping of industrial waste in Nandesari GIDC

Conclusion

In the entire study area, the percentage of percentage of clay in the sediment was maximum and helped in restricting the percolation rate of water in association with the parameters of iron and nitrite from the surface to the subsurface. The concentration of iron and nitrite in subsurface soil significantly augmented after passing through the industrial region which clearly indicated the contribution of the industries. River Mini played an important role and worked as a vector in this concern. Both the parameters had positive relationship which also indicated the importance of grain size distribution of the region both in surface and subsurface.

Acknowledgement

One of the author (Prof. Rolee Kanchan) is thankful to Indian Council of Social Science Research, New Delhi for funding the Major Research Project (ICSSR No F. No. RP 02/120/2009/RP dated 23.02.2010).

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